Official Norwegian Reports NOU 2012: 16

Cost-Benefit Analysis

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Review from a committee appointed by Royal Decree of 18 February 2011.
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To the Ministry of Finance

By Royal Decree of 18 February 2011 an expert committee was appointed to review the cost-benefit analysis framework. The committee hereby presents its recommendation.

Oslo, 3 October 2012

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(Chairperson)

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Chapter 1
Appointment, terms of reference and recommendations

1.1 Cost-benefit analysis of public measures

The resources available to society are scarce. Cost-benefit analysis[1] is a tool for clarifying the consequences of public sector resource use. Such analysis may be applied to investments, regulatory changes and programmes; what we may collectively refer to as “public measures”. The main purpose of cost-benefit analysis is to clarify and highlight the consequences of alternative measures prior to deciding whether to implement such measures. Consequently, cost-benefit analysis is a way of systematically organising information (NOU 1998: 16 Green Paper). Such analysis shall form part of the basis for making decisions, without thereby amounting to a decision rule.

In Norway, the first guide within this area was drafted under the direction of the Ministry of Finance in 1978, under the name of “Programme Analysis”. New technical reports were prepared in 1990s by the “Cost Calculation Committee”, whose work resulted in the NOU 1997: 27 Green Paper; Cost-Benefit Analysis, and the NOU 1998: 16 Green Paper; Guidance on Using Profitability Assessments in the Public Sector. The guide to cost-benefit analysis by the Ministry of Finance was published in 2000 on the basis of such reports.

It is important that the framework is updated. The Ministry of Finance revised its guidelines on cost-benefit analysis in 2005. Key elements of such revision were modifications to the guidelines for determining the discount rate, presentation of more examples, as well as making the guide more pedagogic and user friendly. In order to further improve user friendliness, the Norwegian Government Agency for Financial Management published a cost-benefit analysis handbook in 2010. Technical developments have taken place nationally and internationally within the area of cost-benefit analysis since the revision in 2005. The Government appointed, against this background, an expert committee to review certain aspects of the public sector cost-benefit analysis framework anew. Key themes of such review are social effects that change during the analysis period and that are realised in the distant future, and uncertainty in such regard. The present NOU Green Paper is a supplement to the NOU 1997: 27 Green Paper and the NOU 1998: 16 Green Paper. Information in the present Report is up to date as per 1 September 2012.

1.2 Terms of reference

On 18 February 2011, the Government appointed an expert committee to review the cost-benefit analysis framework. The terms of reference of the Committee were worded as follows:

> Technical developments have taken place nationally and internationally within the area of cost-benefit analysis since the Ministry of Finance published its cost-benefit analysis guide in 2000, and subsequently revised it in 2005. The Stern Review placed a special focus on social effects in the distant future. Similar and other types of issues have been noted by Norwegian academics. An expert committee is appointed for these reasons, to review the cost-benefit analysis framework, and to consider the potential expansion and specification of the cost-benefit analysis guidelines.
>
> The Expert Committee shall review technical developments within cost-benefit analysis since the establishment of the framework in 2000, and shall examine relevant issues on such basis. Issues it will be appropriate for the Committee to address will be discussed in the following.

[1] Cost-benefit analysis is used as a common term for the three different alternative analysis methods: cost-benefit analysis, cost-effectiveness analysis and cost-effect analysis (cf. Chapter 2). In cases where it is important to distinguish between the different methods of analysis it is specified which method is used.

The cost-benefit analysis guide of the Ministry of Finance does not explicitly address the fact that analysis parameters may change over time, for example that the value of time and time savings may be assumed to increase in line with real wage growth in the economy. Correspondingly, the willingness to pay for environmental goods may change over time, whilst technological progress may change future costs. This type of considerations may have a major impact of the assessment of costs and benefits in long-term projects, like for example infrastructure investments within the transportation sector. The Expert Committee shall examine whether and, if applicable, how changes in parameter values over time may be included in the cost-benefit calculations.

The discount rate level has a significant impact on the profitability of long-term measures. The guidelines for determining the discount rate are based on exponential discounting and the so-called Capital Asset Pricing Model. However, financial markets provide limited information about risk premiums for projects with a long economic life, such as for example transportation investments. The Stern Review has recommended a discount rate of 1.4 percent for climate calculations, whilst other economists have argued that such estimate is too low. The Committee shall assess, against this background, which discount rate should be applied in respect to long-term measures, and whether the required rate of return should be differentiated on the basis of the duration of such measures. The Committee shall review existing literature within this area, and assess various methods for determining the discount rate. The Committee shall consider, in this context, whether the theoretical framework for determining the discount rate should be based on the opportunity cost of capital or on consumer behaviour. Moreover, both the cost side and the benefit side are subject to systematic uncertainty from a portfolio perspective. The Committee shall make a recommendation as to how systematic uncertainty should be handled in public investment analysis.

There is considerable uncertainty associated with future international climate negotiations, and consequently with future emission prices. By basing the cost-benefit analysis of public measures on uniform assumptions with regard to the future prices of greenhouse gas emissions, everyone preparing calculations for public investment projects will apply the same assumptions in such respect. This will contribute to projects being dealt with in a consistent and comparable manner. The NOU 2009: 16 Green Paper; "Global Environmental Challenges - Norwegian Policy", recommends that a carbon price path be included in the cost-benefit analysis circular of the Ministry of Finance, thus making this mandatory for all central government cost-benefit analysis. The Expert Committee shall assess the said recommendation and propose potential guidelines for the pricing of greenhouse gas emissions in view of two alternatives; one carbon price path that reflects current expectations with regard to future prices in the EU ETS, and one path that supports the 2-degree target supported by Norway.

Furthermore, the Expert Committee shall consider how cost-benefit analysis is to deal with catastrophic effects with a small, but not negligible, probability, as well as the matter of irreversible effects.

The Committee shall assess how gains from, for example, transportation investments should be dealt with in cost-benefit analysis, including benefits that are currently often not assigned a price tag in cost-benefit analysis, such as productivity effects from increased geographic density, increased labour supply, as well as the interaction between transportation services and land use. The Committee shall assess how the framework may potentially be made more specific when taking into consideration any net contribution from wider impacts of a public transport measure.

The guide published by the Ministry of Finance does not prescribe the analysis period for a measure. The discrepancy between the analysis period and the technical lifespan is in certain sectoral guides dealt with by calculating a residual value as per the end of the analysis period. The Committee shall assess how the analysis period and the residual value should be determined.

The cost-benefit analysis guide offers general recommendations as to how one may seek to quantify the value of accident-reducing measures. This may, for example, be of relevance to cost-benefit calculations concerning safety measures within the transportation sector. The estimated value of a statistical life lost is presented in such a context. The Directorate for Health and Social Affairs recommended, in a report from 2007, the broad use of such a concept in intersectoral health impact assessments. The Committee shall examine what weight intersectoral cost-benefit assessment standards should carry in the evaluation of the impact on life and health, including within the health sector, and any ethical issues that may be raised thereby.

Distribution weights may be used in cost-benefit analysis to specifically adjust for income distribution effects. The Committee shall assess whether and, if applicable, how income distribution effects shall be included in economic project analysis.

The work of the Expert Committee should be based on the technical work carried out in this area in Norway, including, *inter alia*, the NOU 1997: 27 Green Paper and the NOU 1998: 16 Green Paper on cost-benefit analysis. Besides, the Expert Committee should summarise main features of technical cost-benefit analysis developments subsequent to the established current framework. The Committee should also compare the criteria applied by some other countries within the area of cost-benefit analysis, including the United Kingdom and the Scandinavian countries.

The Expert Committee should itself evaluate the need for hiring additional experts in its work. The Committee is requested to facilitate presentation, by representatives from various sectors, on technical issues and experiences from the development and use of cost-benefit analysis before the Committee.

The Committee shall assess financial/administrative implications of its proposed measures.

The Expert Committee shall submit its recommendation to the Ministry of Finance by 1 June 2012.

1.3 The work and composition of the Committee

The Committee members were:

– Kåre P. Hagen, Professor Emeritus, Norwegian School of Economics, Chairperson
– Stein Berntsen, Executive Vice President, Dovre Group
– Brita Bye, Researcher, Statistics Norway
– Lars Hultkrantz, Professor, Örebro University
– Karine Nyborg, Professor, University of Oslo
– Karl Rolf Pedersen, Associate Professor, Norwegian School of Economics
– Maria Sandsmark, Researcher, Møreforsking Molde AS
– Gro Holst Volden, Researcher, Norwegian University of Science and Technology/SINTEF
– Geir Åvitsland, Director General, Ministry of Finance (from 1 June 2011)

The Secretariat of the Committee had the following members:

– Frode Karlsen, Deputy Director General, Ministry of Finance, Head of the Secretariat
– Gry Hamarsland, Head of Section, Norwegian Government Agency for Financial Management
– Vegard Hole, Adviser, Ministry of Finance
– Erling Motzfeldt Kravik, Adviser, Ministry of Finance
– Johan Nitter-Hauge, Senior Adviser, Ministry of Finance
– Kjartan Sælensminde, Senior Adviser, Norwegian Government Agency for Financial Management
– Elisabeth Aarseth, Senior Adviser, Norwegian Government Agency for Financial Management

Moreover, affected line ministries have been represented in the Secretariat when matters within their areas of responsibility have been under discussion. This applies to the Ministry of Transport and Communications, the Ministry of Health and Care Services and the Ministry of the Environment. The following individuals from these ministries have contributed to the work of the Secretariat:

– Beate Ellingsen, Adviser, Ministry of the Environment
– Leif Ellingsen, Adviser, Ministry of Transport and Communications
– Annelene Holden Hoff, Senior Adviser, Ministry of Transport and Communications
– Marit Måge, Senior Adviser, Ministry of Health and Care Services
– Bent Arne Sæther, Specialist Director, Ministry of the Environment

The Committee has held a total of 20 meetings in connection with the work of revising the cost-benefit analysis guidelines. In addition, two seminars with international participation have been held: one concerning net wider impacts of transportation projects; “Wider Impacts and Transport Infrastructure”, and one concerning the discount rate; “The Social Discount Rate”. Moreover, affected ministries have submitted written inputs to the

Committee, and national experts in individual areas have also made presentations before the Committee. A seminar in which the ministries presented their views on, and experiences from, cost-benefit analysis has been held. On 8 December 2011, the Ministry of Finance consented, upon application from the Committee, to the deadline for completion of the work being postponed until 1 October 2012.

1.4 Recommendations

Chapter 2 discusses the fundamental cost-benefit analysis approach, including principles relating to the valuation of cost and benefit elements. These fundamental principles remain fixed and have not been subjected to renewed discussion by the Committee. The issues raised by the terms of reference are discussed by the Committee in the subsequent chapters:

- Chapter 3 Distribution effects
- Chapter 4 Real price adjustment
- Chapter 5 The social discount rate
- Chapter 6 Lifespan, analysis period and residual value
- Chapter 7 Net wider impacts of transportation projects
- Chapter 8 Disasters and irreversible effects
- Chapter 9 Carbon price paths
- Chapter 10 Valuation of life and health
- Chapter 11 Financial and administrative implications

Each Chapter addresses issues raised in the terms of reference. Moreover, the Committee presents its assessments and recommendations in each Chapter. All recommendations are unanimous. Readers are referred to the individual chapters for further details and contexts.

The recommendations of the Committee may change the ranking of various projects relative to each other, as measured by the net economic benefits of such projects. Whether this has any impact on which projects are adopted by the decision makers depends on what the decision makers emphasise when making a decision. If weight is attached to the net economic benefits, the recommendations may have an impact on which projects are implemented. If the upper budget limit remains unchanged, either nationally or within a sector, the proposals will have no budgetary consequences.

In the following are presented, based on the Committee's discussion of the various issues, the unanimous recommendations made by the Committee in Chapters 3–10:

Chapter 3 Distribution effects:

- Cost-benefit analysis should continue to estimate the aggregate, unweighted willingness to pay. In other words, explicit distribution weighting is not recommended.
- The Committee holds the view that economic profitability shall be interpreted as a summary measure of the net amount the population as a whole is willing to pay for a project, and not as a measure of what is in the best interest of society in a wider sense. This implies that the estimated economic profitability of projects, as calculated in ordinary cost-benefit analysis without explicit welfare weights, cannot in itself be interpreted normatively as a matter of course.
- The distribution effects for especially affected groups, including any conflicts of interest, should be examined and discussed in a manner providing the decision maker with the best possible basis for taking these into consideration when assessing the public measure. It should be explained how different objectives with regard to distribution and conflicts of interest may influence the desirability of implementing the measure.

Chapter 4 Real price adjustment:

General recommendations

- Real price adjustment (up or down) should only be considered for cost and benefit components where there is a firm theoretical and empirical basis for estimating how developments in the valuation of the relevant goods will deviate from general inflation.
- When future real developments in calculation prices are subject to considerable uncertainty, and different development paths are of importance to the analysis, sensitivity calculations may be an appropriate alternative.
- Cost-benefit analysis should also present and discuss how non-priced effects may change over time.

Values of time

- The Committee recommends that the valuation of time savings be based on the opportunity cost principle. Furthermore, the Committee proposes that time use be split into two main categories: work and leisure. The Committee is

of the view that more precise categories may also be used if good information is available.
- The valuation of time at work should be based on the value added lost by the employer (as measured by gross real wage costs).
- Estimates of saved/increased working hours should, to the extent practicable, reflect the *effective* time gain/time loss.
- The valuation of *leisure* should be based on willingness to pay surveys. If no such survey is available, it will be appropriate to use the net real wage as representing the value of leisure time.
- The value of time at work should be price adjusted by using the expected growth in GDP per capita.
- Correspondingly, the value of leisure time saved should be subjected to real price adjustment by using the expected growth in GDP per capita. This implies that the elasticity of the willingness to pay for leisure with regard to GDP per capita is 1.
- If possible, the values of time of the people who are affected by the measure should be used in the analysis. If adequate information about these values of time is not available, it will be appropriate to use national averages.

Environmental goods

- The Committee finds that the value of statistical lives, and the imputed calculation prices (including health and mortality-related environmental effects), should be subjected to real price adjustment based on the growth in GDP per capita.
- Calculation prices for health and mortality-related environmental effects should also be adjusted for estimated developments in the health effect of the environmental damage.
- As far as concerns calculation prices based on individual willingness to pay for environmental goods, the Committee does not think there is an adequate empirical basis for proposing general real price adjustment rules.
- Calculation prices derived from political decisions and commitments should be based on current policy and knowledge about future objectives and commitments. No adjustment should be made with respect to policy development assumptions. Such considerations may, for example, be addressed by a sensitivity analysis if deemed to be of particular relevance to the decision maker. As far as the calculation price for greenhouse gas emissions is concerned, reference is made to a separate discussion in Chapter 9.
- Factors that influence the future scarcity and importance of affected environmental goods should be presented and discussed in the economic analyses, irrespective of whether calculation prices are available and used.

Chapter 5 The social discount rate

- In principle, the real risk-adjusted social discount rate should reflect the risk-free interest rate and the risk associated with the project and, consequently, reflect the project's risk adjusted opportunity cost of capital. The discount rate applied in the assessment of public measures should, however, nonetheless be based on simple rules that address the main aspects of the matter.
- For commercial public sector operations in direct competition with private sector, it will be appropriate to use a discount rate faced by corresponding private enterprises.
- A real risk-adjusted discount rate of 4 percent will be reasonable for use in the cost-benefit analysis of an ordinary public measure, such as a transportation measure, for effects in the first 40 years from the date of analysis.
- Beyond 40 years, it is reasonable to assume that one will be unable to secure a long-term rate in the market, and the discount rate should accordingly be determined on the basis of a declining certainty equivalent rate as the interest rate risk is supposed to increase with the time horizon. A rate of 3 percent is recommended for the years from 40 to 75 years into the future. A discount rate of 2 percent is recommended for subsequent years.

Chapter 6 Lifespan, analysis period and residual value

- A cost-benefit analysis should seek to include all relevant effects of the measure throughout its lifespan.
- The lifespan used in the analyses must reflect the period during which the measures under analysis will actually be in use or be of service to society. The lifespan therefore needs to be discussed for each project, or in sectoral guidelines within sectors where a large number of similar projects are implemented. It is appropriate for the approach within each sector to be as uniform as possible to ensure comparability between projects.

- The main principle should be to bring the analysis period as close to the lifespan as practicable. It would, for example, seem more appropriate to apply 40 years as the analysis period for road projects than the 25 years applied until now.
- If the analysis period is shorter than the lifespan of the measures, it will be necessary to calculate a residual value that estimates the total economic net present value the project is expected to generate from the end of the analysis period until the end of the project lifespan.
- Residual value should principally be calculated on the basis of the net benefit flow over the last years of the analysis period. It should be adjusted for any cyclical or other expected variations during the time interval from the end of the analysis period until the end of the lifespan of the project, for example due to a need for major upgrades or reinvestments. For projects where most effects have been valued, it should be assumed that the flow of net benefits will approach zero in the last year of the lifespan.
- The best possible method should be used in the event of any knowledge and documentation, including any market value estimate, suggesting that a different method for calculating the residual value of the specific measure in question would be better.
- If the residual value period is assumed to be long and the effects (and thus the lifespan) are subject to considerable uncertainty, sensitivity analysis and scenario analysis should be used as supplementary analysis methods to shed light on the importance of particularly uncertain estimates.

Chapter 7 Net wider impacts of transportation projects

Productivity and economies of scale

- It has proven very difficult to identify a relationship between town size and productivity when evaluating the effect of a transportation project or a series of such projects subsequent to its or their implementation. According to the view of the Committee it cannot, therefore, be recommended to generally assume such a relationship when evaluating a project prior to its implementation.
- Since the literature gives reason to believe that there may be positive net wider impacts of transportation projects in urban areas, the cost-benefit analysis of large projects in connection with an urban area in which it can be shown to be probable that productivity is systematically higher, may be expanded to include a separate discussion of net wider impacts. Such an analysis may be both qualitative and quantitative, and should discuss whether such effects are likely to materialise. However, in order to ensure comparability across projects, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to a main analysis of the net economic benefit associated with a project.

Labour supply

- For major projects concerning which it can be shown to be probable, on an empirical basis, that the project will influence overall labour supply in the country through increased working hours, or through increased labour force participation, a cost-benefit analysis could be expanded with a separate discussion of these effects. Such an analysis may be both qualitative and quantitative, and should discuss whether such effects are likely to materialise. It is important to avoid double counting of the benefits from the project in such contexts, and the correct approach will in practice be to only take into account the change in tax revenues as the result of higher employment. However, in order to ensure comparability, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to the main analysis of the net economic benefits associated with the project.

Land use and transportation

- As a main rule, price changes in the property market as the result of a transportation project only represent a redistribution of the original direct benefits from such project. Including both effects in the analysis will therefore amount to double counting. If one has sought to estimate the value of increased productivity as the result of increased functional city size directly, it will also amount to double counting if the property market implications of such effects are taken into account. In those cases where a transportation project releases areas with a positive opportunity value, there may be a real economic effect that is not reflected in the direct user benefits of the project.

Imperfect competition

- Based on the available documentation, the Committee is not in a position to conclude as to whether the effect on imperfect competition is of any material importance to the net economic benefit of transportation projects. The review also shows that it is difficult to establish any simple method for identifying any such potential effect in a robust manner, and with a solid empirical basis. If it can be shown to be probable, on an empirical basis, that the project may influence the degree of competition, or that it will influence markets that are in particular characterised by imperfect competition, a cost-benefit analysis may be expanded to include a separate discussion of these effects. However, in order to ensure comparability, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to a main analysis of the net economic benefits associated with a project.

The ex post analysis of the primary markets

- The effort to analyse projects subsequent to their implementation should be continued. A systematic approach, like that adopted by the Norwegian Public Roads Administration, generates new knowledge about the analyses carried out, and makes it possible to use these findings to improve the estimates. The systematic follow-up of such studies and other approaches may contribute to ensuring that the specification of the cost and benefit elements is complete, that projections are correct in the long run, and that there are no other sources of incorrect estimates within the cost-benefit analysis framework.

Chapter 8 Disasters and irreversible effects

- When faced with irreversible effects, it will at times be possible to get more information about the effects of the measures by postponing execution. In formal terms, this may be expressed as a (quasi-)option value. Such values may be difficult to estimate, but the advantages of postponing implementation should nevertheless be described and assessed.
- In the cost-benefit analysis of situations with a potentially catastrophic outcome, it is important to examine whether or not the probability of such catastrophic outcome is negligible. In order to safely ignore a disaster probability it is, in principle, necessary to know 1) that the level of the disaster probability is very low, 2) that the level of the disaster probability is well known (and therefore not uncertain in itself), and 3) that the cost increase in the event of more extreme outcomes is not sufficiently steep to (in full or in part) outweigh the fact that more extreme outcomes are less probable.
- If the probability is not negligible, or if one is unable to conclude that such is the case, the standard method of analysis may underestimate, potentially to a significant extent, the cost associated with society being exposed to an unknown degree of disaster risk. The Committee is of the view that one should in such cases attach considerable weight to describing both what one knows about the possibility of catastrophic outcomes, as well as the knowledge deficiencies as the decision makers have to be aware of. The level of ambition will usually, at least implicitly, be determined as a "safe minimum standard".
- Cost-benefit analysis should be used to highlight what amount of resources used, implicitly or explicitly, for risk reduction within various sectors, in order to improve the basis for making decisions about sensible resource allocation. The theoretical literature within the area of safety regulation is in development. Various types of breakeven analysis may provide information about the minimum probability of a terrorist act, or a similar incident, that may justify a safety regulation.

Chapter 9 Carbon price paths

- The current differentiated tax and quota structure for the private sector is not suitable for use in cost-benefit analysis. A joint carbon price path should be applied for purposes of cost-benefit analysis.
- The appropriate calculation price for greenhouse gas emissions depends on what question one would like the analysis to answer. The Committee adopts the assumption that the authorities are subject to binding emission limitation targets, thus implying that increased emissions in one location necessarily have to be compensated by reductions elsewhere. The Committee recommends, on this basis, that the calculation price for greenhouse gas emissions be based on the marginal cost of emission reductions (the marginal abatement cost). If there are no binding emission limitation tar-

gets, the carbon price path should, in principle, be based on the marginal social cost of carbon instead.

- If the authorities are subject to binding domestic emission reduction targets, the calculation prices should be derived from the constraints resulting from such targets. Climate Cure 2020 (2010) has calculated a number of such paths towards 2020.
- If binding Norwegian targets are related to the contribution to total global emissions caused by Norway, and Norwegian emissions are subject to an international cap-and-trade system, the calculation price for greenhouse gas emissions should be based on expectations as to the international allowance price. From the various allowance prices in current international trading systems, the Committee recommends the use of the EU ETS allowance price. The path should be based on market expectations of future allowance prices. For years in respect of which no prices are quoted, the price path should over time approach an assumed two-degree path based on internationally recognised model computations.
- For projects where the cost-benefit analysis is particularly sensitive to different carbon price paths, it will be useful to prepare sensitivity estimates assuming a two-degree path for all years.

If the national or international political situation changes, such as to make new climate targets binding on the Norwegian economy, it is the marginal abatement cost given these new targets that should form the basis for the main joint calculation price alternative for greenhouse gas emissions.

If Norway finds itself, in future, in a situation where the authorities are not subject to binding emission reduction targets, thus implying that emission increases in one location cannot be assumed to imply emission reductions elsewhere, the carbon price path in cost-benefit analysis should, in principle, be based on the marginal social cost of carbon.

The specific paths should be prepared by the Ministry of Finance in consultation with other affected ministries.

Chapter 10 Valuation of life and health

- Health indicators will have to be chosen on the basis of the specific character of the public measures in question. It will, for example, be more appropriate to use statistical life-years than statistical lives when expected remaining life years deviate sharply between alternative measures. Correspondingly, it will be more appropriate to use indicators for quality-adjusted life years when improved health-related quality of life is an important consequence. It may also be relevant to use specific health indicators.
- It is not necessary to attribute an economic value to the health indicators statistical lives, statistical life-years or quality-adjusted life years in order to include these in cost-effectiveness analysis or cost-effect analysis.
- It is proposed an economic value of a statistical life (VSL) at NOK 30 million at 2012 prices. It is recommended that this be applied to all sectors (cf. intersectoral standard in the terms of reference).
- In the analyses of measures specifically targeting the safety of children one may apply, by way of supplementary analysis, a higher value of a statistical life than for the general population. An appropriate level is twice the VSL of the general population.
- In principle, the value of equivalent consequences should be the same irrespective of sector, also for other health-related benefit indicators, like value of a statistical life year (VOLY) and quality-adjusted life years (QALY). However, the Committee is of the view that the technical basis for estimating the willingness to pay for these is currently not sufficiently established to merit the recommendation of intersectoral standard values for VOLY and QALY.
- It is proposed that the economic value of VSL be adjusted in line with the growth in GDP per capita (cf. Chapter 4 on real price adjustments).
- For measures where effects on life and health represent a main consequence, especially where the measures imply significant risk changes for individuals and/or where the identity of those especially affected is known, it will often be more appropriate to use cost-effectiveness analysis or cost-effect analysis than cost-benefit analysis (as a specific method of analysis).

Chapter 2
Cost-benefit analysis – Main features

2.1 Introduction

The present Green Paper supplements the NOU 1997: 27 Green Paper and the NOU 1998: 16 Green Paper. The present Chapter briefly explains the basic cost-benefit analysis approach and principles relating to the valuation of cost and benefit elements that remain fixed and have not been subjected to renewed discussion by the Committee. The Chapter is intended to offer readers an overview of cost-benefit analysis as a topic, but does not provide a complete discussion of existing recommendations. Reference is made to the discussions in the NOU 1997: 27 Green Paper; *Cost-Benefit Analysis*, the NOU 1998: 16 Green Paper; *Guidance on Using Profitability Assessments in the Public Sector*, and the Ministry of Finance cost-benefit analysis guide from 2005 for a more comprehensive review of such issues. Reference is also made to the NOU 2009: 16 Green Paper; *Global Environmental Challenges – Norwegian Policy*, which examines environmental goods in a cost-benefit analysis context. In the subsequent chapters, the Committee will discuss issues that merit revisiting in view of recent theoretical developments, cf. the terms of reference of the Committee.

2.2 Main forms of cost-benefit analysis

We distinguish between various forms of cost-benefit analysis. Cost-benefit analysis is used as a common term for the three different alternative analysis methods: cost-benefit analysis, cost-effectiveness analysis and cost-effect analysis (cf. Chapter 1, footnote 1). In cases where it is important to distinguish between the different methods of analysis it is specified which method is used

Cost-benefit analysis, as a specific method of analysis, involves the valuation, to the extent feasible, of all positive and negative effects of a measure, based on the fundamental principle that the value of a consequence is what the population as a whole would be willing to pay to achieve it. If the willingness to pay for all benefits emanating from the measure exceeds its total costs, such measure is defined to be economically profitable (NOU 2009: 16 Green Paper). In principle, the cost of a project shall reflect of what one *must* forgo to implement such project, whilst its benefits shall reflect how much one is *willing* to give up (NOU 1997: 27 Green Paper).

If the various measures to be compared entail the same benefits, or benefits that can be measured on a uniform scale, it is not necessary to attach a monetary value to such benefits for purposes of ranking the economic profitability of the said measures. The ranking will in any case depend on the costs of the measure only. A *cost-effectiveness analysis* involves the ranking of measures on the basis of costs, in order to identify the measure that will realise a given objective at the minimum cost.

In some contexts, it will be difficult or undesirable to attach a monetary value to the benefits, although the benefits resulting from various measures differ from each other. One may in such case calculate the costs of the measures in the usual manner, whilst describing the resulting benefits in the best possible way, but not necessarily in monetary terms or on a uniform scale. This is termed *cost-effect analysis* (NOU 1998: 16 Green Paper). Cost-effect analyses do not enable the measures to be ranked on the basis of economic profitability, but nevertheless provide decision makers with valuable information.

2.3 The purpose of cost-benefit analysis

The main purpose of cost-benefit analysis is to identify and elucidate the consequences of alternative measures prior to making a decision on which measure to implement. Consequently, cost-benefit analysis is a method for organising information (NOU 1998: 16 Green Paper). The analysis shall provide part of the basis for making decisions, without thereby amounting to a decision-making rule.

Cost-benefit analysis and cost-effectiveness analysis, as specific methods of analysis, enable the uniform ranking of measures based on their economic profitability (defined as in Chapter 2.2 above). However, economic profitability is not necessarily the only consideration of relevance to decision makers. In addition to focusing on the economic profitability of measures, the analysis should also aim at describing all consequences assumed to be of importance to the assessment to be made by decision makers, including non-priced effects and the distributional implications of measures. The final discretionary assessment should then be left to decision makers. The handling of distributional considerations in cost-benefit analysis is examined in more detail in Chapter 4.5 of the NOU 1997: 27 Green Paper and is discussed in Chapter 3 of the present Green Paper.

2.4 Valuation principles

A monetary value is attributed to costs and benefits to the extent theoretically justifiable and expedient. Whilst business analysis would use market prices in the valuation of a measure, cost-benefit analysis uses calculation prices. These shall reflect the value of the resources or inputs devoted to the measure used under the best alternative option. In perfectly competitive markets and with no direct or indirect taxes, the calculation prices are given by the market prices. In practice, market prices have to be adjusted for direct and indirect taxes, as well as, if possible, for various forms of market failure; see Chapter 2.5. We have no prices in certain areas of relevance to cost-benefit analysis, such as for many health and environmental goods. These issues are discussed in more detail in Chapters 5 and 6 of the NOU 1997: 27 Green Paper and are summarised in Chapter 2.6.

The cost and benefit implications of a measure often materialise at different points in time. The net present value method is a calculation method that enables the comparison of benefits and/or costs which occur at different points in time. Estimated costs and benefits are discounted to a specific reference year by applying a discount rate. By adding together the discounted future benefits and costs, we then arrive at the net present value of a measure. The measure is defined to be economically profitable if the net present value is positive. Hence, the discount rate may be interpreted as a required rate of return. Principles for determining the discount rate are discussed in more detail in Chapter 5 of the present Green Paper.

2.5 Rules for determining optimal calculation prices

This section summarises the rules that may be applied in the pricing of market goods for cost-benefit analysis purposes. We refer to the NOU 1997: 27 Green Paper and the NOU 1998: 16 Green Paper for thorough discussion of each rule. The present summary[1] largely mirrors the discussion in Chapter 7 of the NOU 2009: 16 Green Paper.

Tax effects

Most goods and services are subject to taxation, and hence there is almost always a need for examining how to deal with taxes in a cost-benefit analysis context. The underlying principle is that the resources devoted to a project shall, to the maximum extent possible, be assessed at their value under the best alternative option. It can be shown that if the authorities have sufficient tax instruments available in an economy with free competition, the inputs considered in a cost-benefit analysis shall be valued in the same manner as they would be valued by a private enterprise.[2] Such use of producer prices means that labour is valued at the market wage before tax (inclusive of social costs), whilst goods and services that are subject to a value added tax are valued at the market price exclusive of the value added tax.[3]

Externalities

Externalities arise if the activities of a person or an enterprise have a direct impact on the welfare of

1 A somewhat more rigorous, but nonetheless readily accessible, presentation is provided in Hagen (2005), which also discusses other aspects of cost-benefit analysis and public decisions. See for example Dreze and Stern (1987) for a more technical analysis.

2 This is a consequence of the so-called Diamond-Mirrlees Theorem, cf. the NOU 1997: 27 Green Paper and Hagen (2005). A technical analysis is presented in Diamond and Mirrlees (1971a and 1971b).

3 Valuation in the same manner as would be done by private enterprises is a special instance of what is often termed the weighted average rule, and the resources are still valued at their value under the best alternative option, cf. the discussion in Chapter 6 of the NOU 1997: 27 Green Paper.

other persons or the profitability of other enterprises, which impact is not conveyed through market prices, for example the pollution of a river used by a number of users. It is typically the case that many persons and enterprises are exposed to the externalities caused by each individual user. This makes it difficult for the polluter and those affected to reach agreement on compensation.[4]

In order for such *negative* externalities to be taken into account, one may introduce a tax reflecting the value of the marginal detrimental effect, or alternatively use tradable quotas. Taxes and quotas as policy instruments in the regulation of greenhouse gas emissions are discussed in more detail in Chapter 9. In other cases one may consider using prohibition or other quantitative restrictions to deal with an externality, for example if it is administratively challenging to establish taxes or tradable quotas, or when minor emission changes have major environmental impacts, cf. Weitzman (1974). These issues are discussed in more detail in the NOU 2009: 16 Green Paper.

Some forms of economic activity may also entail *positive* externalities. A standard example is research and development activities. Such activities on the part of an enterprise may, for example, generate knowledge that can also be used by other enterprises over time, or give rise to new products with a higher overall value in the market than can be captured by the enterprise itself through the product price.[5] Positive externalities in production or consumption constitute an argument in favour of public support for research and development activities, as well as other activities involving corresponding externalities, in the same way that negative externalities should be curtailed through taxes, etc.

The use of taxes or tradable quotas means, provided the appropriate level is chosen, that polluters take the externalities into account in making their decisions. For cost-benefit analysis purposes this implies that we deal with the externality by valuing taxed goods inclusive of environmental taxes or allowance prices, cf. the discussion in Chapter 6 of the NOU 1997: 27 Green Paper. When calculation prices include taxes or allowance prices that reflect the cost of emissions to society, no further corrections shall be made in the cost-benefit analysis with regard to the relevant externality. This Committee addresses adjustment for externalities from greenhouse gas emissions in Chapter 9. The valuation of externalities that are not related to goods traded in markets is discussed in more detail in Chapter 2.6.

Other types of market failure

Various types of market failure, such as monopolistic pricing, unemployment and asymmetric access to information, imply that market prices should in principle be corrected to arrive at the appropriate calculation prices, cf., *inter alia*, the discussion in Chapter 5 of the NOU 1997: 27 Green Paper. One issue is the extent to which we should in practice take market failure into consideration when carrying out cost-benefit analysis. One example may be valuing inputs at a price below market price because these are manufactured by an enterprise that exercises market power. Such a correction of market prices is in conformity with the social opportunity cost principle, and is therefore theoretically correct. However, it is challenging to determine what degree of market failure is of relevance to each individual project. In addition, the authorities pursue projects and measures specifically targeting various types of market failure, for example in the form of labour market measures or competition policy measures. The NOU 1997: 27 Green Paper therefore recommended the use of actual producer prices for analysis purposes, unless otherwise indicated by special considerations.

2.6 Valuation of goods not traded in markets

Many effects may be difficult or undesirable to value in cost-benefit analyses. In Chapters 9 and 10, the Committee discusses the valuation of greenhouse gas emissions and the concept of the value of a statistical life. The terms of reference instruct the Committee to examine how the valuation of environmental goods, health effects and time savings may be expected to develop over time, which is discussed in Chapter 4. Apart from that, the Committee does not embark on any renewed assessment of the valuation principles underpinning cost-benefit analysis.

There are two main approaches to measuring the willingness to pay for goods that are not

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[4] The scope of private players for solving the problem depends on clearly defined property rights to the relevant resource, cf. Coase (1960). In addition, the level of transaction costs needs to be moderate (the number of agents affected should, for example, be small).

[5] In some cases the market may also generate excessive research and development, because the enterprises are competing for the distribution of a fixed profit, cf. e.g. the overview in Tirole (1988).

traded in markets. The first approach, which is often discussed under the general term *indirect methods*, is based on the actual behaviour of individuals in existing markets. This approach can be useful when the use of the non-market good is closely related to market-traded goods, for example by way of housing prices being influenced by external noise, or when the use of a wilderness area involves travel expenses to access such area. The second approach, often termed *direct methods*, is based on asking individuals how much they are willing to pay. For a more comprehensive discussion, see the NOU 1997: 27 Green Paper or e.g. Freeman (1993), Perman et al. (2003) or Pearce et al. (2006).

No definite answer can be given with regard to how far one should go in attributing monetary values to, for example, environmental goods or good health. Some economists have argued that cost-benefit analysis should normally only value goods with a readily definable market value, whilst other goods should normally be excluded from the analysis of valued elements. Others have noted, *inter alia*, that the choices eventually made will in any case reflect a form of implicit valuation, and that it may therefore be desirable to perform an explicit (albeit uncertain) valuation in a cost-benefit analysis context. This has previously been discussed in the NOU 1997: 27 Green Paper, the NOU 1998: 16 Green Paper and the NOU 2009: 16 Green Paper. The monetary valuation of environmental and nature goods for cost-benefit analysis purposes is a major, and at times disputed, theme in economic theory; see Hanley and Barbier (2009) for en overview and examples of practical uses.

In October 2010, the Government appointed a designated expert committee on ecosystem services, charged with examining, *inter alia*, the valuation of the diversity of nature in Norway. The Expert Committee appointed to examine the cost-benefit analysis framework has not addressed the issues to be discussed by the said committee.

2.7 Tax costs and user payments

Many public measures concern public services that may often be difficult to fund in the market. In such cases, these measures need to be funded through taxes or user payments.[6] Taxes will generally result in consumers and producers facing different prices. Such tax wedges will distort production and consumption decisions, thus imposing an efficiency loss on the economy.[7] For all projects to be funded via public budgets, one should therefore calculate a tax funding cost, which is the marginal cost of collecting one additional krone in tax.[8] The tax funding of public projects is discussed in more detail in the NOU 1997: 27 Green Paper. As discussed above, the tax system is also characterised by a number of taxes intended to correct so-called externalities, like environmental and health costs, in the consumption of certain goods. If these taxes are designed correctly, they do not give rise to such an economic efficiency loss. Taxes intended to correct for externalities are discussed in more detail in the NOU 2007: 8 Green Paper; *An Evaluation of Excise Duties*, and the NOU 2009: 16 Green Paper; *Global Environmental Challenges - Norwegian Policy.*

User payments will, unlike general taxation, only affect those individuals who make use of the relevant goods or services. However, the economic effects of certain forms of user payments may in many cases have similarities with the effects of general taxation. If central government introduces user payments, for example tolls to meet a need for funding an investment in a road with no queuing problems, and such tolls exceed the use-contingent operational and maintenance costs of the road, users will be faced with a price exceeding the economic cost of using the said road. Consequently, the road will be used less than would be economically desirable. The difference between the economic cost and the user payment corresponds to the tax wedge arising upon general taxation. When making a trade-off between tax funding and user payment, we need to compare the welfare loss arising through user payment with the welfare loss arising through general taxation. In addition, we need to take the cost of collecting the tolls into account.

In the case of toll funding of a road investment that involves, generally speaking, no queuing or other externalities, including no wear and tear, etc., the optimal user price will be zero if we disregard funding needs.

When analysing a road with queuing problems, user payments may be considered a charge

6 The text in Section 2.7 is in large part obtained from Chapter 7 of the NOU 1997: 27 Green Paper.

7 A tax on labour will for example insert a wedge between the net wage received by workers and the gross wage paid by enterprises. The amount of work performed is less than the economically optimal amount, thus giving rise to an efficiency loss; see for example Hagen (2005).

8 The NOU 1997: 27 Green Paper refers to calculations that estimate this cost to be about 20 percent on average.

introduced to correct for externalities. If there is queuing on the road it will therefore be optimal to make use of road pricing[9] to allocate the limited road capacity unless the collection costs are excessive. This example serves to remind us that we should always make use of taxes that improve resource allocation before resorting to distorting taxes. The use of road pricing to allocate the limited road capacity does, when taken in isolation, reduce the need for investing in additional road capacity. Consequently, a cost-benefit analysis of road projects in an area characterised by queuing problems should be based on a situation with optimal pricing of road capacity, instead of assuming that the capacity problem as a whole must be solved through expanded road building. The relationship between road pricing and any wider impacts of transportation projects in urban areas is discussed in Chapter 7 on wider impacts.

2.8 Partial and general equilibrium models

The use of calculation prices offers a simple and expedient method for evaluating the economic profitability of a project. However, if a project is sufficiently large to have a significant impact on market prices, fixed calculation prices cannot be used. Consequently, we need to know when a project is of such a magnitude as to require other methods than calculation prices. In an open economy like Norway, most projects can be considered relatively small. Large projects may induce interactions between price and income changes requiring that these effects be examined simultaneously. This will normally necessitate the use of a general equilibrium model. International measures against climate changes are examples of large projects, because such measures will influence the prices of energy goods and transport-intensive goods. The Committee reverts in more detail to the use of general equilibrium models in Chapter 4 on real price adjustment over time and in Chapter 7 on wider impacts.

9 Road pricing (also termed road user charges) is discussed in more detail in the NOU 2007: 8 Green Paper.

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Chapter 3
Distribution effects

3.1 Introduction

From the terms of reference of the Committee:

> Distribution weights may be used in cost-benefit analysis to specifically adjust for income distribution effects. The Committee shall assess whether and, if applicable, how income distribution effects shall be included in economic project analysis.

It follows from Chapter 2.3 that the main purpose of cost-benefit analysis is to identify and elucidate the consequences of alternative measures prior to making a decision on which measure to implement. Moreover, it is there stated that in addition to focusing on the economic profitability of measures, the analysis should also aim at describing all consequences assumed to be of importance to the assessment to be made by decision makers, including non-priced effects and the distributional implications of measures. Distributional considerations in cost-benefit analysis were also discussed in Chapter 4.5 of the NOU 1997: 27 Green Paper.

In the present Chapter, the Committee will address more specifically how to include the distribution effects of projects in the cost-benefit analysis.[1] This Chapter examines distribution effects internally within one generation. Distributional considerations across generations are discussed in Chapter 5 on the social discount rate. The present Chapter first presents some general perspectives relating to distribution effects and cost-benefit analysis (3.2), before we embark on a more detailed discussion of the use of distribution weights in cost-benefit analysis (3.3). In Chapter 3.4, we discuss various approaches to the inclusion of distribution effects in cost-benefit analysis and the challenges this involves. Thereafter, we provide an overview of guidelines in other countries relating to the presentation of distribution effects (3.5). Finally, we present the assessment of the Committee (3.6) and its recommendations (3.7).

3.2 Distribution effects and cost-benefit analysis

Economic theory tends to identify a division of responsibilities between distribution policy and allocation policy. According to a well-known theorem,[2] any efficient distribution can be achieved as an equilibrium under perfect competition if the income distribution existing at the outset can be redistributed without economic costs. If it had been possible to redistribute income through non-distorting taxes, one could therefore have distinguished between policy measures to promote economic efficiency and distribution, respectively (see for example Hagen, 2005). Cost-benefit analysis of public resource use could in such case have focused exclusively on efficiency, or economic profitability, whilst distributional considerations could have been left to tax policy.

However, in real life the assumptions underpinning such a clear distinction between distributional considerations and resource use are not met in full. The economy is characterised by various forms of market failure resulting from deviations from free competition and the existence of public goods and externalities. Moreover, there is only limited scope for redistributing income through non-distorting taxes.

There is general agreement in the economic literature that the distribution effects of the project, as well as the distribution policy of the decision maker, must be taken into consideration to the extent that cost-benefit analysis is to measure changes in society's welfare (see, *inter alia*, Boadway, 2006, and Dreze and Stern, 1987). If efficient taxation had been possible, it can be argued that distributional effects of a tax-funded public invest-

1 Reference is made to footnote 1 in Chapter 1.

2 The second fundamental theorem of welfare economics (see for example Hagen, 2005).

ment project are of lesser importance on the cost side because these are spread across the entire population through the tax system (NOU 1997: 27 Green Paper). However, it will still be relevant to take the distribution effects on the benefit side into consideration.[3]

The NOU 2009: 16 Green Paper notes that a cost-benefit analysis based on individuals' willingness to pay does measure the effects of projects in monetary values (even if these are not restricted to market values), and not in utility or welfare as such. The purpose of such cost-benefit analysis is to organise information relating to key variables for the decision maker prior to an investment or a project decision. However, since the willingness to pay varies with the wealth level of individuals, the rich will systematically carry more weight than the poor in calculating the aggregate net willingness to pay. A cost-benefit analysis may therefore be supplemented by an analysis of the distribution effects. For example, the NOU 1997: 27 Green Paper recommended describing the distribution effects for each individual group in such a way as to provide the decision maker with the best possible basis for taking distribution effects into account in evaluating the project. Besides, the project analyst should describe the robustness of project profitability with regard to different distribution objectives.

Another approach is to handle distribution effects by adjusting the various effects identified in the cost-benefit analysis directly via *distribution weights*. This means attaching more weight to effects that affect low-income individuals than to effects affecting high-income individuals, if this is in line with society's preferences. This approach is discussed in more detail in Chapter 3.3 below.

In the same way that the decision maker attaches weight to income disparities, one may wish to attach more weight to specific age brackets, geographic regions or other socio-economic dimensions. Most countries also have legislation intended to counteract various types of discrimination, for which reason consequences of this type are also relevant. Consequently, an analysis of distribution effects should not be restricted to effects on high- and low-income groups. Nevertheless, explicit distribution weights are probably most relevant for purposes of correcting for income disparities.

[3] The NOU 1997: 27 Green Paper notes that certain reforms can often have the opposite implication. These will entail effects that are spread throughout the entire population, whilst the costs are often carried by a small number of people.

3.3 Distribution weights

The analysis shall, as noted in Chapter 2.3, form the basis for making decisions, without thereby amounting to an outright decision -making rule. If the findings from a cost-benefit analysis are used to determine what is the *best* solution for society, it means that the analysis is interpreted normatively. In that case there is a need for examining the normative implications of such an interpretation of the findings. Evidently, this involves making implicit assumptions concerning distribution between individuals. However, one might envisage including distribution weights in the analysis if one would like to adopt other distributional assumptions.

The NOU 1997: 27 Green Paper briefly explains the theoretical assumptions underpinning cost-benefit analysis. Chapter 2 of the present Report provides a condensed summary of the conclusions from the said Green Paper. We will here outline those parts of the theoretical framework that are required to discuss the use of distribution weights in cost-benefit analysis.[4]

3.3.1 Utility, willingness to pay and social welfare functions

Utility and willingness to pay

We start out by examining the utility concept. This is discussed in all standard microeconomic textbooks. Let us first look at one individual and assume that such individual only cares about her own private consumption, as measured in monetary terms, as well as a public good that may be made available by central government. This may for example be a clean-up measure or other environmental improvement measure, with environmental quality being measured in physical units. Environmental quality is a public good that is available to everyone in society. Utility is a relative measure of needs satisfaction and expresses the preferences of an individual across various combinations of goods; in our example various combinations of the goods private consumption and environmental quality. If a specific combination of these goods is preferred to another specific combination of these same two goods, we can say that the individual's utility from the preferred combination is *higher* than her utility from the other combination. However, there is generally speaking not much one can meaningfully say about by

[4] This presentation is largely based on Nyborg (2012).

Box 3.1 The relationship between utility and willingness to pay

Let X_i be the private consumption of person i as measured in monetary terms, and let E be a measure of environmental quality that is the same for all individuals (a public good), measured in physical units. Furthermore, let us assume that the utility of person i is expressed by U_i, which is a function $u_i(X_i,E)$:

(1) $U_i = u_i(X_i, E)$

The function is assumed to be upward sloping in both variables. If the private consumption of the individual or the environmental quality increases, utility will also increase. Marginal changes may be expressed by differentiating (1):

(2) $dU_i = u'_{iX} dX_i + u'_{iE} dE$

Here d expresses a marginal change in a variable, u'_{iX} expresses the change in utility as the result of a one krone increase in private consumption and u'_{iE} expresses the change in utility as the result of a one unit increase in environmental quality. In other words, we may say that u'_{iX} is the derivative of u_i with regard to private consumption. This is often termed the individual's marginal utility of consumption. Since all consumption is here measured in monetary terms and expressed as one consumption good, we may also consider this to be the marginal utility of income.

The willingness of an individual to pay for an environmental improvement dE is defined as how much the individual will have to reduce her consumption, as measured in monetary terms, in order to get back to the same utility level as before the environmental improvement. This is defined by $dU_i = 0$. Let BV_i be the willingness to pay of individual i. The willingness to pay says by how much consumption will have to be reduced to achieve $dU_i = 0$, and consequently $dX_i = -BV_i$. If we insert this in (2) and rearrange, we get an expression for the willingness to pay:

(3) $BV_i = \frac{u'_{iE}}{u'_{iX}} dE$

The ratio between two marginal utilities is termed the marginal rate of substitution. $\frac{u'_{iE}}{u'_{iX}}$ is the marginal rate of substitution between environmental goods and consumption, and expresses how much consumption individual i is willing to forgo in return for one more unit of the environmental good and still remain at the same utility level. This is what may be termed the marginal willingness of individual i to pay for the environmental good E. If we envisage a one-unit change in the environmental good, dE, we note from (3) that the willingness to pay for this is the marginal rate of substitution between consumption and the environmental good.

Let us now assume that the individual needs to reduce her consumption by C_i in order to contribute to the funding of the environmental improvement. We express this as $dX_i = -C_i$. By combining (2) and (3) we can then arrive at an expression showing the relationship between the utility effect of a measure, the willingness of the individual to pay and the cost of the measure to such individual:

(4) $$dU_i = u'_{iX}(-C_i) + u'_{iE} dE = u'_{iX}(-C_i) + u'_{iE} \frac{u'_{iX}}{u'_{iE}} BV_i = u'_{iX}(BV_i - C_i)$$

We note that the change in utility is proportional to what may be termed the net willingness to pay, which can thus be measured in monetary terms, with the proportionality factor being the individual's marginal utility of money, which cannot be measured or observed.

how much the individual prefers one combination to the other.[5]

In cost-benefit analysis, the analyst wishes to compare benefits across different individuals. It is easier to do so in a consistent and systematic manner if the benefits can be measured in the same units. Costs are usually measured in monetary terms. One question is therefore whether a change in individual utility can also be measured in monetary terms. In our example: if environmental quality changes, is it possible to express *in monetary value* how this affects the utility of the individual?

One approach is to examine the individual's willingness to pay. If the environmental quality is

5 Expressed in technical terminology, we may say that utility is only measured ordinally, and not cardinally.

improved and such individual's income and private consumption remain unchanged, the individual will prefer the new situation to the situation prior to the environmental improvement. In other words, she has reached a higher utility level. We may in such a situation ask by how much the individual needs to reduce her consumption, as measured in monetary terms, in order to return to the same utility level as before the environmental improvement. The answer to this question is the individual's willingness to pay for the relevant environmental improvement.[6] Chapter 2.6 briefly discusses various methods for measuring the willingness to pay for goods that are not traded in the market, such as for example environmental goods.

However, willingness to pay does not provide a measure of the individual's utility effect from the environmental improvement *as such*. How important a one-unit improvement in the environmental good is for an individual is often referred to as the individual's marginal utility of the environmental good. Correspondingly, the marginal utility of consumption expresses how important a one-krone consumption increase is to the individual. The willingness to pay for the environmental good may be expressed as the ratio between these two marginal utilities, and it therefore provides information about how important the environmental good is *relative to* money. It follows from this definition that a high willingness to pay may both mean that the environmental good is important to the individual and/or that money is of minor importance. Let us now assume that the individual must contribute to funding the environmental improvement through somewhat reduced private consumption, for example in the form of a tax. Since both the willingness to pay and private consumption are measured in monetary terms, these can be compared. The willingness to pay less the consumption reduction may then be termed the individual's net *willingness to pay* for the environmental improvement. However, the magnitude of the *utility change* experienced by the individual as a result of the measure depends on how important one extra krone is for her, i.e. on the individual's marginal utility of income. The relationship between utility and willingness to pay is examined in more technical terms in Box 3.1.

Social welfare functions

One may envisage society's welfare being expressed as a function of the utility of the members of society. This function may depend both on the utility level of the individuals in society and on how such utility is distributed between the individuals.[7] Society's welfare must here be understood as a normative concept that is intended to capture how "good" a society is. Consequently, there is in practice no one "correct" or "true" social welfare function, unless one believes in the existence of one "correct" or "true" answer to what constitutes a good society. This raises both ethical and philosophical questions. Hence, a social welfare function may therefore be considered to be an expression of an ethical stance or of specific political priorities on the part of a decision maker.

Let us now use the concept of social welfare functions to examine the effects of a marginal project. The project will have two effects on society's welfare. The first effect relates to how important the utility of the affected individuals is considered to be in the social welfare function. The second effect relates to how much change there is in the utility of such individuals. As explained above, the utility of the individuals will change through their net willingness to pay for the project and their marginal utility of income.

3.3.2 Distribution weights and cost-benefit analysis

The total weight attributed to an individual's or a group's net willingness to pay may be termed a welfare weight or distribution weight. This is the term referred to in the following sentence in the terms of reference of the Committee: "Distribution weights may be used in cost-benefit analysis to specifically adjust for income distribution effects". A more technical presentation is set out in Box 3.2. We have shown there that the distribution weights comprise two components. The first reflects how important money is on the margin for the affected individual, i.e. the individual's marginal utility of income. The second reflects how important a marginal change in the utility of the

6 We here assume that the project is "small" in the sense that it only causes changes that are too minor to influence market prices, cf. the discussion in Chapter 2.8, Partial and general equilibrium models, and also that it is too small to change the individual's marginal willingness to pay. If the latter assumption does not apply, it may be of importance whether one asks about willingness to pay or compensation claims (Hanemann, 1991).

7 How good a society is may also depend on other things than individual utility. Reference is made to Sen (1979), Kaplow (2008) and Nyborg (2012) for a more detailed discussion of this.

Box 3.2 Social welfare functions and distribution weights

A social welfare function may be written as follows:

(5) $W = V(U_1, \ldots, U_n)$

where W is a measure of welfare in society, n is the number of individuals in society, and U_i is defined in Box 3.1. V is usually assumed to be increasing in U_i for all $i = (1, \ldots, n)$.

If we differentiate (5), we get

(6) $dW = V_1' dU_1 + \ldots + V_n' dU_n$.

Equation (6) states that the change in welfare is a weighted sum of the utility changes. The weight V_i' expresses the importance attributed to the change in the utility of individual i. If we use the expression from (4) in Box 3.1 above, which stated that $dU_i = u_{iX}'(BV_i - C_i)$, we get

(7) $dW = \sum_i (V_i' u_{iX}'(BV_i - C_i))$ where $i = (1, \ldots, n)$.

The weight attributed to each individual's net willingness to pay, $(BV_i - C_i)$, is expressed as $(V_i' u_{iX}')$. Hence, the change in welfare resulting from a project is a weighted sum of individuals' net willingness to pay for the project. This weight, $(V_i' u_{iX}')$, is the one referred to when the terms of reference refer to "distribution weights".

It follows from (7) that an unweighted sum of individuals' net willingness to pay will only express total *welfare change* if $(V_i' u_{iX}')$ is the same for all i. Cost-benefit analysis provides us with an unweighted sum of the individuals' willingness to pay less the cost of the measure. This corresponds to letting $(V_i' u_{iX}') = 1$ for all i, which implies that $V_i' = 1/u_{iX}'$. If the marginal utility of income (the denominator) is lower the richer you are, this implies that V_i' is higher for the rich than for the poor. Thus, in the social welfare function more weight is attached to changes in utility on the part of rich individuals compared to changes in utility on the part of poor individuals. If such a perspective on distribution is not shared by the decision maker, cost-benefit analysis cannot be directly interpreted as a normative expression of the overall change in welfare.

affected individual is considered to be from the perspective of overall welfare.

This section will examine these two components of distribution weights.

The marginal utility of income

The marginal utility of income of the individuals in society expresses by how much a person's utility increases when her income increases by one krone. This may be approached as a descriptive, and not a normative, problem. However, we noted in 3.3.1 that the standard utility concept in economics only expresses whether an individual prefers one combination of goods to another, and cannot be used to say anything about by *how much* one combination of goods is preferred to another (utility is ordinal, but not cardinal). If a utility estimate shall be used to say anything about several individuals it must also be comparable across individuals. This requires the utility of a good to be measured in absolute value, not only relative to another good. This necessitates a different utility concept than is normally used in economics. Several attempts have been made at establishing methods for the measurement of utility levels that are both cardinal and comparable across individuals, but no generally accepted method currently exists (Nyborg, 2012).

We can nevertheless make some assumptions that can tell us something about the shape of the utility function of each individual. If more of a good increases utility, we know that marginal utility is positive. If one values a unit of a good more when one has little of it from before, we know that the marginal utility decreases the more one has of such good. Provided that these assumptions hold true for consumption and income, a rich individual will derive less "enjoyment" from one additional krone than will a poor individual. If we also assume that all individuals have the *same comparable utility function*, we may say that a rich person derives less "enjoyment" from one additional krone than does a poor person.

Many different attempts have been made at anchoring the choice of welfare weights in observed behaviour. One example is studies based on the tax system. Such studies assume that the progressivity of the current tax system represents central government's views as to what is the "appropriate" distribution, and a social welfare function is derived from the tax system. Such studies seek to identify society's valuation of one additional krone for each individual, and hence no distinction is made between the individual's valuation of one additional krone and society's valuation of each individual's utility as such.[8] Taking this approach, and based on assumptions implied thereby, Cowell and Gardiner (1999) find, for example, that the British tax system in the late 1990s implied that if the income of a household increased by one percent, the marginal utility of income was reduced by between 1.28 and 1.43 percent, when viewed from the perspective of central government. Cowell and Gardiner (1999) also report that if they use estimates for the risk aversion of individuals to represent society's distribution preferences, they find values in the region of one percent.[9] By using various indirect methods, including the tax approach, Evans (2005) takes the view that a value in the region of 1 percent will be an appropriate approach to the aversion against inequality reflected in current policy in the United Kingdom. However, a joint characteristic of these various approaches is that they are based on many strict assumptions that may be difficult to penetrate. If these assumptions are accepted it will still be legitimate for a decision maker to want to base her assessments on a social welfare function that differs from the social welfare functions that can be derived from current policy.

Studies within behavioural economics, neuroeconomics and happiness research have tried alternative methods for analysing the marginal utility of income (see, *inter alia*, Layard et al., 2008, and Oswald 2008). Findings from such studies may be used to get an indication of the possible magnitude and how it depends on factors like income level, health, gender, socio-economic status, etc. Layard et al. (2008) for example, use large data sets on self-reported happiness levels from 50 countries for the period from 1972 to 2005, and conclude that if the income of a household increases by 1 percent, the marginal utility of income is reduced by 1.26 percent. In other words, their findings indicate that a person's marginal utility of income depends on her income level, and that it declines quite steeply. However, Oswald (2008) notes that such conclusions require us to equate happiness with utility, and that the numerical scale used in the happiness questionnaires provides reasonable linear happiness measures. If enquiring about happiness on a scale from 1 to 6, an increase from happiness level 2 to 3 is for example considered as good as an increase from happiness level 5 to 6.

Society's valuation of the changes in utility on the part of individuals

The second component of a distribution weight specifies how much weight shall be attached to the utility of the various individuals in society. This is a purely normative assessment. Two decision makers who have exactly the same understanding as far as the actual consequences of a measure are concerned, may differ in their assessments of such measure because they attribute different social weight to these consequences. Such differences may for example reflect their opinions with regard to distribution. One may in such case say that the two decision makers have different preferences that may be expressed through two different social welfare functions. If a specific social welfare function is used to examine the welfare effect of a measure, the findings will therefore only be useful as an indicator of whether such measure is "good" for persons who share the distribution preferences underlying the chosen social welfare function. The NOU 1997: 27 Green Paper provides a more general discussion of different social welfare functions.[10]

Although we are here discussing the issue based on a situation with one decision maker, reality tends to be more complex. A bureaucracy or a democratic process will involve many agents who need to reach agreement about a conclusion. These agents may have diverging perspectives on what constitutes a good society, and implicitly base their assessments on different social welfare functions. The final decision will typically be made in fairly complex strategic situations. Such situations may also well involve distributional requirements deriving from laws and regulations. These requirements may be interpreted as side conditions, subject to which a social welfare function is to be maximised, whilst the said laws and regulations were adopted on the basis of certain distributional preferences. One may also envisage different political parties systematically tending to favour different social welfare functions. It will not necessarily be possible to incorporate diverging

8 In technical terms this involves estimating the product of u' and V', as these are defined in Box 3.2 on social welfare functions and distribution weights.

9 It is noted in Chapter 3.3.1 that HM Treasury (2003) applies a value of about one percent, citing Cowell and Gardiner (1999) as one of its sources.

10 See, in particular, Box 4.2 on p. 36 of the NOU 1997: 27 Green Paper.

perspectives on what constitutes a good society in one set of distribution weights. The complex decision situation with regard to public projects does instead suggest that cost-benefit analysis should be conducted in such a way as to provide a basis for making decisions that is useful for decision makers with different distribution preferences (Nyborg, 2012).

Distribution weights and cost-benefit analysis – a summary

The discussion thus far in the present Chapter has shown that a distribution weight comprises two components. One component may be considered descriptive, but cannot be estimated without making rigid assumptions. The other component is purely normative. Consequently, it is not possible to define distribution weights for use in cost-benefit analysis without making assumptions that are hard to verify empirically. Intuitively, this reflects a simple principle: The extent to which an actual effect contributes to a better society is a question that will, by its very nature, depend on discretionary as well as normative assessments.

A cost-benefit analysis without the use of distribution weights provides an unweighted total of willingness to pay and costs. This should not be confused with a normative measure of society's welfare. If the rich derive less utility from one additional krone than do the poor, it will only be appropriate to use an unweighted cost-benefit analysis as a normative measure of changes in welfare if one accepts a social welfare function that attaches more weight to changes in the utility of the rich than of the poor.

The current definition of economic profitability, as set out in Chapter 2.2, is as follows:

> Cost-benefit analysis, as a specific method of analysis, involves the valuation, to the extent feasible, of all positive and negative effects of a measure, based on the fundamental principle that the value of a consequence is what the population as a whole would be willing to pay to achieve it. If the willingness to pay for all benefits emanating from the measure exceeds its total costs, such measure is defined to be economically profitable (NOU 2009: 16 Green Paper).

Using the terminology we have introduced in the present Chapter, we note that this definition does not in itself say that economic profitability is a normative expression of how a measure influences society's *welfare*. Economic profitability, as defined in Chapter 2.2, tells us whether the aggregate willingness to pay for those effects that can be quantified in monetary terms exceeds those aggregate costs than can be quantified in monetary terms. The above discussion shows that a normative interpretation of economic profitability can only be based on very restrictive assumptions.

3.4 Presentation of distribution effects in the analysis

Chapter 3.3 addressed the use of distribution weights. If one does not make use of explicit distribution weights, distribution effects may be presented more directly. We will here provide a more specific discussion of various approaches to presenting distribution effects in the cost-benefit analysis and the challenges posed by such approaches.

3.4.1 Can we know what the distribution effects are?

If seeking to analyse distribution effects, one first needs to take a view on whether it is at all *possible* to perform such an analysis. There will be cases when a cost-benefit analysis can be carried out, but not a distribution analysis.

A key aspect concerns wider impacts, as discussed in Chapter 7. Although one frequently examines the economic effects in the primary market where the project is implemented, a distribution analysis necessitates the examination of the effects where these eventually end up. For example, we primarily measure the utility of a new road by looking at travel time savings, but these time gains are subsequently spread via taxes, land prices, etc., to other people in the affected communities. A complete *distribution analysis* must examine the final effects resulting from the road investment. In principle, this will only be possible within the framework of a general equilibrium model, and falls outside the scope of what can normally be elucidated through a cost-benefit analysis. If such wider impacts are significant, neither weighting of the direct effects, nor a more explicit distribution analysis of the direct effects, will convey a correct picture of the project consequences. The problem of partial distribution analysis will become more pronounced the larger the wider impacts of the project are assumed to be. One may note that this pertains to all wider impacts, both those that only involve redistribution of the direct effects and those that influence net economic profitability, defined as net wider impacts in Chapter 7; *Wider impacts in the transportation sector*.

It may also be that the final distribution effects do not only depend on redistribution of the original gains from the project, but on dynamic effects influenced by the project in a lifetime perspective. This may, for example, be the case within the education sector. Such analysis will often fall outside the natural scope of an ordinary cost-benefit analysis. However, if the measure under consideration is primarily motivated by redistribution, such an analysis will be necessary.

Furthermore, it will often be the case that the analyst does not have data about individual persons affected by the project. For road traffic one will, for example, normally proceed on the basis of traffic measurements that do not say much about individual road users. These tend to only distinguish between different types of vehicle. Hence, an analysis seeking to show how the effects are distributed across various income groups requires the gathering of – in some cases extensive – additional data over and above those that form the basis for an ordinary cost-benefit analysis. If the cost-benefit analysis is to be corrected for distribution effects, it is a requirement that the unweighted profitability is the sum of affected individuals' willingness to pay. In practice, however, the transportation sector tends to use the average willingness to pay across different groups. As discussed in Chapter 4, transportation bodies in Norway do for example apply the same values of travel time for travels throughout the country irrespective of project type. Since the magnitude of several unit prices, including values of time, will be proportional to wage income, the Ministry of Transport and Communications takes the view that areas with high mean income will undoubtedly have a higher willingness to pay, and thus higher estimated unit prices. Hence, using mean figures is a form of implicit distributive welfare weighting.

3.4.2 Presentation of distribution effects

HEATCO (2006) is an EU project for harmonising the valuation of transportation projects. Its report from 2006 notes that three main methods are used in EU countries to take distribution effects into account, either in the actual cost-benefit calculation, or as a supplement: 1) distribution weighting, 2) presentation of benefits and costs by different income groups and 3) stakeholder analysis. This forms the basis for the discussion below, where we address each of these approaches.

Distribution weighting

One approach to handling the issue of distribution is, according to Boadway (2006), to state explicit assumptions with regard to distribution preferences and assume that all individuals have corresponding and comparable utility functions. On this basis, the cost-benefit analysis is carried out with explicit distribution weights. Thereafter, one may perform sensitivity analyses to examine how the findings change when using different weights. The decision maker will then see how different measures are ranked for different distribution weights. Boadway (2006) notes that one will in such contexts often combine considerations with regard to the marginal utility of income and the shape of the social welfare function into one parameter that expresses aversion against income disparities. This parameter forms the basis for the distribution weights.

Chapter 3.3 discussed methodological and normative problems relating to the use of distribution weights. Chapter 3.4.1 noted that wider impacts may mean that distribution weighting does not appropriately correct for the distribution effects of the project, even in case of agreement as to the weights applied. The problem that one often will not have data on the income of the individuals influenced by the project is also noted.

Presentation of benefits and costs by different income groups

If one is in possession of information on the expected income of those who are affected by a project, one may present benefits and costs by different income groups. In such a presentation it is important to be clear about which income measure is being used. Moreover, it needs to be taken into consideration that income is often presented at household level, whilst effects in cost-benefit analysis are often estimated at the level of the individual.

A practical approach that is recommended, *inter alia*, in the United Kingdom, is to divide the population into income quintiles. This involves determining what income interval the fifth with the lowest income falls into, which income interval the next fifth falls into, etc. Thereafter the costs and benefits can be specified for each of these quintiles in a table and the like.

As noted in Chapter 3.4.1 above, one will often lack information about the income of the individuals affected by the project. The problem of wider impacts will also apply here. Another approach is therefore to conduct an analysis of those groups that may be assumed to gain or lose from the project. This is termed stakeholder analysis below.

Stakeholder analysis

Stakeholders may be defined as persons or organisations that contribute to, or may be affected by, a measure, directly or indirectly (Ministry of Finance, 2008). Under the central government quality assurance regime, central government projects with an expected cost in excess of NOK 750 million are subjected to external quality assurance of concept choice (QA1) before a decision is made with regard to further planning. The projects shall undergo external quality assurance as to the cost budget and project management documentation (QA2) before it is decided whether to implement the project. QA1 requires a needs analysis, which shall include the identification of stakeholders through a stakeholder analysis. Under QA1, the stakeholder analysis and the needs analysis precede the assessment of requirements, restrictions and possibilities, the establishment of various alternatives and the cost-benefit analysis of these.

If one would like to analyse the distribution effects of a project, one approach may be to identify stakeholders in a stakeholder analysis as mentioned above. The cost-benefit analysis may then be supplemented by an analysis of distribution effects based on the stakeholder analysis. This may be presented as an overview of which groups can be expected to gain or possibly lose from the project in question. The categorisation of stakeholders will have to be decided on in view of the specific character of each project. It may also be based on the various categories identified in the cost-benefit analysis as well as the identification of stakeholders in similar projects. The lack of sufficient data to assess the consequences for a specific stakeholder would in itself be information of relevance to the decision maker.

3.5 Guidelines for the presentation of distribution effects in other countries

3.5.1 United Kingdom

The cost-benefit analysis guidelines in the United Kingdom are laid down in the so-called “Green Book”, which was published by Her Majesty's Treasury in 2003 (HM Treasury, 2003).

These guidelines recommend performing an analysis of how the costs and benefits of a measure are distributed across various socio-economic groups. It is noted that relevant groups may be specified on the basis of income, gender, ethnicity, age, geography or disability.

It is specifically noted that analysis should show how benefits and costs are distributed across various income groups. The guide presents two tables showing income per household across five quintiles and different types of households. It is observed that the groups specified in these tables may form an appropriate basis for such analysis.

It is further recommended that additional analysis of distribution effects *may* be carried out by using explicit distribution weights. It is stated that benefits accruing to households with relatively low income should be accorded more weight than benefits accruing to households with higher income. This will influence the findings from the cost-benefit analysis. The guide observes that benefits and costs measured in monetary terms should *in principle* be weighted on the basis of the income level of those who carry the costs or enjoy the benefits. However, it is noted that sufficient information to perform such an analysis will in many cases not be available at an acceptable cost. Whether to use distribution weights should be examined on the basis of three criteria: 1) the magnitude of the effects, 2) the probable robustness of the calculation of the specific distribution weights, and 3) the type of project under analysis. If distribution weights are not used, the guide requires the reasons for this to be explained as part of the analysis.

The guide presents a method for determining distribution weights for use in the analysis. Reference is made to summaries of empirical studies of the magnitude of the effect of the income level on the marginal utility of income, which according to HM Treasury (2003) are consistent with the assumption that the elasticity of the marginal utility of income is 1.[11] An elasticity of 1 is consistent with a logarithmic utility function $U = log\ C$, where

C is consumption. The marginal utility will then be *1/C*. It is noted that one method for constructing distribution weights is to start out from an analysis in which benefits and costs are specified by quintiles. A distribution weight can then be attributed to each quintile, and a weighted total can be calculated. The distribution weight may be specified as the marginal utility for a household with median income in each quintile as a percentage of the marginal utility of a household with the median income of the overall population. Using British data, the resulting distribution weights are in the region of 0.4 to 2.3. This approach means that the willingness to pay for the good can be grouped on the basis of which income quintile each person reporting her willingness to pay belongs to, and that thereafter the willingness to pay of each the group may be weighed using the distribution weights. The British guide does not distinguish between what we above have termed the marginal utility of income and the decision maker's valuation of the utility of individuals. As noted in 3.3.2, the estimates referred to in the British guide are obtained from studies of the aversion against income disparities as reflected in current policy.

3.5.2 HEATCO (EU)

As discussed in 3.4.2 above, HEATCO (2006) is an EU project for harmonising the valuation of transportation projects, which notes that three main methods are used in EU countries to take distribution effects into account, either in the actual cost-benefit calculation, or as a supplement: 1) distribution weighting, 2) presentation of benefits and costs by different income groups, and 3) stakeholder analysis.

It is emphasised that a presentation of benefits and costs by income groups enables the decision maker to assess whether the distribution effects of a measure are acceptable. However, it is noted that such a method requires highly detailed data, which implies that it is rarely used in practice. A simpler and more practical way of presenting information on the distribution effects of a project is to provide an overview of project winners and losers based on categories that are more readily established, like for example geography, private sector vs. public sector, etc.

[11] Cowell and Gardiner (1999) conclude that the elasticity is just above or below 1. Pearce and Ulph (1995) find elasticities of between 0.7 and 1.5.

It is recommended, as a minimum, to prepare a table of winners and losers to supplement the findings from a cost-benefit analysis. To the extent data are available, the decision maker should be presented with a specification of benefits and costs by income groups. If deemed useful and worthwhile in terms of the resources required, findings using distribution weights may be presented in the form of a sensitivity analysis.

3.5.3 Sweden

An updated recommendation addresses how considerations relating to distribution and equal opportunities shall be dealt with in cost-benefit analysis within the transportation sector in Sweden (Swedish Transport Administration, 2012). For projects of special importance, as defined in the Swedish guidelines, a so-called "cumulative effects assessment" is required to be prepared in Sweden. This is a standardised approach to the presentation of economic profitability, distribution effects and the realisation of transportation policy objectives, respectively, summarised in a defined two-page format. It is recommended that this approach be used to shed light on aspects relating to equal opportunities and distribution.

This format presents the distribution analysis in terms of how the effects of the measure are distributed across various groups in society, including, *inter alia*, by gender, age, geographic area, type of traffic and disabilities. It is noted that this is in line with HEATCO's minimum requirements for addressing distribution effects, cf. the above discussion.

Several reasons are given for not recommending the use of explicit distribution weights. It is noted that distribution effects are, in the absence of generally accepted weights, better presented by separately explaining how the effects are distributed across various groups. Moreover, it is noted that the use of distribution weights makes it difficult for the decision maker to weigh what is "efficient" against her evaluation of the distribution effects. Finally, it is noted that it is difficult to know what will be the final distribution effects of measure, since these are the result of interactions through the markets and through the tax and transfer system.

3.6 The assessment of the Committee

Cost-benefit analysis is not a tool for making direct normative recommendations, but rather an indicator that must normally be supplemented by other information, such as, *inter alia*, the assessment of anticipated distribution effects. Generally speaking, a cost-benefit analysis measures the effects of projects and measures in monetary values (although these need not be restricted to market values), and not utility or welfare as such. Cost-benefit analysis *only* measures the net effect of various measures on society's *welfare* under the assumption that, from the perspective of society, one additional krone is considered equally important for all affected individuals. This is, as pointed out in the NOU 2009: 16 Green Paper, a controversial assumption, that can hardly be expected to reflect a complete consensus. Normative recommendations on the basis of cost-benefit analysis must be expected to be equally controversial when the projects entail distribution effects that are not dealt with through other policy measures. It is worth noticing in this context that the controversial aspect of a normative interpretation of cost-benefit analysis, as discussed in the analysis above, is not primarily related to any potential contribution the project may make to *changing* the income distribution in society. It is rather that a normative interpretation of the cost-benefit analyses implies a specific stance with regard to how different interests shall be weighted when these are in conflict – even if the project entails insignificant changes in the distribution of income or utility in society. Generally speaking, the decision maker should therefore receive information about which conflicts of interest the project gives rise to, thus enabling her to evaluate for herself how to address the resulting tradeoffs.

In the present Chapter, we have discussed the use of explicit distribution weights in cost-benefit analysis as a method of adjusting for the distributional consequences of measures in the analysis. If generally accepted distribution weights existed, it would have been easier to recommend normative interpretation of the analysis. Such weights are a product of the marginal importance of money to each individual and how important a marginal change in utility on the part of the affected individual is deemed to be in terms of overall welfare, as seen from the perspective of the decision maker. The latter reflects the decision maker's social welfare function, i.e. her views about what characterises a good society.

The discussion in this Chapter has shown that distribution weights cannot be determined without making assumptions about the normative perspective of the decision maker and the marginal utility of money. No established method for determining individual's marginal utility of money exists, whilst defining a social welfare function is a purely normative exercise. Besides, an actual decision-making process tends to be a complex strategic situation involving several agents with diverging perspectives on distribution. Even if one were to agree on the normative aspects of the matter, we would nevertheless be left with the problem that we have no generally accepted and objective method for determining individuals' marginal utility of money. Establishing explicit distribution weights for use in cost-benefit analysis therefore requires strict assumptions that do not readily lend themselves to empirical testing. Normative interpretation of an unweighted cost-benefit analysis involves applying an implicit distribution weight equal to 1 for all individuals. Such implicit distribution weights suffer from exactly the same problems as do explicitly defined distribution weights.

The cost-benefit analysis framework should be such as to enable the analyses to provide the best possible informational basis for the decision maker, irrespective of her political and ethical views. This means that the calculations should be as easy as possible to understand, and that the assumptions underpinning the analysis should be clearly indicated. The Committee therefore holds the view that the cost-benefit analysis of public projects should not primarily seek to estimate a project's contribution to society's welfare. The main reason for this is that the answer to such a question would only be of relevance to individuals who share the normative perspectives on which the applied distribution weights, implicit or explicit, are premised.

This view implies, firstly, that the Committee will not recommend explicit distribution weights in cost-benefit analysis. However, it also implies that the estimated economic profitability of projects, as calculated in ordinary cost-benefit analysis *without* explicit welfare weights, cannot readily be interpreted normatively. The latter also applies to projects with only limited distribution effects and/or no redistributive purpose. Hence, the view expressed by the Committee implies that economic profitability shall be interpreted as a summary measure of what the population as a whole is willing to pay for a project, and not as a measure of what is in the best interest of society in the wider sense, as discussed in Box 3.2.

The Committee therefore agrees with the suggestion in the NOU 2009: 16 Green Paper that it may be useful to consider cost-benefit analysis a tool for organising information on effects, rather than as a tool for direct normative recommendations. The estimated economic profitability must then be considered an indicator that will normally have to be supplemented by other information, prior to making final decisions.

In order to provide the best possible informational basis for the decision maker, the Committee therefore takes the view that cost-benefit analysis should seek to describe economic profitability, non-priced effects (whenever possible), as well as the distributional implications of measures, as discussed in Chapter 2.3. This approach is in line with current cost-benefit analysis guidelines in Norway. As recommended in HEATCO (2006), the distributional consequences may for example be summarised as a list of winners and losers supplementing the findings from a cost-benefit analysis, i.e. a type of stakeholder analysis. One may also prepare a presentation of benefits and costs specified by income groups to the extent that data are available. If one has the data and capacity required to incorporate explicit distribution weights, one may in the form of a sensitivity analysis present what impact different levels of aversion against inequality will have for the ranking of projects.

The Committee has noted that it will in some situations be possible to perform a cost-benefit analysis, but not a distribution analysis, because it may be difficult to estimate, within a project analysis framework, which groups are affected, and the degree to which these are affected, by the final effects. The analyst should be conscious of this when performing analyses of the distribution effects.

3.7 Summary recommendations

Based on the discussion in the present Chapter, the Committee makes the following recommendations:

- Cost-benefit analysis should continue to estimate the aggregate, unweighted willingness to pay. In other words, explicit distribution weighting is not recommended.
- The Committee holds the view that economic profitability shall be interpreted as a summary measure of the net amount the population as a whole is willing to pay for a project, and not as a measure of what is in the best interest of society in a wider sense. This implies that the estimated economic profitability of projects, as calculated in ordinary cost-benefit analysis without explicit welfare weights, cannot in itself be interpreted normatively as a matter of course.
- The distribution effects for especially affected groups, including any conflicts of interest, should be examined and discussed in a manner providing the decision maker with the best possible basis for taking these into consideration when assessing the public measure. It should be explained how different objectives with regard to distribution and conflicts of interest may influence the desirability of implementing the measure.

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Chapter 4
Real price adjustment

4.1 Introduction

From the terms of reference of the Committee:

> The cost-benefit analysis guide of the Ministry of Finance does not explicitly address the fact that analysis parameters may change over time, for example that the value of time and time savings may be assumed to increase in line with real wage growth in the economy. Correspondingly, the willingness to pay for environmental goods may change over time, whilst technological progress may change future costs. This type of considerations may have a major impact of the assessment of costs and benefits in long-term projects, like for example infrastructure investments within the transportation sector. The Expert Committee shall examine whether and, if applicable, how changes in parameter values over time may be included in the cost-benefit calculations.

In order to compare the current and future benefits and costs of a project, assumptions have to be made as to how the various calculation prices will develop during the analysis period. However, it is challenging to estimate how future prices will change relative to each other. A common simplification when calculating the economic benefits of a project is to keep all prices unchanged throughout the analysis period in real terms, i.e. it is assumed that all nominal prices increase at the same rate (in line with the increase in the retail price index). If the price of a good or a service on the benefit side of a project is expected to increase relative to the prices of other goods and services, the project will seem less profitable than is actually the case unless this is taken into consideration in the analysis. In the present Chapter, we will examine whether the assumption of constant calculation prices in real terms fails to reflect expected developments in some cases, thus implying that a change in real prices should be assumed for certain goods in the cost-benefit analysis. The adjustment in calculation prices motivated by an expectation that these will increase at a different rate than general inflation as measured by the retail price index is referred to as real price adjustment.

In Chapter 4.2, we explore the issue in more detail, before looking at the theoretical relationship between price growth and real wage growth in 4.3. Chapter 4.4 discusses real price adjustment of the value of time savings, which is often a key benefit component in cost-benefit analysis in the transport sector. Chapter 4.5 discusses price developments over time for environmental goods in general, whilst carbon price paths are examined specifically in Chapter 9. The valuation of health goods is primarily discussed in Chapter 10, but real price adjustment of the value of statistical lives is addressed in the present Chapter. Chapters 4.6 and 4.7 present the assessment and recommendations of the Committee.

4.2 Background and scope of discussion

Costs and benefits (in monetary values) arising at different points in time need to be modified such as to become comparable in a cost-benefit analysis. The most common method for making such a comparison is to convert the annual cost and benefit elements into a net present value. The net present value is the value *today* of the aggregate benefits and costs arising at various times during the project period. A net present value calculation discounts all future amounts by applying a discount rate.

It is currently common practice to assume constant real prices for the costs and benefits of a project throughout the project period. The prices used are most often those applicable in the base year or prices adjusted to the expected price level of the commencement year of the project. The net present value of the project is then determined by applying the real interest rate (the nominal interest rate less the expected percentage increase in the retail price index) as the discount rate. The choice of discount rate and its time profile are discussed in more detail in Chapter 5.

Keeping real prices constant throughout the project period is based on the assumption that all costs and benefits will undergo the same price developments as the standardised basket of consumption goods on which the retail price index is based. However, nominal price developments for some project-specific costs and benefits will deviate from the said index.

In a project context, this can be stated as follows: If a cost or benefit is valued at P_0 in the base year, the relevant valuation in any given period t is determined as $P_t=P_0(1+p)^t$, where p is expected real price growth (price growth in excess of the growth rate of the retail price index) over the period. Such valuation will exceed the base year price if the nominal value is expected to increase at a higher rate than the retail price index, and vice versa. Making no real price adjustment means adopting an implicit assumption to the effect that every p=0, i.e. that the growth rate of the nominal price level of the various goods and services is identical to the growth rate of the retail price index.

4.2.1 Real price growth – general observations

Developments in the real prices and values of goods and services are influenced by a number of factors.

The prices of goods and services for which well-functioning markets, and thus market prices, exist will be determined by supply and demand. Reduced supply of a good will usually result in price increases until demand has adapted to the lower supply. Higher demand for a good will normally also result in higher prices for such good.[1] In a small, open economy like Norway, nominal price changes for many goods will nevertheless be determined by the world market, adjusted for changes in the nominal exchange rate.

Changes in productivity or efficiency in the production of a service or a good may cause supply changes, and thus price changes. Classical examples are high-technology products like for example computers, for which major productivity improvements have been witnessed internationally, thus leading to lower prices in Norway as well. Such cost and price changes will spread through the input and product markets to other producers, thus also affecting other prices. Car prices, for example, depend on the prices of electronics, ironware, electricity, etc.

Chart 4.1 illustrates nominal price developments for different types of goods between 1979 and 2011. Retail price index developments are also indicated. Chart 4.2 illustrates real price developments (nominal price growth less inflation as measured by the retail price index) for these types of goods, and Table 4.1 specifies annual percentage growth in these and certain other real prices. We note that growth in real wages (real wage cost per hour for employers, but also the purchasing power of employees) has been 1.9 percent in the relevant period. The real price of clothing has declined by 3.6 percent, which is largely explained by the "China effect" on international prices and has very little to do with Norwegian wage cost growth (see for example Chapter 7 of *Economic Analyses*, 1/2011 (Statistics Norway, 2011). The real price of services relating to leisure and culture, on the other hand, has increased by 1.7 percent, which can largely be explained by domestic wage cost increases. The reduction in the real price of telecommunications services (5.8 percent) is principally caused by new technology and increased competi-

Table 4.1 Real prices, average annual percentage increase, 1979 - 2011.

Foodstuffs	-0.21%
Clothing	-3.56%
Estimated rent	0.33%
Electricity, heating oils and other fuels	2.41%
Transportation services	1.53%
Telecommunications services	-5.79%
Services relating to leisure and culture	1.69%
Insurance	1.33%
Wage costs per man-hour	1.92%
-	-
Retail price index	4.09%

Source: Statistics Norway

[1] As long as producers are facing increasing marginal costs of production, expanded demand for these goods will result in higher prices. Consequently, economic theory suggests that when a country experiences economic growth, demand for luxury goods will grow more, and demand for necessities will grow less, than average, all else being equal. This will affect relative prices. A good or a service is defined as a luxury good if the income elasticity of demand of such good is greater than 1. By income elasticity of demand is meant how demand changes when income increases by 1 percent.

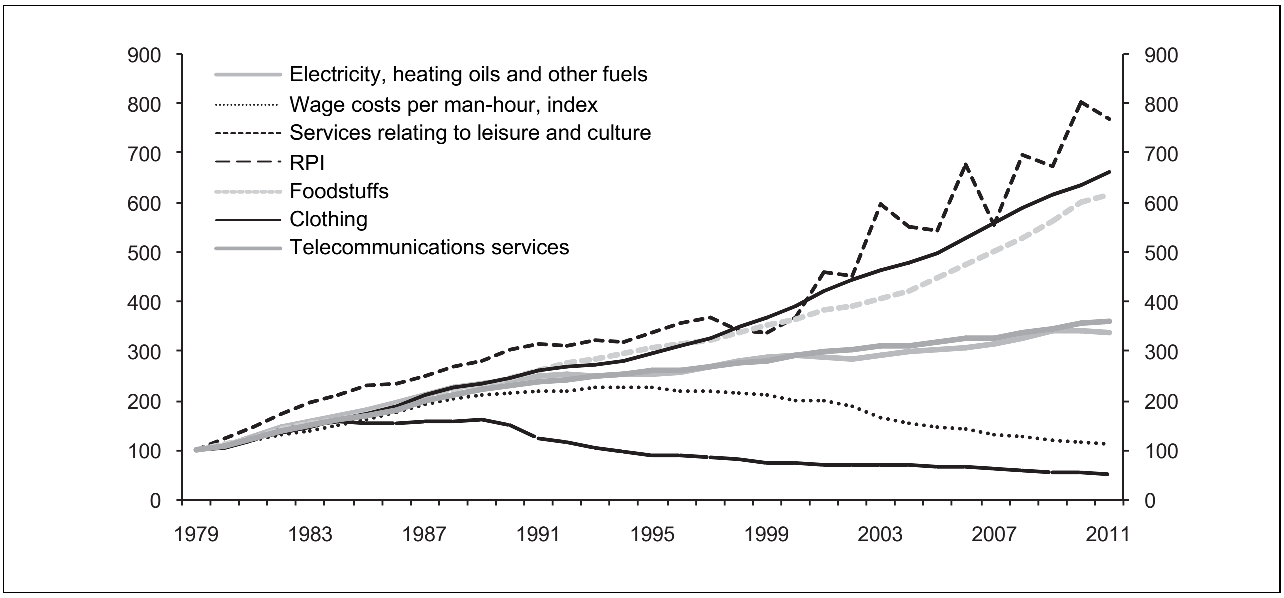

Figure 4.1 Nominal price developments for selected goods. Prices are inclusive of value added tax and other taxes. 1979 = 100

Source: Statistics Norway

tion as the result of deregulation. We further note that the real price of foodstuffs has declined by 0.2 percent on average over the period, whilst electricity and heating oil prices have increased by an annual average of 2.4 percent. We also note from the table that annual inflation as measured by the retail price index was about 4.1 percent over the same period. Although historical figures do not necessarily say anything about the future, there is reason to believe that future price developments for different goods and services will continue to be differentiated.

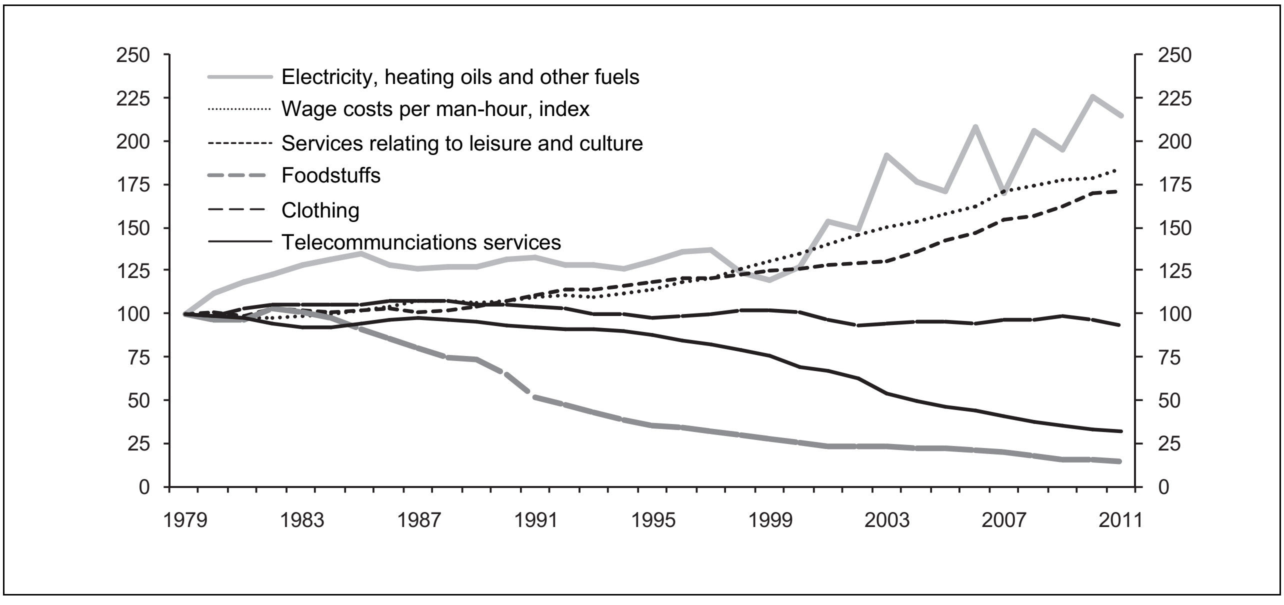

Figure 4.2 Real price developments for selected goods (nominal price growth less inflation as measured by RPI growth). 1979 = 100

Source: Statistics Norway

4.2.2 The issues examined by the Committee

A cost-benefit analysis will typically include a large number of prices, and real price adjustment may be challenging for a majority of these. A sensible approach may be to only consider real price adjustment of prices for which there are sound reasons to expect nominal growth to deviate from general inflation.

The Committee has chosen to focus on the examples mentioned in the terms of references of prices that may be subjected to real price adjustment; the value of time and environmental goods. There is, as will be discussed later in this Chapter, good reason to assume that the value of time will be influenced by real wage growth (which is normally positive, cf. Chart 4.2 and Table 4.1). Chapter 4.5 discusses factors that may suggest that the willingness to pay for certain environmental goods will increase at a rate in excess of general inflation.

In comparison, the British cost-benefit analysis guide, published by Her Majesty's Treasury; the "Green Book" (HM Treasury, 2003), names the following examples of goods that should be subjected to real price adjustment:

- High-technology products, the prices of which can be expected to decline in real terms.
- Fuel prices, which may be influenced by resource scarcity.
- Wages, if productivity growth implies that wage growth can be expected to outpace general inflation.

High-technology products are very hard to define precisely. Correspondingly, good long-term fuel price estimates are not readily available. The Committee has chosen not to address these two groups in further detail.

Box 4.1 Productivity growth

A distinction is usually made between two productivity concepts. The most commonly used is *single-factor productivity*, which tends to be measured by developments in gross output per factor, for example per man-hour. By gross output is meant production less intermediates. Gross output will for example increase if labour is equipped with more capital goods or other inputs or if new natural resources are discovered.

Another frequently used productivity concept is *total factor productivity*. Total factor productivity growth is a measure of such part of gross output growth as cannot be attributed to changes in the quantity of one or more inputs, i.e. labour, capital, intermediates, etc. Consequently, total factor productivity provides a measure of how efficiently inputs in the economy are organised for the production of goods and services. The change in gross output less the growth in measured inputs is used as an approximate measure of total factor productivity growth (Statistics Norway, 2011). Sources of total factor productivity growth may be the development of new technologies (Research and Development – R&D), the dissemination of existing technologies, improved education and learning processes associated with the implementation of new technologies.

4.3 Theory – real wage growth and price growth

The price of labour – the real wage – differs from other prices inasmuch as it is, in addition to the price of an input, also an indicator of purchasing power. A "rich country" manages to maintain high average real wages over time.

The basis for real wage growth in an economy is capital accumulation and productivity improvements.[2] More capital makes labour more productive on the margin, which results in higher equilibrium real wages. By productivity growth is meant growth in output per unit of input. Countries with high labour productivity growth normally experience high real wage growth. Chart 4.2 shows that real wages in Norway have increased by an average of about 1.9 percent annually over the period 1979–2011. See also Box 4.1.

The impact of real wage increases on prices differs. Under perfect competition, standard economic theory suggests that wages (before tax) will over time be equal to the value of the marginal productivity of labour. If one sector of the economy experiences productivity growth that justifies real wage growth, labour will be attracted to such sector via higher wages. This may force real wages upwards in other sectors of the economy as well. The impact of developments in the real price of an input on developments in the real cost of a

[2] Broadly defined (including human capital, natural resources, etc.)

project depends, *inter alia*, on such input's share of the original budget, the scope for factor substitution, as well as productivity growth as far as concerns the type of "production activity" to which the project is intended to contribute.

Let us, as an example, look at a project with no scope for substitution, i.e. where the inputs are used in a fixed proportion to each other (so-called Leontief technology). The scale of the good/service output over time is assumed to be constant. Assume that L_0 units of labour are needed in the base year and that the real wage is W_0. Real wage costs are then $L_0 * W_0$. Annual growth in real wage costs can then be expressed as the percentage growth in the real wage per hour (V_W) less the percentage productivity growth (V_L), i.e. V_W-V_L.

Table 4.1 puts average real wage growth at 1.9 percent for the period 1979-2011. Assume that we expect the same real wage growth over the lifespan of the relevant project. We then note that real wage cost developments depend on expected productivity growth, which will be project-specific. For most types of service production (e.g. health and care services, maintenance, bus transportation), there is reason to believe that productivity growth is below the average for the economy and that real wage costs will increase over time, i.e. that real wage costs in period *t,* $L_t * W_t = L_0 * W_0 (1+V_W-V_L)_t$, will exceed those in the base year. For other types of production, especially certain types of capital-intensive goods production, the opposite will apply. Hence, this line of reasoning predicts that real prices of goods and services in capital-intensive production can be expected to decline over time, whilst real prices of goods and services in labour-intensive production can be expected to increase over time. Only if productivity growth equals real wage growth will real wage costs be constant over time (cf. the presentation of historical data in Table 4.1 and the "Baumol Effect"[3]). Box 4.2 provides a brief overview of key aspects of economic growth theory.

[3] The theory that the prices of services increase by more than the prices of physical goods is often termed the Baumol Effect (Baumol and Bowen, 1966). Baumol and Bowen noted, in a well-known example, that the number of musicians needed to play one of Beethoven's string quartets is still the same as in the 18th and 19th century. The lack of productivity improvement within entertainment is descriptive of many sectors where the work performed is the actual production. In their own words: "the work of the performer is an end in itself, not a means for the production of some good" (page 164).

4.4 The value of time savings and real price adjustment

4.4.1 The value of time and previous evaluations

In order to evaluate how the value of time or time savings should be subjected to real price adjustment we need to look at the basis and methods for the valuation of time. Such valuation is based on the premise that time savings may be used for alternative purposes that could not have been realised in the absence of these savings. Correspondingly, additional time used will involve a cost in the form of the value of the alternative time uses crowded out by such additional time use. Major parts of the economic benefits from investments in, for example, improved roads, new airports or upgraded railway lines are precisely in the form of (travel) time savings. The benefits of investments in new IT systems will in many cases take the form of a reduction in time use. One may also envisage investments or projects (for example reorganisations) in other sectors that may influence the utilisation of time. In cost-benefit analysis, the time saved needs to be valued at its value in its new use, less its value in its previous use, in line with the opportunity cost principle.

The value of time reflects the fact that time is used differently for different purposes. The value of time is determined by the activity to which time is devoted, and the value of such activity. Little or no value is, for example, attributed to time "wasted" (e.g. in waiting for the bus). Time spent on productive work or on holidays and recreational activities may, at the same time, be accorded a high value. The value of time spent working on the train may differ from that of time spent listening to the radio in the car. The value of time will also differ between people. Persons who are "pressed for time" will for example have a high willingness to pay for fast transportation. Studies show that high-income groups generally place a higher value on time than other groups.

The NOU 1997: 27 Green Paper includes a fairly thorough discussion of the value of time, with a special focus on the transportation sector. That report classified the value of time into two categories: the value of time at work and the value of time outside work; private time. This Committee has chosen to adopt the same classification.[4]

Box 4.2 Economic growth theory

Neo-classical growth theory

Basic (neo-classical) growth theory was developed in the 1940s and 1950s. This theory is often referred to as the Solow-Swan model after the important contributions of Robert Solow and Trevor W. Swan in the 1950s.[1]

The key assumption in this type of model is diminishing returns on capital in the economy. One additional unit of capital per unit of labour yields a smaller increase in production quantity than did the previous unit of capital. For a given savings rate, the economy will grow when capital is accumulated, but the assumption of diminishing returns on capital means that when investments have reached a certain level, one additional unit of capital will exactly compensate for the loss of the capital depreciated each period, thus implying that the economy will no longer grow – in the sense that GDP per capita will remain constant. This is termed the *steady state*. Higher levels of savings and investment will shift this state and result in increased per capita production and higher consumption and real wage levels in the long run.[2] The model describes the transition (growth) of the economy from one steady state to the other, but it does not seek to explain why the economy experiences growth in the long run, i.e. after it has reached the steady state. In order to achieve growth *in* the steady state it has to be assumed that the economy experiences productivity growth (caused by labour-saving technological progress). In other words, the model is not intended to shed light on how such growth arises, and the theory is therefore often referred to as an *exogenous* growth model.

The model also delivers predictions for developments in the real wage level. During the period until the steady state is reached, real wages will increase because the economy as a whole (including the capital stock and production per unit of labour) is growing. Once the economy has reached the steady state, no further real wage growth will be experienced. Only exogenous productivity growth can deliver real wage growth in the long run (in the steady state).

Cass (1965) and Koopmans (1965) refined the model by letting the savings rate be determined by utility-maximising consumers. This is termed the Ramsey model (after Ramsey (1928)), which models how the savings rate of consumers is determined by, and interacts with, other parameters in the model. This model does not explain long-term economic growth either.

These models, as described above, assume a closed economy in which the market interest rate is determined endogenously. Norway is a small, open economy, and it is therefore more commonly assumed that the market interest rate, and thus the capital level, in Norway is determined exogenously from abroad. (Savings and investment levels do not have to match in an open economy). Hence, the open-economy version of the neo-classical model loses its transition dynamics unless further assumptions are adopted in such model, since the capital level is no longer determined by domestic savings. Real wage growth in the steady state is driven by exogenous productivity growth in the open-economy version as well.

Endogenous growth models

Endogenous growth models explain how economic growth, including real wage growth, happens in the long run as well. One of the mechanisms modelled results in the assumption of diminishing returns on real capital being moderated or eliminated. A well-known example of this is Romer (1986), which introduces positive *spillover effects* from investments in knowledge-intensive capital goods. This results in growth in the steady state as well.

In addition, Romer (1990) and Jones (1995) model productivity growth by letting different varieties of capital being produced on the basis of patents resulting from R&D production. Producers of finished goods generate demand for the new capital goods, and the productivity of their capital increases with the number of new varieties to which they get access. This results in welfare gains and lasting economic growth.[3]

Box 4.2 (cont.)

Other models achieve similar outcomes by introducing public goods in the production process (Barro, 1990), or by introducing interaction effects between capital goods and human capital (Lucas, 1988).

Another type of endogenous growth theory models enterprises that upgrade and improve, and thus replace, existing capital goods. These models are often referred to as Schumpeterian models[4] (Aghion & Howitt, 1992).

1 Solow (1956) and Swan (1956).

2 However, the model also shows that it is theoretically possible for savings to be too high, resulting in a situation where the long-term consumption level would increase if savings were reduced.

3 This is often termed Spence-Dixit-Stiglitz love-of-variety effect in the literature.

4 After Joseph Alois Schumpeter's term "creative destruction"; see Schumpeter (1934).

The value of time at work

The NOU 1997: 27 Green Paper notes that the cost of travel for work purposes has traditionally been linked to the value of the production lost during travel time, in line with the opportunity cost principle and economic theory. The employer's valuation of the loss of production is measured by real wage costs. By real wage costs are here meant the employer's total labour expenses, i.e. wages, employer's social security contributions, social costs and any other costs involved in using labour.[5] The background to this approach is that the real wage reflects the marginal productivity of labour in a profit-maximising enterprise. From the perspective of the employer, the cost of increased time use at work equals the value of the loss of production as the result of reduced time for production.

However, the NOU 1997: 27 Green Paper goes on to note that there may be several reasons why real costs differ from those implied by the theoretical model. Labour market imperfections caused by, for example, market power on the supply or demand side, market regulation or wage formation rigidities may result in the opportunity value of labour not being reflected in the gross real wage on the margin.

The NOU 1997: 27 Green Paper also discusses how the value of travel time is influenced by what use is made of such travel time. The better the scope for work during travel, the less worth is a reduction in travel time. If basing the value of time spent on travel for work on the employer's real wage costs, one therefore needs to adjust for such time during travel as is spent efficiently. If, for example, the traveller is able to work at half efficiency throughout the journey (or work at full efficiency for half the journey), it necessarily follows that only half of the travel time represents real man-hours lost. If one fails to adjust for this in the calculations, one exaggerates the economic value of investments that contribute to reducing travel time. Likewise, such an adjustment will convey a more accurate impression of the real economic benefits from investments that improve opportunities for work during the journey, without reducing actual travel time (an example may be the installation of web access facilities on airplanes). Hjorthol (2008) analyses the use of travel time onboard trains in Norway. She finds that "more than half of those undertaking business travel or other work-related journeys, … , spend the [travel] time doing work".[6]

In principle, the personal time costs or gains of employees should be included in the calculation of the costs of increased travel time, in addition to the employer's costs. For example, for a given reduction in travel time it will, under such a broader cost concept, be of relevance whether a train journey is filled to capacity and one needs to stand up, or whether there is enough room to sit down and read a book. This approach suggests, *inter alia*, that it will be appropriate to apply different values of time in respect of different means of transport, depend-

4 Some countries adopt more detailed classifications of time, for example by defining commuting time as a separate category. However, it may argued that reduced commuting time will result in either more time at work or more private time for each person. The Committee has therefore chosen to maintain the classification from the NOU 1997: 27 Green Paper.

5 See Chapter 2.5 in Chapter 2 concerning general rules for the pricing of market goods for cost-benefit analysis purposes.

6 See also Fahlén, Thulin and Vilhelmson (2010), which looks at Swedish data for both bus and train journeys, as well as Lyons, Jain and Holley (2006), which studies train journeys in England.

ing on the said factors. Consequently, investments that influence comfort or work opportunities will influence the values of time.[7]

Although studies have previously been conducted based on the method of adjusting for how travel time can be used efficiently (e.g. Institute of Transport Economics ("TØI") in Norway (Ramjerdi et al., 1997)), it is in the most recent Norwegian value of time survey from TØI and SWECO (Samstad et al., 2010) recommended to apply the employer's time costs from its loss of labour input as the value of employees' business travel, without adjusting travel time for work opportunities, etc.

The value of leisure time

One may also use the opportunity cost concept in the valuation of *private time* savings.[8] The classical theoretical framework assumes that the net real wage per hour reflects the opportunity value of one hour of leisure. By net real wage is meant the wage less marginal tax. Since the labour supply response of the consumer will be such that the last hour spent on work will, on the margin, give the consumer the same utility as does one additional hour of leisure, the implication is that the consumer values private time, or leisure, at the net real wage on the margin. If the consumer has not made such adaptation, it will be possible to change the amount of work and thus achieve a higher utility level. According to this reasoning, the net real wage will always express the value of one hour of additional leisure on the margin.

There are some objections to this approach. Firstly, many employees may have less flexible working arrangements than assumed by such model, for example because working hours are largely predetermined or because one receives as fixed annual salary. This would mean that employees are not necessarily able to fine tune their trade-off between work and leisure, thus implying that many employees work more or less than they would have preferred.

Secondly, far from everyone in Norway is involved in income-generating work. Many of those who are not in employment are likely to consume more leisure than they would if they had been able to take a job at the current market wage. This suggests that their valuation of leisure is lower than the net real wage observed in the market.

Thirdly, many people will probably argue that they derive inherent utility from being at work, apart from the real wage they receive from their employer, or that much work is in actual fact investment in human capital/learning from which the employee will benefit later. These factors suggest that the value of leisure time exceeds the net real wage; by choosing to consume one additional hour of leisure, one does not only forgo the wages lost, but also other benefits from work.

Fourthly, the value of leisure time will depend on how time is spent (whether the time is used efficiently, the level of comfort, etc.). In the transportation sector, for example, the values of time will thus be influenced by whether the journey is an activity holiday or other factors that influence the valuation of time use.

Willingness to pay surveys as a valuation method and previous evaluations[9]

Empirical studies of willingness to pay offer an alternative approach to the valuation of time. The idea is to uncover travellers' willingness to pay for travel time savings by using statistics or questionnaires. Such an approach brings out directly how each person values the journey.

There are two main types of surveys: revealed preferences and expressed preferences (also frequently termed indirect and direct methods, respectively). The first method is premised on observations of actual behaviour. In the transportation sector, for example, one can use available data on journey lengths, prices, alternatives, travel habits, etc., to estimate the implicit values attributed by road users to time savings when making travel choices. The second method, expressed preferences, is based on hypothetical behaviour, and may again be divided into conditional valuation (direct questions about willingness to pay) and conjoint analysis (where the respondent is requested to take a view on simultaneous changes in several factors, thus revealing the indirect willingness to pay).

In the NOU 1997: 27 Green Paper, the Committee concluded with a recommendation to apply the "simple opportunity cost method" for minor

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7 The method of correcting for the utilisation of time is referred to in the literature as the cost savings principle. A detailed discussion can be found in Chapter 3 of Mackie, et al. (2003). The said article also discussed Hensher's formula. Hensher (1977) systematises the use of time savings from business travel. The formula distinguishes between time savings used for work and time savings used for leisure. Hensher adjusts for the value of such time during the journey as can be used for work, as well as for the comfort level of the traveller.

8 The value of private time is also discussed in the NOU 1997: 27 Green Paper.

9 See also Chapter 2.

projects. The Committee acknowledged the value of willingness to pay analyses for major projects, but expressed some scepticism about attaching too much weight to hypothetical methods.

The following is stated in *Guidance on Using Profitability Assessments in the Public Sector* (NOU 1998: 16 Green Paper; Cost-Benefit Analysis): *"In those cases where no designated surveys are carried out, the Committee recommends starting out from wages inclusive of tax and employer's social security contributions and wages exclusive of tax and employer's social security contributions, respectively, depending on whether the time savings are used to increase working hours or to increase leisure hours."*

4.4.2 The value of time over time

Time is a major component on both the cost and the benefit side of calculations in many areas. In the cost-benefit analysis of, for example, a new stretch of road, values of time will play an absolutely key role on the benefit side of the analysis. However, the travel time savings are not only realised in any one year, but also in the distant future. It is therefore necessary to estimate the economic benefits from motorists arriving one hour earlier for every year of the analysis period. The calculations of future values may have a decisive impact on the profitability of investment projects where much of the benefits from the project come in the form of the value of time savings.

We noted from Chapter 4.4.1 that the value of time is influenced by a number of factors, although wages before or after tax – depending on what type of time we wish to put a price on – are normally a key component in the valuation of time. An exemption is the use of willingness to pay studies, where the valuation of time is not directly dependent on wages. However, it is reasonable to assume a positive correlation between changes in real wages and changes in the willingness to pay for time savings, since wages are amongst the factors influencing the willingness to pay.

It is reasonable to expect the elements that make up the value of time at present to also determine the value of time in future. Hence, one must examine these factors in order to say something about developments in the value of time over time.

Time saved at work

It was explained above that time savings at work should be valued on the basis of the employer's measure for the actual production benefits resulting from the time released. In addition, the value of the time savings was influenced by the employee's work opportunities and inconveniences/benefits associated with the journey. The same principles should form the basis for *projections* of the value of time savings at work.

Historically, wage level increases have outpaced retail price index increases by a considerable margin, cf. Chart 4.2 and the discussion of the relationship between productivity growth, capital and wages in Chapter 4.3 above. If it is assumed that Norway will continue to experience real wage growth in future as well, it may be concluded that the value of time will develop differently from retail price developments.

In some contexts it is reasonable to assume that the employee's inconvenience costs and effective utilisation of time have changed. Means of transport are becoming more comfortable and better adapted for work during travel. Opportunities for engaging in work or leisure activities via laptops, mobile phones, etc., have increased the utilisation of travel time and reduced personal inconvenience costs. If one assumes that this trend will continue, a projection of the valuation of reduced travel time based exclusively on real wage growth will overestimate the actual economic benefits from the travel time saved.[10]

If information about all elements that influence time costs is available for the coming years, it will be appropriate to include this in the cost-benefit analysis. However, it will in most cases be problematic to estimate projections for, in particular, changes in employees' personal inconvenience costs associated with travel time.

Time saved during leisure hours (private time)

It was noted in 4.4.1 that the net real wage was the measure of the value of one hour of leisure in the classical theoretical framework. Within such framework, one hour saved that results in one additional hour of leisure for the consumer must therefore be valued at the current net real wage level in a cost-benefit analysis. Moreover, the same must apply for every year, including future years. Consequently, it is reasonable to assume, based on the classical theoretical framework, that

[10] An objection against this is again that more comfortable journeys will be reflected in lower wage growth than in a situation where travel comfort is not improved. Based on this assumption it is sufficient to use wage growth as a measure of increases in economic travel costs; all improvements for travellers in travel methods during work are reflected in wage changes.

the growth rate of the net real wage and of the value of leisure time saved will be equal.

However, as with the description of the value of time at work, the description of the value of leisure time in 4.4.1 showed that the value of time is influenced by more elements than wages. Inflexible work arrangements and the uses to which saved leisure time is put are elements that will also affect the value of saved leisure time in future.

If using empirical willingness to pay surveys to assess the value of leisure time, it is not obvious that one should use wage level growth to estimate growth in these values of time. It has therefore become common practice in many countries to use data on the *elasticity of the willingness to pay with respect to income* to estimate how much the values of time will increase over time.[11] This elasticity measures by how many percent the willingness to pay for time savings increases when income increases by one percent. If this elasticity of the willingness to pay is known, and one also has a good estimate for future income growth, one will be able to estimate developments in the willingness to pay over time on that basis. It is normally assumed that this elasticity has a value of between 0 and 1. If it is 0, the values of time do not depend on the income level, and must therefore be expected to develop in line with general inflation. If the elasticity is 1, the values of time are growing in step with real income. If it is 0.5, the values of time will increase by half the growth rate of real income.

Let us assume, as an example, that the benefit side of an investment in the transportation sector comprises, *inter alia*, travel time savings. If annual real income growth is estimated to be 3.0 percent, the value of each hour saved will increase by E*3 percent every year, with *E* being the said elasticity. If calculations show this to be 0.5, the implied assumption in this example is that the value of time will increase by 1.5 percent every year. If an estimate of the current value of travel time has been established through willingness to pay surveys, such estimate is used to find the future value of time as well.

11 The literature terms this elasticity the "income elasticity of demand" with respect to the value of time. However, the income elasticity of demand will normally refer to how the quantity demanded of a good or a service changes when income increases by 1 percent. As far as the value of time is concerned, it is not a matter of how the quantity demanded changes, but how the *willingness to pay* changes when income increases. In this Chapter we therefore refer to this as simply the elasticity or as the elasticity of the willingness to pay.

4.4.3 Empirical studies, elasticities and the income concept

Empirical studies of values of leisure time over time

In order to improve understanding of how values of leisure time change over time, a number of studies have sought to shed light on the issue. One type of empirical study looks at the income dependence of values of time in *cross-sectional data*. By obtaining information on various individuals' wage income and their willingness to pay for time savings, one can establish a measure for the correlation between income and values of time. If one also has an average income growth estimate, this information can be combined to provide a measure for the value of future time savings in the project analysis.

However, differences in the willingness to pay between income groups at a specific point in time do not necessarily tell us anything about how the average willingness to pay will change if society as a whole becomes richer.

A more appropriate approach is therefore to compare the values of time from reasonably similar value of time studies conducted in the same country or area at an interval of a few years, and study how the willingness to pay for time savings seems to vary with the general income level in society. Such national value of time studies have been carried out in, *inter alia*, Norway, the United Kingdom and Sweden.

In Sweden, exactly identical analyses have been performed in 1994 and in 2007 to establish how values of time develop over time, WSP Analysis & Strategy (2010). Börjesson et al. (2012) has analysed the findings and has found – based on cross-sectional data for the two years – that the elasticity of the willingness to pay with respect to the value of time is not significantly different from zero for income groups below the median income. For income groups above the median income, the elasticity is estimated to be in the region of 1. In other words, according to the said article, the elasticity with respect to the value of time is not constant, but positively correlated with income. Hence, when the average income increases, the elasticity also increases.

A similar study has recently been published by the Institute of Transport Economics for Norwegian data (Ramjerdi et al., 2012). This also compares data from two studies (from 1996 and 2009). The authors find that elasticities based on cross-sectional data are in the region of 0.5-0.6, but if one looks at the willingness to pay of each income group, little change has been recorded over this time period. This implies, according to the authors, an elasticity for the population as a whole of about 1. Moreover, the authors note that the reason for the differences between the findings from cross-sectional data and time series data is that the portion of income people allocate for consumption is what is relevant for evaluating elasticity, whilst the income information from cross-sectional data does not correspond to the budget portion allocated to consumption.

A final type of study is labelled meta studies in the literature. These may draw on data from many more sources than do the national value of time studies, and for many years, not only one or two. Mark Wardman has conducted a series of meta studies on British data (Wardman, 2001, Wardman, 2004 and Abrantes and Wardman, 2011). In the latest and most up to date analysis, the authors find an elasticity of the willingness to pay with respect to GDP of 0.9.

Which income measure should be used in cost-benefit analysis for the value of leisure time?

The simplest theoretical approach discussed above suggests that the opportunity cost of leisure is determined by the net real wage per hour. A person who receives more capital income or other non-labour-related income will not experience any change in her opportunity cost of leisure. However, if her real wage increases, the opportunity cost of leisure increases. Consequently, it is correct to use net real wage growth as a measure of the increase in the value of leisure time, according to this theory.

However, this method does not take into consideration a number of factors like inflexible working hours, the scope for partial utilisation of the time (e.g. reading during the journey), etc. If one does instead use willingness to pay surveys in combination with an elasticity to estimate the future value of leisure, it becomes less obvious that the real wage is necessarily the appropriate income concept. We concluded above that the value of time changes for more reasons than changes in wages only. If there is a correlation between these causes and, for example, a country's gross domestic product (GDP) per capita, it is conceivably also acceptable to use GDP per capita as the income concept. However, one should to the extent possible use the same income concept in preparing estimates for future values of time as was used in estimating the actual elasticity; see also Box 4.3.

Box 4.3 Various income measures

The white paper on long-term perspectives for the Norwegian economy, which is submitted to the Storting every fourth year, provides estimates for future Norwegian income growth. The most recent of these white papers, Report No. 9 (2008-2009) to the Storting, presents three different future income growth estimates for Norway until 2060; see Table 4.2. The estimates, which are generated by using the general equilibrium model MSG6 (Heide et al., 2004), are based on a number of assumptions and therefore cannot necessarily be considered forecasts.

Gross domestic product (GDP) per capita is a measure of annual national value added, and is a frequently used measure of a country's real income level. Disposable real income also includes, in addition to total value added, net capital and wage income from abroad, including dividend and interest income generated by the Government Pension Fund Global. The magnitude of such interest income means that growth in average disposable real income is estimated to be somewhat higher than GDP growth. Norway's petroleum revenues may result in the three income concepts mentioned above varying somewhat more over time than is the case for other countries.

Table 4.2 Income growth indicators. Percent

	Average annual growth 2007-2060	Percentage change from 2007 to 2060
Disposable real income per capita	1.6	128
GDP per capita	1.4	109
Mainland GDP per capita	1.7	149

Source: Report No. 9 (2008-2009) to the Storting; Long-Term Perspectives for the Norwegian Economy 2009

Differentiation of values of time

In principle, cost-benefit analysis should be based on the income level of those individuals who are affected by the investment. The aggregation level of values of time may, however, hide major differences between individuals. For example, the Ministry of Transport and Communications notes, in its feedback to the Expert Committee, that cost-benefit analyses carried out by the transportation bodies in Norway apply the same values of travel time for journeys throughout the country, irrespective of project type. Since a number of unit prices, including values of time, will vary with wage income, there is little doubt, according to the Ministry of Transport and Communications, that areas with high mean incomes will exhibit a higher willingness to pay, and thus higher estimated unit prices. In other words, using the national average in the analysis of investments in high-income areas will, for example, result in the underestimation of time costs. Corresponding objections also apply if one expects different income growth in different geographical locations.

Börjesson and Eliasson (2011) (in Anderstig et al., 2011) note, based on Swedish data, that the value of travel time varies considerably, and not only with the income of the traveller, but also with the specific purpose of travel, the number of children and other factors.

If cost-benefit analysis is conducted using the same value of time irrespective of where in the country the measure would be implemented, and irrespective of e.g. the mode of transport, one deviates from the general cost-benefit analysis principle that the benefit side shall be based on the actual willingness to pay (and thus deviates from the principle adopted elsewhere in the analysis).

4.4.4 Real price adjustment practice – various perspectives

Traditional practice within the area of transportation in Norway has been to use an elasticity of 0 for cost-benefit analysis purposes – i.e. to apply the current values of time and assume no real price adjustment, thus implying that all prices are subject to the same nominal rate of change. The value of time at work has not been subjected to real price adjustment either. In other words, it has not been common practice in Norway to subject the values of time used in cost-benefit analysis to real price adjustment.

If one assumes that the willingness to pay for time savings does in actual fact increase over time, the absence of real price adjustment over time will result in projects where time savings feature heavily on the benefit side being perceived as less profitable than in fact they are. Consequently, this might in theory result in economic underinvestment in time-saving measures. Likewise, projects that result in increased time use (for example road projects proposing a routing *around*, instead of *through*, certain areas) will appear to be less costly, and thus more profitable, than is actually the case.

However, values of time are also used in other sectors. The Committee is aware that cost-benefit analyses within the ambit of the Ministry of Trade and Industry value time savings associated with simplifications for the business sector, and that time savings often form an important part of the benefits from ICT projects. The Ministry of Defence has informed the Committee that it prepared a designated cost-benefit analysis guide for investment activities within the defence sector in 2010. Wages[12] are used as the calculation price of the value of time saved. The guide recommends that average annual real wage growth be put at 1.5 percent. Other prices are also subjected to real price adjustment.

Guides in several other countries recommend using an elasticity of between 0.5 and 1 for travel time savings during leisure hours and 1 for time savings at work. The following is a listing of recommendations from guides in some countries and findings from selected Norwegian studies/reports:

– *EU:* a consortium lead by the German IER institute (University of Stuttgart, Institute of Energy Economics and the Rational Use of Energy) prepared, over the period 2004-2006, a proposal for harmonised guidelines for transportation infrastructure projects in Europe through an EU-funded research project called HEATCO (Harmonised European Approaches for Transport Costing and Project Assessment).

  The HEATCO report (2006) concludes that analyses based on cross-sectional data are not adequate for preparing estimates over time. Instead, the report refers to the study by Wardman (2004), which finds an elasticity of 0.72 with regard to GDP per capita for all purposes of travel. As explanation of why the elasticity deviates from 1, they observe that low-income workers may have less flexibility in adapting their time, that household income may differ from personal income, and that travel time may be used in an efficient manner.

  HEATCO recommends using an elasticity of 0.7 for both work and leisure travel

12 It is not specified whether these are gross or net wages.

(HEATCO, pages 63-64), with GDP per capita as the income measure.[13]

- *United Kingdom:* The web-based document WebTAG (2012) represents the official British cost-benefit analysis framework within the area of transportation. It recommends using an elasticity of 0.8 for private journeys, with GDP per capita as the income measure. The value of time at work is assumed to increase at the same rate as labour income (inclusive of estimated costs in excess of gross wages, like insurance, pensions, etc.). WebTAG also presents estimates for the specific values to be used in the analyses.
- *Sweden:* Sweden adheres to the transportation sector guidelines of the Swedish Transport Administration. ASEK 5 (Swedish Transport Administration, 2012) recommends using an elasticity of 1 for the value of travel time, based on willingness to pay surveys (leisure). The income measure is GDP per capita. Gross wages are used for work journeys. These prices are also subjected to real price adjustment based on GDP per capita. It may also be mentioned that ASEK 5 recommends adjusting the value of time for train journeys to reflect that 15 percent of the time is used for work.
- The consultancy firm COWI has been commissioned by the Norwegian Public Roads Administration to analyse which unit costs should be subjected to real price adjustment, and based on which forecasts (COWI, 2010). The recommendations in the COWI report are primarily based on a review of the literature, and it follows from the report that it is largely based on discretionary assessments. The report concludes by recommending an elasticity of 0.8 for leisure journeys, as well as the use of disposable real income as the basis for adjustment. It is also recommended that the value of time during business travel be subjected to real price adjustment, based on disposable real income.
- A study based on Norwegian data (Ramjerdi et al., 2010) finds elasticities for different means of transport of between 0.25 and 0.62. In addition, it finds that high-income groups have a higher value of time than low-income groups. The estimates are based on cross-sectional data. The report emphasises that these elasticities are low compared to those found in other studies, and that more research is required on the elasticity of the value of time. In the meantime, the authors of the report propose using an elasticity of 1 for all means of travel during leisure hours. Ramjerdi (2012), discussed in 4.4.3, finds elasticities of about 1.

COWI's recommendations on real price adjustments are used in the input from the Norwegian National Rail Administration and the Norwegian Public Roads Administration for the National Transport Plan 2014-2023. The Government plans to publish the National Transport Plan in the spring of 2013.

4.4.5 Summary: Real price adjustment of the value of time savings

Valuation is based on the premise that time savings may be used for alternative purposes that could not have been realised in the absence of these savings. Time is commonly divided into two categories: work and leisure.

The value of *time at work* has traditionally been related to the loss of production at work. The employer's valuation of the loss of production is measured by real wage costs. However, Chapter 4.4 discussed reasons why real costs may differ from real wages. Labour market imperfections may imply that the value of labour is not reflected in gross real wages on the margin. The value of travel time savings at work may also depend on how such travel time is used. The more efficiently travel time is used, the less valuable are travel time savings. One may also adjust for the personal time costs of the employees.

The value of *time at work over time* may be estimated on the basis of wage level projections, potentially adjusted for expected changes in employees' inconvenience costs and their effective utilisation of the time.

For time savings during leisure hours, the classical theoretical framework suggests that the net real wage per hour reflects the opportunity cost per hour of leisure. However, we have in Chapter 4.4 discussed several reasons why this relationship may be more complex – for example inflexible working hours, unemployment and inherent utility from time spent at work.

An alternative method for valuing time savings during leisure hours is to use willingness to pay surveys. The idea is to reveal travellers' willingness to pay for travel time savings by using statistics or questionnaires.

[13] The HEATCO report also proposes that values of time relating to commercial traffic be adjusted by an income elasticity of demand of 0.7, based on the reasoning that the time costs can primarily be related to the driver and crew.

The value of *leisure time over time* may, by using the classical theoretical framework, be projected on the basis of expected changes in net wages. However, it is more common to use a method seeking to estimate an *elasticity of the willingness to pay with regard to real income* for purposes of estimating how much values of time will increase over time. This elasticity measures by how many percent the willingness to pay for time savings increases when income increases by one percent (normally assumed to be between 0 and 1). A number of attempts have been made at estimating such elasticity, and different methods exist. Two recent studies (Abrantes and Wardman, 2011, and Ramjerdi et al., 2012) arrive at point estimates of about 0.9 and 1, respectively. The most recent recommendations from Sweden and the United Kingdom (both for the transportation sector) are to use elasticities of 1 and 0.8, respectively.

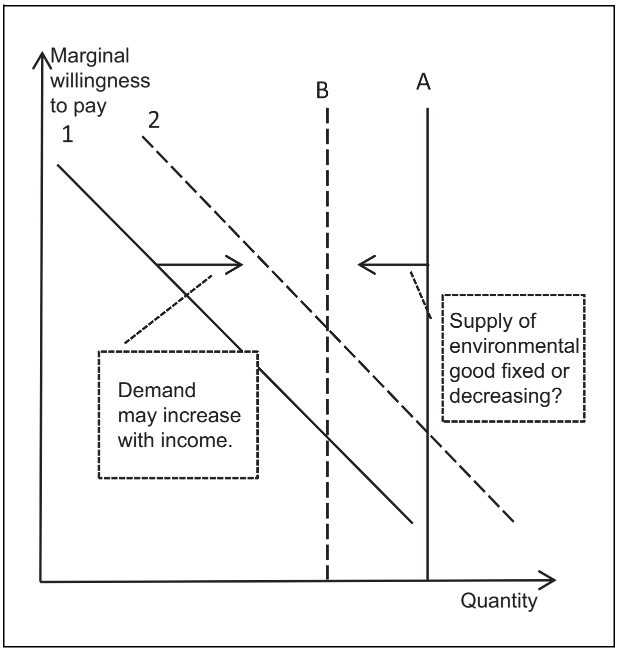

Figure 4.3 Supply of, and demand for, environmental goods – an illustration

4.5 Price developments over time for environmental goods

The valuation of goods that are not traded in the market is discussed in Chapter 2.6. The terms of reference stipulate that the Committee shall examine whether and, if applicable, how changes in calculation prices for environmental goods over time may be included in the cost-benefit calculations. The reason for highlighting environmental goods in this context is that a number of factors suggest that the willingness to pay for such goods may increase at a higher rate than general inflation. The most important factor is that the supply of environmental goods cannot, as a main rule, be expanded, and that these environmental goods are thereby assumed to become scarcer over time, given growing populations, production and consumption. Moreover, it is possible that at least some environmental goods may be "luxury goods"[14] – i.e. that demand for these increases relatively more when the income level increases.

This reasoning is based on traditional market theory, cf. Chart 4.3. Curves 1 and 2 here designate possible demand curves for an environmental good, with 2 representing a higher income level than 1. A and B specify possible supply curves for the environmental good, with B representing an impairment of the environmental good relative to A. However, most environmental goods are not traded in a market, thus implying that we are not faced with supply and demand curves in the ordinary sense. The question of for which situations and, if applicable, how such calculation prices are to be calculated is therefore important. This includes the issue of how to define and delimit an environmental good for which the willingness to pay is to be estimated. Without calculation prices to start out from, the question of price developments over time is meaningless, at least for practical analysis purposes.

The range of environmental goods is very wide. Valuation possibilities and methods will depend on which environmental good we are dealing with. The discussion of developments over time should therefore be made with reference to environmental goods or groups of environmental goods that are as specific as possible.

The Committee will focus on discussing future price developments for environmental goods for which established calculation prices are available at present, i.e. prices that are actually used in cost-benefit analysis. These calculation prices are primarily based on calculations relating to health effects and political decisions/commitments. This will include a discussion of real price adjustment of the value of a statistical life. In addition, the Committee will discuss how to deal with calcula-

[14] Goods or services are defined as luxury goods if the income elasticity of demand with respect to such goods is in excess of 1, i.e. that the percentage increase in the demand for such goods exceeds the percentage increase in income. All else being equal, prices of luxury goods will increase relative to the average price level.

tion prices for individual goods based on different types of willingness to pay surveys.

It is important to recall that cost-benefit analysis will include qualitative and/or quantitative descriptions, but not monetary values, for a large number of environmental effects. Future developments in value may also be important with regard to such environmental effects. The Committee does not specifically address such environmental effects, but emphasises that a description of future access to, and scarcity of, non-valued environmental goods, and their future importance, forms a natural part of a cost-benefit analysis.

Furthermore, the Committee notes that the Government appointed a separate expert committee in October 2011 to examine, *inter alia*, the value of nature and ecosystem services in Norway. The Committee will here restrict itself to a brief discussion of various types of environmental goods and valuation methods. We then look at what the literature says about real calculation price developments for environmental goods that actually lend themselves to being valued.

4.5.1 What are "environmental goods"?

"Environmental goods" is an established concept in traditional environmental economics. Some environmental goods, such as fresh air, clean water and accessible recreation areas form part of people's consumption, and this has a direct impact on welfare. Other environmental goods may be considered production process inputs, thus contributing indirectly to goods and services we are used to obtain in markets. Insect pollination of fruit trees is an example, another one is nature's inherent ability to absorb and purify waste emissions from production.

In other words, the range of environmental goods is very wide. The Committee will not describe this range, but briefly discusses the concept of "ecosystem services", which is in frequent

Box 4.4 Ecosystem services

The term "ecosystem services" is fairly new, but is now in widespread use in the literature. Key projects like the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity ("TEEB") use this approach, cf. Millennium Ecosystem Assessment (2005) and Kumar (2010). This approach describes the various types of benefits people obtain from the earth's ecosystems.

Ecosystem services are often divided into four main categories:

– "Supporting services" – like for example soil regeneration, photosynthesis and nutrient cycling. These are basic processes on which all life, and all other ecosystem services, depend. The economic value of these services only shows up indirectly, through the production and consumption they support. These exist in fixed quantities, i.e. they can be impaired through human influence, but not expanded.
– "Regulating services" – such as pollution filtration in wetlands and plants, climate regulation through carbon sequestration in forests and soils, as well as insect pollination of plants. These services can be said to be closer to human economic activities, and can to some extent be replaced. Water may be filtered naturally in intact wetlands, but also in technical facilities.
– "Provisioning services" – which give us, *inter alia*, meat, fish, fruit, cotton and flax, cereal products and medicines based on plant materials. Some of these products – like berries and mushrooms – are in most cases used directly in people's own consumption. But products like fish, agricultural goods and textiles represent enormous markets, nationally and globally. The provisioning services therefore provide many goods that can be treated as ordinary market goods in a cost-benefit analysis.[1]
– "Cultural services" are those that provide us with recreation, spiritual and aesthetic experiences, learning and belonging. These services are predominantly of direct benefit to us, and not market-traded. A nature area within travelling distance is an environmental good with no market price, and provides a free ecosystem service. The largest number of willingness to pay surveys has been carried out for environmental goods with these characteristics.

[1] It is a matter of opinion whether one chooses to call these goods "environmental goods". Traditionally, economists have distinguished between environmental goods and goods from the harvesting of biological resources.

use, and which describes the benefits we obtain from nature and ecosystems in a systematic manner. This concept can be closely linked to the concept of environmental goods, and includes a division into four main categories, cf. Box 4.4.

Ecosystem services originate from ecosystems and cycles of nature, and depend on certain functions of these. The ecosystem concept describes nature from a human benefit perspective, in line with the concept of "environmental goods", and is therefore suited for cost-benefit analysis. Let us take, for example, the environmental good "clean water", which is negatively affected by pollution. Nature, for example wetlands, does on the other hand have an ability to purify. If the pollution exceeds the ongoing capacity to purify, water quality will deteriorate and the environmental good will be impaired. The ability of nature to purify may be described as a "regulating ecosystem service" (cf. Box 4.4). The service contributes to, or "produces" the environmental good clean water, which again contributes to new ecosystem services (like for example the "cultural" services swimming and recreational fishing). This illustrates the close link between ecosystem services and environmental goods. In the following, we will primarily focus on the concept of environmental goods.

4.5.2 Valuation of environmental goods

The total economic value of environmental goods is usually separated into use value and non-use value. (Some authors use the terminology "active use value" and "passive use value" (Bergstrom and Randall, 2010).) *Use values* may be direct (for example through recreation or harvesting), or indirect (for example through insect pollination, which again creates products that can be harvested). Option values include the value of environmental goods being saved for later use. *Non-use values* include the value of environmental goods existing and being preserved, even if one does not plan to experience them personally.[15]

A general discussion of methods for the valuation of environmental goods or ecosystem services that are not traded in the market can be found in Chapter 2.6. We also refer to the discussion in Chapter 9, where the Committee addresses how different valuation principles for non-market goods can often answer fundamentally different questions. As a basis for discussion of future price developments, we will here look at some specific examples.

The monetary valuation of environmental goods may take place through direct and indirect methods, cf. Chapter 2.6. *Direct* methods include "contingent valuation", where respondents express their willingness to pay for an environmental good to be maintained or improved, or alternatively what economic compensation they need in order to accept the loss or degradation of such environmental good. Because the method is very flexible, it is possible to examine people's willingness to pay for virtually anything – large or small, simple or complex, close or distant. The NOU 1997: 27 Green Paper recommended that one should limit the use of contingent valuation to "*... areas where the agents directly or indirectly can be assumed to have some experience of valuing the relevant environmental good in economic terms.*" (NOU 1997: 27 Green Paper, Chapter 10.3.) On the other hand, this is the only approach that can, in principle, uncover non-use values. It is quite possible that Norwegians have a willingness to pay for preserving a nature area they are not using – whether on grounds of principle, or because they wish to have the option of later use.

A large number of willingness to pay surveys based on contingent valuation have been conducted, the vast majority of which have taken place in other countries than Norway. The surveys are wide in scope. They may address anything from specific nature areas, animal and plant species, air and water quality, to the willingness to pay for reducing the risk of accident or death. In the latter approach, respondents' willingness to pay is often combined with dose-response relationships between the state of health and environmental quality.

Indirect valuation methods seek to reveal preferences and derive the willingness to pay from people's actual behaviour. The travel cost method, for example, involves estimating the value of nature areas on the basis of visitors' travel costs. This method restricts itself to measuring the travel costs of actual users as a minimum estimate of their willingness to pay. Hedonistic valuation is a method based on the fact that the market price of a property – a house, holiday home or apartment – depends on many different factors, some of which are environmentally related. One can seek to isolate the effects of air quality, noise and proximity to nature through regression analyses, and use the estimates as calculation prices. There are also examples of differences between other

15 In cases where an environmental good may be irredeemably lost, a "quasi-option value" may be attached to not destroying such good. More on this in Chapter 8.

market prices being analysed with a view to calculating implicit values of environmental goods.

One may also calculate the social cost of damage associated with a specific environmental state, compared to the cost of an alternative state. Local emissions of sulphur, nitrogen oxides and particles, for example, have health implications. Knowledge about dose-response relationships between air quality and morbidity/mortality, as well as knowledge about the number of people affected, will be key elements of such social cost of damage functions. Dose-response knowledge may be linked to surveys of people's willingness to pay for changes to their state of health and changes to their risk of death. Chapter 10; *Valuation of life and health*, discusses methods and calculations for this type of willingness to pay. Such calculation prices are used in cost-benefit analysis in, *inter alia*, the transportation sector. In a report for the Climate and Pollution Agency, Sweco has sought to quantify the cost of emissions of priority environmental toxins (Magnussen et al., 2010). The health implications dominate these calculations as well.

Moreover, it is possible to estimate what it would cost society to make up for the loss of an environmental good. In principle, one may for example estimate the cost of a purification solution to replace an area of wetlands. In other cases one may estimate the cost of countering the inconvenience, for example through measures for the soundproofing of homes. An advantage of such replacement and compensation calculations is that calculation prices are based on amounts associated with actual or potential projects. These will, on the other hand, result in calculation prices that only partially reflect the environmental damage. Soundproofing a home alleviates problems indoors, but not on the outside, and an area of wetlands is more than simply a water purification facility.

Calculation prices can also be derived from political decisions. Political authorities, nationally and locally, make decisions that impose certain costs on enterprises and consumers, and which thus indirectly put a monetary value on environmental goods. In some cases, a national environmental target will reflect an international commitment. If, for example, the Storting adopts a noise target, the marginal cost of reaching such target can be used to arrive at a calculation price for noise level changes.

Politicians adopt policy measures to realise objectives. When the policy measure is an environmental tax, the tax rate may on certain conditions be used as the calculation price. One condition is that the tax rate matches the adopted objective. It is, for example, fairly common for a tax to be one of several policy measures with an effect on the same environmental objective. In order for the tax to be used as a calculation price, it is in principle necessary for it to reflect the marginal cost of realising the objective. Furthermore, political decisions may reflect several, conflicting social considerations, thus implying that it is difficult to know what a tax rate actually expresses. (Such issues are discussed in more detail in Chapter 9 on carbon price paths.)

Different valuation methods may be combined. As far as the emission of nitrogen oxides is concerned, Norway has made a national commitment, through the Gothenburg Protocol, to reduce our national emissions to certain levels. Calculation prices may be derived from the marginal cost of meeting the commitment. At the same time, these emissions also have detrimental effects on people's health, which may be addressed by social cost of emission calculations. However, these detrimental effects will usually vary between urban and rural areas, partly because they depend on concentrations locally and partly because the number of affected inhabitants varies considerably. One may in such cases have a national calculation price determined by the international commitment – and higher rates in some cities based on social cost of emission calculations. An example of this can be found in "Handbook 140: Impact Assessments" (Norwegian Public Roads Administration, 2006 – Chapter 5; Priced impacts).

4.5.3 Price developments for environmental goods

Scarcity and willingness to pay

A main argument for assuming an increasing willingness to pay for environmental goods is that the quantity of nature surrounding us is fixed. It is true that impaired ecosystems may in some cases be restored, but as a main rule we cannot create "more" nature than in a natural state. A growing population will gradually need more space, and growing production and consumption of material goods must, when taken in isolation, be assumed to increase the strain on the natural environment and ecosystems. For ordinary goods in fixed supply, one will intuitively assume that the market price increases with increased demand.

As with ordinary goods, the issue of more efficient use needs to be addressed here. When the production of goods and services can increase at a noticeably higher rate than labour input, this is measured as increased labour productivity. A strong increase in "environmental efficiency" may counter the underlying factors – and may result in the environmental strain remaining constant or declining despite population and production growth. A relevant global example is emissions of ozone-depleting gases, which have declined steeply because one has switched over to other substances in aerosols, insulation foams and cooling systems. The ozone layer does of course provide us with a "regulating" service, inasmuch as it protects the earth and its population from harmful UV radiation. If the ozone layer does actually get thicker in future, this may in principle justify a lower calculation price for the good, in the form of a lower price for the environmental damage associated with the emission of one unit of an ozone-depleting substance.

However, some questions remain. Firstly, such a calculation price is not a "technical" entity, but depends on human assessments. New knowledge may change such assessments. Future research may demonstrate that the dangers are greater than we believe at the moment, thus implying a much higher ambition level – or conversely: that the risk is exaggerated. Mankind may decide to be absolutely certain that a positive trend will not be reversed, or may want to take a precautionary approach to dealing with an unknown probability of catastrophic effects (cf. Chapter 8). Such caution may be reflected in strict regulation, and a continuation of high, maybe even increasing, emission shadow prices. But it is also conceivable that technological developments make ozone-friendly alternatives so cheap relative to CFCs, etc., as to make the additional costs insignificant.

Environmental goods as luxury goods?

It is often assumed that people with low incomes attach little weight to the state of the environment, and consequently have a low willingness to pay for environmental improvements, whilst they take a different view when income increases. Environmental goods are in the literature often assumed to be "luxury goods", which are in market theory defined as goods with an income elasticity of demand in excess of 1.[16] Assuming fixed relative prices, this means that the budget share of such goods increases when real income increases. However, Pearce (1980) argued early on that these ideas were unfounded.

However, environmental goods do not, as a general rule, have any known demand curve or budget share. Calculating income elasticities of demand with respect to environmental goods is therefore complex. Hökby and Söderquist (2003) is amongst the small number of studies carried out, and is based on five surveys concerning the willingness to pay for a reduction of overfertilisation in the Baltic Sea. It found income elasticities of demand with respect to environmental quality in the 0.6-1.3 interval. This suggests that the environmental good, as defined in the five surveys, may be characterised as a "normal good" – possibly a "luxury good". It is of decisive importance to the viability of the conclusion whether the environmental good is defined identically, and perceived identically by the respondents, in all of the surveys. Different environmental goods must be assumed to differ in this respect, and elasticities cannot necessarily be transferred or combined. Another objection is that one cannot automatically conclude from calculations based on cross-sectional data – from respondents with different incomes at a given point in time – to the elasticity of demand with respect to income developments over time.

For cost-benefit analysis purposes one is not interested in demand functions, but in the *willingness to pay* for an environmental good, or more precisely for a specific "amount" of the good – most often defined as a specific environmental quality compared to another level of said environmental quality. As with values of time, calculations have also been made with regard to how such willingness to pay depends on income, i.e. the "elasticity of the willingness to pay with respect to income"[17]. In the Hökby and Söderquist study, the estimate for this elasticity falls in the 0.24–0.35 interval. It may again be objected that this estimate is based on cross-sectional data, and cannot be perceived as an elasticity with respect to changes in real income over time.

Flores and Carson (1997) note that the elasticity of the willingness to pay for a good is not necessarily related to whether the good is "inferior", "normal" or a "luxury good". From the perspective of the terms of reference, developments in the willingness to pay over time are precisely what is of interest, because calculation prices for environ-

[16] In contrast, an "inferior good" has an income elasticity of demand of less than zero, whilst "normal goods" have elasticities of between zero and one. See also footnote 17.

[17] In Chart 4.3, a change in demand will represent a horizontal shift, whilst a change in the willingness to pay will be vertical.

mental goods are often based on willingness to pay surveys. Hence, it is not necessarily important to determine which of these three classes of goods an environmental good falls into. However, it is important to recall that the willingness to pay may change over time for other reasons than income developments. Knowledge and preferences may, for example, change, as may also the state of the environment as such.

Individual willingness to pay surveys can hardly say anything much about developments in the willingness to pay over time, including the effect of income developments. Meta analyses of valuation surveys for a specific environmental good face the problem that individual surveys do not specify the mean income of respondents. However, such meta analyses have been conducted, and generally show that the willingness to pay for a given environmental good increases over time. Serret and Johnstone (2006) conclude, based on available analyses, that the elasticity of the willingness to pay with respect to income for environmental goods falls in the 0.3-0.7 interval.

In a paper commissioned by the Committee, which reviews the literature in this area, Ståle Navrud (Navrud, 2011) states that the income elasticity of the willingness to pay for environmental goods may be used as a "first approach" for determining increases in the relative value of environmental goods over time, for a given change in real income. Navrud (2011) is partly based on the same sources as Serret and Johnstone (2006). He tentatively recommends an elasticity of 0.3-0.5, but also recommends that this be updated based on further analyses of Norwegian studies. He then writes the following: "The income elasticities of demand for different environmental goods may differ, but the above interval seems to encompass both use and non-use value, different environmental goods and environmentally-related health effects." (Navrud, 2011). This will, in particular, include the group of environmental goods associated with what we have termed "cultural" ecosystem services in Chapter 4.5.1.

However, Navrud, 2011, concludes by reiterating that other factors than real income also influence our valuation of environmental goods over time.

4.5.4 Price developments for the value of statistical lives

The value of reduced risk – or the value of statistical lives saved – will in many cases influence either the benefit side or the cost side of an analysis. Improved road safety will for example reduce the number of accidents, which may be of considerable value on the benefit side of various cost-benefit analyses.

In Chapter 10, we discuss the basis and methods for valuing risk and determining the value of a statistical life (VSL). In the present Chapter, we therefore restrict ourselves to discussing how to subject the value of statistical lives, and imputed calculation prices, to real price adjustment for cost-benefit analysis purposes.

As with the traditional environmental goods discussed above, no market exists for statistical lives or reduced risk. Although theory may indicate how the valuation of statistical lives will change with income,[18] it is problematic to find a good theoretical basis for determining how such valuation will develop relative to the value of market goods. Consequently, willingness to pay surveys are needed to examine the valuation of such goods.

As with the willingness to pay for time savings (see Chapter 4.4.3), there are several methods for estimating the correlation between income developments and VSL. Studies based on cross-sectional data examine the relationship between different income groups and their willingness to pay. Other studies compare the willingness to pay across countries with different income levels. Meta analyses combine findings from several different studies. A fourth method for obtaining information about how the willingness to pay develops over time is to use (a minimum of) two identical surveys amongst the same population at different points in time. Based on developments over this time period one may thus estimate a correlation between income developments and the valuation of statistical lives.

Although the latter type of survey more pertinently answers the question we pose – i.e. how the willingness to pay for statistical lives develops with income – even such a set of data will be problematic to use. Changes in culture, age, health status and risk level will in themselves also influence preferences, irrespective of income. It may be difficult to adjust for such elements in empirical studies.

Hammitt and Robinson (2011) analyse the *elasticity of the willingness to pay for statistical lives with respect to income* in both rich countries (the

[18] One may model, by using life-cycle models, the relationship between the willingness to pay for risk reductions and income. One theoretical finding from such models is that *VSL ≥ remaining lifetime consumption*, i.e. that the willingness to pay for life must be at least as high as the value of remaining lifetime consumption (or income) since the model does not include the willingness to pay for life in itself (see Hammitt and Robinson (2011)).

United States) and developing countries. The authors find indications that the said elasticity may be considerably in excess of 1 in developing countries. They note that surveys have arrived at elasticity estimates of close to 3 (in Taiwan), although this may be caused by a change in attitudes in a rapidly growing economy. As far as high-income countries are concerned, it seems as if elasticities may be somewhat lower than in developing countries. The authors refer, *inter alia*, to a meta analysis from 2003 (Viscusi and Aldy, 2003), which estimates elasticities in the region of 0.5–0.6. Figures of this magnitude are used in public sector analyses in the United States (Hammitt and Robinson, 2011). Hammitt and Robinson note that subsequent meta analyses have come up with somewhat higher figures, in most cases between 0.4 and 1. Studies across medium-income countries have resulted in elasticity estimates in excess of 1.

OECD (2012) notes that few empirical studies examine the correlation between income and VSL on the basis of time series data. The OECD recommends, by reference to meta analyses based on cross-sectional data and observed practice, to subject VSL to real price adjustment on the basis of an elasticity of the willingness to pay of 0.8 and a sensitivity analysis of 0.4 (using GDP per capita as the income concept).

Sweden adheres to the ASEK 5 guidelines for the transportation sector (Swedish Transport Administration, 2012). These recommend real price adjustment of accident costs, including VSL, based on an elasticity of the willingness to pay for statistical lives with respect to GDP per capita of 1. Real price adjustment based on an elasticity of 1 is also recommended in the United Kingdom.

4.6 The assessment of the Committee

The Committee is of the view that the advantages of real price adjustment of calculation prices need to be balanced against the uncertainty necessarily associated with such adjustment. Real price adjustment should therefore only be considered for cost and benefit components in respect of which there is a solid theoretical and empirical basis for estimating how developments in the valuation of such good will deviate from general inflation. When future developments in real calculation prices are subject to considerable uncertainty, and different development paths are of importance to the analysis, sensitivity estimates will be an appropriate alternative. The analysis shall also present and discuss how non-priced effects may change over time.

4.6.1 Price developments for time savings in cost-benefit analysis

The Committee recommends that the valuation of time savings be based on the opportunity cost principle. Furthermore, the Committee proposes that time use be divided into two main categories: work and leisure. More detailed categorisation may be used if good information is available.

The valuation of time at work should be based on the value added lost on the part of the employer (as measured by gross real wage costs). Any deviations from this should be based on good empirical measurements. The Committee refers to Chapter 3 on distribution effects, where it is noted that cost-benefit analysis based on individuals' willingness to pay does measure the effects of projects and measures in monetary values, and not utility or welfare as such, and is of the view that the correct approach would, in principle, be to use the values of time of the persons affected by the relevant measure for analysis purpose. If adequate information about these values of time is not available, it is appropriate to use national averages.

The Committee takes the view that there may be good reasons why significant parts of the time travelled for business can be used efficiently at present. In principle, cost-benefit analysis should value the change in *efficient time use*. Estimates for changes in time use during working hours should therefore be adjusted, to the extent practicable, to ensure that analyses reflect changes in *efficient* working hours.

The valuation of *leisure* should be based on willingness to pay surveys. If such surveys are not available, it is appropriate to use the net real wage as the value of leisure.

Moreover, the Committee is of the view that economic theory and empirical research provide adequate support for the conclusion that the increases in the value of time must be expected to outpace general inflation. The Committee therefore recommends real price adjustment of values of time. This is of particular importance for projects where the value of time plays a key role on the benefit or cost side.

It seems appropriate to apply the same income measure in all analyses, to ensure that cost-benefit analyses are comparable across sectors. In the absence of specific estimates for long-term Norwegian real wage growth, the Committee recommends that GDP per capita development estimates from the most recent white paper on long-term perspectives for the Norwegian economy be used in respect of both work and leisure travel.

As far as real price adjustment of the value of leisure time is concerned, the most recent studies have found that the percentage increase in the general willingness to pay for leisure is equal or almost equal to real wage (or GDP per capita) growth, i.e. an elasticity of close to 1. However, some factors suggest that the elasticity is somewhat lower, and what can reasonably be assumed in this respect is fairly uncertain. It may seem as if low-income groups generally have a low elasticity.

Nonetheless, the Committee finds than an elasticity of 1, i.e. that the values of time increase in line with the (expected) GDP per capita growth rate, should be assumed. This is also in line with the most recent recommendations from the Swedish Transport Administration. The Committee emphasises the need for applying the same elasticity in all analyses across all sectors to ensure the comparability of such analyses.

4.6.2 Price developments for environmental goods in cost-benefit analysis

The Committee will distinguish between environmental goods whose valuation relates to health effects, political decisions/commitments and willingness to pay surveys, respectively.

The Committee is of the view that environmental goods valued on the basis of political commitments should be examined separately (see discussion of this in Chapter 9 on carbon price paths). If future changes in political commitments are expected, one may consider including the implications of such changes for imputed calculation prices. In principle, assumptions concerning future developments would have to be based on available knowledge about upcoming processes, contract negotiations and future commitments. Even if one were able to assume that the income level will influence people's political behaviour in the form of voting and their expressed views on environmental issues, we have no basis for assuming that the implicit, political "willingness to pay" will be systematically correlated with income developments in society.

Including expected policy developments may also conceal a major element of uncertainty in the analysis, which the decision makers may be better served by having examined explicitly, for example in a sensitivity analysis. The decision makers who can influence the political environmental commitments will in many cases be same who shall assess whether to implement a measure. This is also an argument in favour of the analyst refraining from evaluations of future policy developments. All in all, this suggests that current policy, including established future targets and commitments, shall form the basis for determining calculation prices, and that adjustments to reflect policy development assumptions should be avoided. Such considerations should be discussed separately, or examined in a sensitivity analysis, if deemed to be of particular relevance.

The Committee finds, based on the discussion in Chapter 4.5.4, that the value of statistical lives should be subjected to real price adjustment in line with GDP per capita growth (i.e. an elasticity of the willingness to pay of 1 with respect to GDP per capita). Imputed calculation prices, like the established calculation prices for noise and some forms of local air pollution, are based on the valuation of health and mortality changes, in combination with knowledge about dose-response relationships between emissions, concentration levels and health effects. In view of the discussion of the value of statistical lives, it is also recommended that such calculation prices be subjected to real price adjustment based on GDP per capita growth. If relationships between environmental states and health effects (dose-response relationships) are expected to change over time, adjustment should also be made for such developments.

The Committee has been expressly requested to examine the use of future price paths for carbon emissions in cost-benefit analysis, which does in itself require something other than rule-of-thumb adjustment based on real income. This issue is addressed in Chapter 9.

Beyond these more established calculation prices, the Committee notes that many surveys have been conducted, and will be conducted, on the population's willingness to pay for other environmental goods. The issue before the Committee has been whether to recommend a "rule-of-thumb" adjustment of calculation prices based on willingness to pay, using estimated future real income growth or other factors, and, if applicable, to which calculation methods and which groups of environmental goods this should apply.

There are methodological problems and challenges associated with surveys of people's willingness to pay for environmental goods. If one chooses to use a calculation price from such a survey, it would at first glance also seem logical to utilise knowledge concerning developments in the willingness to pay over time – for example in the form of estimated elasticities of the population's willingness to pay with respect to income. However, such knowledge comes from analyses that encompass fairly heterogeneous environmental goods. Hence, there would not seem to exist an adequate empirical basis for proposing general rules for the real price adjustment of calculation prices that are based on willingness to pay surveys for environmental goods. (If one chooses to utilise calculation prices from older surveys, these estimates should be adjusted, by using the retail price index, to the base year for the cost-benefit analysis unless there exists knowledge suggesting otherwise.)

There are, as discussed in Chapters 4.5.3 and 4.5.4, factors which may suggest that the calculation prices of several environmental goods should be increased over time, relative to the general price level. It may be appropriate to present and discuss such factors, and potentially also to use sensitivity analyses, when alternative future development paths are of importance to the analysis.

4.7 Summary recommendations

Based on the discussion in the present Chapter, the Committee makes the following recommendations:

General recommendations:

- Real price adjustment (up or down) should only be considered for cost and benefit components where there is a firm theoretical and empirical basis for estimating how developments in the valuation of the relevant goods will deviate from general inflation.
- When future real developments in calculation prices are subject to considerable uncertainty, and different development paths are of importance to the analysis, sensitivity calculations may be an appropriate alternative.
- Cost-benefit analysis should also present and discuss how non-priced effects may change over time.

Values of time:

- The Committee recommends that the valuation of time savings be based on the opportunity cost principle. Furthermore, the Committee proposes that time use be split into two main categories: work and leisure. The Committee is of the view that more precise categories may also be used if good information is available.
- The valuation of time at work should be based on the value added lost by the employer (as measured by gross real wage costs).
- Estimates of saved/increased working hours should, to the extent practicable, reflect the *effective* time gain/time loss.
- The valuation of leisure should be based on willingness to pay surveys. If no such survey is available, it will be appropriate to use the net real wage as representing the value of leisure time.
- The value of time at work should be price adjusted by using the expected growth in GDP per capita.
- Correspondingly, the value of leisure time saved should be subjected to real price adjustment by using the expected growth in GDP per capita. This implies that the elasticity of the willingness to pay for leisure with regard to GDP per capita is 1.
- If possible, the values of time of the people who are affected by the measure should be used in the analysis. If adequate information about these values of time is not available, it will be appropriate to use national averages.

Environmental goods:

- The Committee finds that the value of statistical lives, and the imputed calculation prices (including health and mortality-related environmental effects), should be subjected to real price adjustment based on the growth in GDP per capita.
- Calculation prices for health and mortality-related environmental effects should also be adjusted for estimated developments in the health effect of the environmental damage.
- As far as concerns calculation prices based on individual willingness to pay for environmental goods, the Committee does not think there is an adequate empirical basis for proposing general real price adjustment rules.
- Calculation prices derived from political decisions and commitments should be based on current policy and knowledge about future objectives and commitments. No adjustment should be made with respect to policy development assumptions. Such considerations may, for example, be addressed by a sensitivity analysis if deemed to be of particular relevance to the decision maker. As far as the calculation price for greenhouse gas emissions is concerned, reference is made to a separate discussion in Chapter 9.
- Factors that influence the future scarcity and importance of affected environmental goods should be presented and discussed in the economic analyses, irrespective of whether calculation prices are available and used.

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Chapter 5
The social discount rate

5.1 Introduction

From the terms of reference of the Committee:

> The discount rate level has a significant impact on the profitability of long-term measures. The guidelines for determining the discount rate are based on exponential discounting and the so-called Capital Asset Pricing Model. However, financial markets provide limited information about risk premiums for projects with a long economic life, such as for example transportation investments. The Stern Review has recommended a discount rate of 1.4 percent for climate calculations, whilst other economists have argued that such estimate is too low. The Committee shall assess, against this background, which discount rate should be applied for long-term measures, and whether the required rate of return should be differentiated on the basis of the duration of such measures. The Committee shall review existing literature within this area, and assess various methods for determining the discount rate. The Committee shall consider, in this context, whether the theoretical framework for determining the discount rate should be based on the opportunity cost of capital or on consumer behaviour. Moreover, both the cost side and the benefit side are subject to systematic uncertainty from a portfolio perspective. The Committee shall make a recommendation as to how systematic uncertainty should be handled in public investment analysis.

Most public measures have both cost and benefit effects that materialise over a number of years. In order to evaluate measures we therefore need to be able to weigh economic cost and benefit effects that occur at different points in time. At the same time, effects arising in the distant future are subject to considerable uncertainty. A cost-benefit analysis should also take such uncertainty into consideration.

The NOU 1997: 27 Green Paper recommends that these considerations be taken into account through the application of a discount rate that both captures the trade-off between different periods and the consequences of an uncertain future for a decision maker who would prefer to avoid uncertainty. Alternatively, one may use a risk-free rate, whilst correcting for risk in the uncertain net project benefits, thus implying that the discount rate only captures the trade-off between different periods.

Some public measures may have effects into the very distant future. These may include, for example, climate measures or measures targeting biodiversity. The NOU 2009: 16 Green Paper discusses uncertainty and the discounting of such measures in more detail.

The present Chapter starts out by examining various theoretical approaches to the discount rate and discusses the handling of systematic risk (5.2). Thereafter, we explain the discount rate guidelines in Norway (5.3) and address theories as to how the discount rate may develop in the very long run (5.4). We will then discuss the discount rate level (5.5), before reviewing empirical estimates as to the social discount rates applied in some other countries (5.6). The assessments and recommendations of the Committee are presented in Chapters 5.7 and 5.8, respectively.

5.2 Discount rate

Discounting future values by applying a discount rate converts these to cash-equivalent values as per a specific reference date. The reference date normally chosen for an investment is the start date of the future costs and revenues of the project. The cash-equivalent value is in such case referred to as the net present value. Hence, discounting facilitates comparison between, and ranking of, measures with economic effects that occur at different dates.

The discount rate concept may be approached in two ways. It may be interpreted as a required rate of return in the form of the minimum economic compensation per krone invested that would be required for one to be willing to forego consumption at present in return for higher consumption one period later. Alternatively, it may be interpreted as a market-determined opportunity cost, inasmuch as it represents the additional consumption one would have achieved after a period by depositing one krone in the bank or investing it in another interest-bearing investment instead of consuming it now. The consumption and savings profile of an individual is optimal when the subjective required rate of return of the individual is equal to the opportunity cost as defined by the market interest rate.

Uncertainty that influences discount rate estimates may be separated into two categories. Firstly, there is uncertainty concerning developments in the economy as such, which were not discussed in this context in the NOU 1997: 27 Green Paper. This encompasses uncertainty relating to both future consumption developments that affect the required rate of return of the consumer, as well as future returns forgone in the capital market. This may influence the choice of discount rate for use in the evaluation of public projects and, if applicable, the time structure of such rate in the very long run. This is discussed in more detail in Chapter 5.4.

Secondly, there is uncertainty about the economic outcome of the projects and measures to which the capital is committed. This uncertainty is reflected in the discount rate in the form of a project-specific risk premium. This is discussed thoroughly in the NOU 1997: 27 Green Paper from the perspective of the Capital Asset Pricing Model. Financial theory has developed well-established models for the pricing of the risk associated with financial assets, including the Capital Asset Pricing Model. However, these are based on assumptions that may be problematic for the evaluation of risk premiums for long-term public projects. This is discussed in more detail in Chapter 5.4.2.

Different theoretical approaches to estimating discount rates shed light on different aspects of the discount rate problem. In Chapter 5.2.1, we start out by looking at a key model for the consumer's required rate of return.

5.2.1 The consumer's required rate of return

An investment is profitable if the future return, as evaluated at present, is deemed to be worth more than the utility loss from foregoing consumption today. A simple approach to such profitability assessments is that they are influenced by the return on the investment, the impatience of the person making the investment and the extent to which the consumer, when faced with an uneven time profile for lifetime income, prefers consumption smoothing over time.

If we assume that this forms the basis for the decisions of a representative consumer, we get an expression for the marginal condition for optimal saving in a situation without any uncertainty with regard to either the return on the project or developments in the economy in general. Impatience may be expressed as a rate of time preference stating by how much a unit of utility shall be adjusted based on how far into the future it comes. The more impatient is the consumer, the higher is the rate of time preference. The preference for consumption smoothing may be expressed through the elasticity of marginal utility of consumption, which shows the percentage change in marginal utility when consumption is changed by one percent. The higher the numerical value of the elasticity of marginal utility of consumption, the stronger is the preference for consumption equalisation over time. Furthermore, we may look at the change in consumption we experience from one period to the next as the result of economic growth. On this basis, we can derive the so-called Ramsey condition for optimal saving:

$$(1)\ r = \rho + \mu g$$

where r denotes the return on investment, ρ is the consumer's rate of time preference, g is relative consumption growth per capita, and μ is the numerical value of the elasticity of marginal utility of consumption.[1] The product μg shows the percentage change in marginal utility when consumption is changed by g percent. When also including the rate of time preference, the right-hand side of (1) thereby expresses the consumption-based required rate of return. If, for example, $\mu = 2$ and future consumption is increased (reduced) by 1.5 percent, the required rate of return on savings will increase (decrease) by 3 percentage points.

Under economic growth, the population will be better off in the future than at present in material terms, which will manifest itself by an increase in consumption per capita. According to the optimum condition (1), this results in a higher required rate of return. A higher rate of return requirement means that one attaches relatively

1 With diminishing marginal utility, the elasticity of marginal utility of consumption is negative, whilst the Ramsey formula features the numerical value of such elasticity.

Table 5.1 Different social discount rates derived from the Ramsey condition

Source	Pure rate of social time preference, θ per cent	Elasticity of marginal utility of consumption, η	Consumption growth rate, g) per cent	Discount rate = θ + ηg per cent
Stern (2007)	0.1	1	1.3	1.4
Quiggin (2006)	0	1	1.5	1.5
Cline (1993)	0	1.5	1	1.5
Garnaut (2008)	0	1-2	1.3	1.3-2.6
HM Treasury (2003)	1.5	1	2	3.5
Nordhaus (2007)	1.5	2	2	5.5
Weitzman (2007)	2	2	2	6
Arrow (2007)	0	2-3	lf 1-2	2-6
Dasgupta (2006)	0	2-4	lf 1-2	2-8
Gollier (2006)	0	2-4	lf 1.3	2.6-5.2
Empirical evidence	0-3	0.2-4	1.2-2.1 (for Australia)	0.24-11 (given range)

The table provides an overview of different social discount rates from different studies. The table contains an overview of discount rates for use on both marginal measures and the global climate issue (for example Stern, 2007, and Cline, 1993).
Source: Harrison (2010), p. 36.

more weight to immediate consumption, as opposed to realising more consumption later. With a high discount rate, a project will only be profitable in those cases where it yields a relatively high return in subsequent periods. Declining per capita consumption – for example as the result of strong population growth – will correspondingly result in a lower required rate of return and a stronger incentive to save. The last element of the required rate of return defined by (1) will result in consumption smoothing over time.[2] It is reasonable to refer to this element as a wealth effect. A presumption of continued positive (negative) wealth developments in a generational perspective should therefore be reflected in an increasing (declining) discount rate over time for projects with correspondingly long-term effects.

It is reasonable for there to be a connection between how consumption is distributed between the rich and the poor at a given point in time and between the poor and the rich at different points in time. However, the elasticity of marginal utility of consumption is not necessarily the same with respect to the two issues, since distribution at a given point in time will by definition be distribution between different individuals, whilst distribution over time may be distribution between "yourself today" and "yourself in future" (see Atkinson et al., 2009, for en empirical study of how these may vary).[3] To estimate a discount rate for use in cost-benefit analysis, one may assume continuous positive economic growth and identify probable values for the various parameters in the Ramsey condition (equation 1). However, different estimates and assumptions as to the parameter values included in the Ramsey condition may produce very different estimates as to the required rate of return. Harrison (2010) shows that different sources arrive at required rates of return that range from 1.4 percent to 8 percent, cf. Table 5.1, which provides an overview of discount rates for use on both marginal measures and the global climate

2 This elasticity is also discussed in Chapter 3 on distribution within one and the same generation.

3 Chapter 3 notes that it is not possible to find a method for estimating the "correct" marginal utility of consumption on the basis of economic theory alone, since neoclassical economic theory uses a utility concept that is not necessarily measurable.

issue (for example Stern, 2007, and Cline, 1993). This illustrates that there is no straightforward answer to what is an appropriate discount rate when using this simple approach, even before introducing the issues of uncertainty as to the return on the project, as discussed in 5.2.2, and uncertainty as to the long run opportunity cost of capital, as discussed in Chapter 5.3, respectively. Box 5.1 illustrates how the choice of discount rate has been a key issue in the climate debate.

5.2.2 Market-based opportunity cost of capital

The use of scarce resources for a specific purpose implies an economic cost inasmuch as it supplants the potential value added from the best alternative use. This is often termed the opportunity cost. It applies to the use of capital as well. When capital is tied up in a specific project, alternative profitable use of such capital is ruled out. The cost of this is the value added lost by deselecting the best alternative. In an economy without capital rationing, all projects delivering a return in excess of the alternative return on the capital in the financial market will normally be realised. Hence, the return in the financial market is the return on the marginal project, and the market interest rate determines the demand for capital.

Society will normally be faced with alternative uses for scarce resources, and the discount rate should, as an opportunity cost, reflect the best alternative return on the capital tied up in a proposed measure. In a closed economy without market failure, the market interest rate realised in an equilibrium between the supply of, and the demand for, capital will therefore express the return on the best alternative investment, which

Box 5.1 The discount rate and the climate issue – an example

Measures aimed at influencing the global climate need to be analysed over a very long time horizon. Profitability assessments are therefore critically dependent on the chosen discount rate. This has, in particular, been discussed in view of the consumption-based approach (cf. the Ramsey condition, Chapter 5.2.1):

$$r = p + \mu g$$

The debate evidenced by the Stern Review on the climate problem (Stern, 2007) and a response to that report (Nordhaus, 2007a), illustrates key issues in choosing a long-term discount rate. Stern (2007) puts the pure rate of time preference, p, close to zero, based on an ethical assessment to the effect that the utility of future generations shall carry as much weight as that of current generations when making intertemporal trade-offs.

Stern (2007) also attributes a low value to μ. This implies that one assumes a low preference for consumption smoothing over time, since little weight is accorded to the expectation that future generations may be richer than current generations. A higher μ value would, when taken in isolation, have implied that the current generation should save less for future generations.

Nordhaus (2007a) emphasises that the return on alternative investments in the market should guide climate investments. This in order to ensure efficient capital allocation in the economy, across sectors. Hence, Nordhaus (2007a) argues that the parameter values in the Ramsey condition should be such as to bring the discount rate on a par with observable market interest rates. Nordhaus (2007a) notes that the discount rate chosen by Stern implies that investment decisions conditioned on such a rate will result in too much being invested too early in low-return climate measures, when compared to the decisions one would have made if applying a discount rate that matches observable market interest rates. According to Nordhaus (2007a), a more effective strategy would be to invest more in conventional capital in an early phase and thereafter use the return on these investments to make large subsequent investments in climate measures.This is consistent with applying the market interest rate as the discount rate for climate measures as well. Moreover, if one is concerned about exceeding potential natural threshold values, such as the melting of the Greenland ice sheet or the disintegration of the West Antarctic ice sheet, Nordhaus (2007b) shows that economic analyses of the climate issue may apply caps that define the maximum permissible temperature increases/carbon dioxide concentrations. Such caps may be introduced into the analyses without changing the chosen discount rate.

Box 5.2 Basic pricing model for all types of uncertain financial claims

Let P_t be the price of an uncertain claim at time t, let C be consumption, let X be cash flow and let r express the pure time preference of investors. Maximising expected utility, subject to a budget restriction, gives the first-order condition:

$$P_t U'(C_t) = E_t[\rho U'(C_{t+1})X_{t+1}]$$

The first-order condition says that the marginal cost of purchasing a unit of the claim must be equal to the expected marginal utility of owning a unit of the claim in the next period. If we solve the equation for P, we get the basic pricing model:

$$P_t = E_t\left[\rho \frac{U'(C_{t+1})}{U'(C_t)} X_{t+1}\right]$$

eller $P_t = E_t[M_{t+1}X_{t+1}]$, hvor $M_{t+1} = \rho \frac{U'(C_{t+1})}{U'(C_t)}$

M is often referred to as the stochastic discount factor. The model says that the price of an uncertain future claim is equal to the expected discounted cash flow of the claim, with the discounting reflecting intertemporal substitution, risk preferences and time preferences (expressed by marginal utility and ρ). Investors prefer claims that provide high returns in those states and at those times when they have relatively low consumption, and thus relatively high marginal utility from an increase in consumption (difficult times). This will put upward pressure on the prices of such claims. Conversely, the prices of claims that do well in good states or at good times (and deliver poor performance in difficult states or at difficult times) will be subject to downward pressure.

In order to get from the general model to a model of practical use, we need to specify the characteristics of the stochastic discount factor. We also need to get around the problem that it is difficult to obtain good consumption data. Various assumptions and simplifications of the model give rise to many of the price models we know from economic theory, including the Capital Asset Pricing Model and other factor models like ICAPM (the Intertemporal Capital Asset Pricing Model) and the Fama-French model.

The factor models solve the problem of poor consumption data by replacing consumption by one or more other factors that are assumed to be good proxies for consumption, and for which better data exist. In addition, one assumes that the relationship between the marginal utility of investors and the said factors is linear.

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will be concurrent with the required rate of return of the consumers who contemplate whether to save or consume today. In an open economy with a given international interest rate level and free capital movement, both capital supply and capital demand will reflect the world market interest rate, and this interest rate will represent the opportunity cost of capital in the financial market and hence the required rate of return of those who supply capital.[4] This will therefore be the relevant calculation price for trade-offs between consumption in different periods. The scope for deviations between the required rate of return of consumers and the real marginal return on capital as well as the interest rate must be related to imperfections in the economy, for example in the form of distorting taxes. The NOU 1997: 27 Green Paper discussed such capital market imperfections in more detail.

The practical application of the opportunity cost principle in the Norwegian context has been that the discount rate of a project comprises two elements. Firstly, all projects must have a return that is at least as high as a presumed risk-free return in international capital markets. Secondly, a premium is added to the discount rate, reflecting the presumed risk associated with the project. This has been used to express the risk-adjusted opportunity cost of capital of a public project, as it is the return forgone in the financial market on a financial investment with the same presumed risk profile. Models for such pricing of risk are presented in Chapter 5.2.3 below. In Chapter 5.4, we will take a closer look at the relationship between uncertainty in the very long run and the relevant discount rate.

4 See Box. 8.1 of the NOU 1997: 27 Green Paper for a formal presentation of such a stylised model.

5.2.3 Models for pricing uncertain financial claims

Financial theory is concerned with how investors should balance their portfolios when the return on future claims is uncertain. The models are based on the general premise that investors maximise the expected utility of consumption. However, well-established models, like for example the Capital Asset Pricing Model, are directly linked to prices and returns in the market. This makes them practical to use, but also requires several simplifying assumptions that may be problematic for public projects.

If we adopt the standard assumptions that the economy comprises rational investors who are able to make marginal investments, we can derive a basic pricing model for all types of uncertain financial claims. Box 5.2 presents the details of such model.[5]

The Capital Asset Pricing Model is such a price model, and is an equilibrium model in which the consumption of investors is linked to one single portfolio comprising all assets in the economy (the market portfolio). The model is normally expressed in return format:

$$E(Ri) = r + ß(E(RM) - r)$$

where $E(Ri)$ is the expected return on a security i, r is the risk-free interest rate, $E(RM)$ is the expected return on the market portfolio, and $ß$ specifies the degree to which the return on the investment is correlated with the return on the market portfolio. The model says that investors will demand higher risk compensation the more the return on an asset is correlated with the return on the market portfolio.

The key message of the model is that only the risk priced in the market is risk that cannot be diversified away by holding different securities. This is called systematic risk. One cannot achieve an expected return in excess of the risk-free interest rate without assuming systematic risk. Box 5.3 contains a more detailed discussion of the distinction between systematic and unsystematic risk.

The Capital Asset Pricing Model has made a major impact since it was developed in the mid-1960s by Sharpe (1964), Lintner (1965) and Mossin (1966). One of the main reasons for this is that the model can be used to estimate the average risk premium in the stock market on the basis of market return data. The model is therefore well-suited for opportunity cost assessments. If one has a project that needs funding, and one has an estimate as to the magnitude of the project risk relative to that of an average project funded via the stock exchange (β), one can obtain an estimate of the project's risky returns by identifying objects in the financial market with the same risk profile. The risk premium on public measures can then be derived from the market rate of return on such financial assets with the same risk characteristics. The Ministry of Finance (2005) provides a more technical discussion of such an approach.

The Capital Asset Pricing Model offers a simple and pedagogic presentation of important asset management principles, and is a well-established model for the pricing of projects that involve risk. However, the model is based on a number of simplified assumptions. The two most important ones are that investors live for one period only and that they have no form of labour income during that period. Moreover, the assumption of a linear relationship between marginal utility and the return on the market portfolio implies either that the preferences of investors are based on expectation and variance only, or that the return on all assets follows a normal distribution.[6] The model also assumes the existence of an investable market portfolio comprising all assets in the economy. As noted in Report No. 17 (2011-2012) to the Storting, Box 2.10, empirical research suggests that the model fails to provide a fully adequate description of how investors act and of how financial markets work. For example, research clearly indicates that systematic parts of the return on equities are determined by other factors in addition to beta (Banz, 1981, Fama and French, 1993, Jagadeesh and Titman, 1993).

A project's contribution to economic value added will normally be subject to uncertainty. The systematic uncertainty of a public project may be made operational by taking into account the extent to which the return on the project co-varies with the return on the national wealth, which is typically measured by the national income. The term "national income" must in this context be

5 The presentation of the general pricing model and the Capital Asset Pricing Model is, in the main, based on Cochrane (2005).

6 The optimisation problem may be solved for different sets of concave utility functions and return distributions. If utility is quadratic, no assumptions are required with regard to distribution characteristics because an investor with such risk preferences will under any circumstance be concerned about expectation and variance only. This is the utility function used in the classical derivation of the CAPM. The problem with quadratic utility is that the so-called absolute risk aversion increases with increasing wealth, which is not particularly realistic.

Box 5.3 Systematic and unsystematic risk

Uncertainty in a project may be divided into systematic and unsystematic risk, respectively. Risk that depends on project-specific circumstances is referred to as unsystematic risk. This may, for example, be the uncertainty relating to the geology of a mountain one intends to drill into to construct a tunnel. In other projects we will also encounter uncertain costs that depend on project-specific circumstances only. In some of these projects the actual costs will be lower than planned, whilst they will be higher in others. Since there is, generally speaking, no correlation between the costs of the various projects, the outcomes of this type of uncertainty will cancel each other out when we look at the portfolio of projects for society as a whole. We say that the unsystematic risk can be diversified away, which implies that we shall not increase the required rate of return of a measure in the face of this type of risk.

By systematic risk, on the other hand, is meant the degree to which the gains from the measure are sensitive to volatility in the marginal utility of consumption. Furthermore, it can be assumed that the marginal utility of consumption is lower when one gets richer. One may, for example, envisage that the return on a transportation investment varies at different stages of the business cycle. The predominant benefits from transportation measures are reduced travel time and increased safety. The Committee recommends that both the value of time and the value of a statistical life be real-income adjusted, and that estimated GDP growth per capita be used as an estimate of such growth, cf. the discussion in Chapter 4 on real-price adjustment. One consequence of this is that the benefit side of transportation projects is positively correlated, to a higher extent than before, with the return on the national wealth, and consequently being perceived as measures with higher systematic risk than would be the case without such real-income adjustment. The value of other measures in society may also be sensitive to business cycle developments. Meanwhile, other measures, for example within welfare services for the elderly or prison services, will have an economic return that cannot be assumed to be sensitive to the business cycle. In practice, one will of course encounter large grey areas when seeking to classify specific uncertainty elements as either systematic or unsystematic.

In the presence of systematic risk, the economic profitability calculation needs to be corrected for this type of uncertainty. The present Chapter notes how to do so by including a risk premium in the discount rate. In theory, the magnitude of the risk premium shall depend on the degree of correlation between the project return and the marginal utility of consumption. The economic return on priced elements is comprised of benefit elements less cost elements. A positive correlation between the net benefits of the project and the remainder of the economy increases the risk, whilst a positive correlation between net cost and the remainder of the economy reduces the risk. Both aspects merit the inclusion of a premium in the discount rate, which reduces the net present value of net benefits (lower profitability) and reduces the net present value of net costs (higher profitability).

Another and more direct approach for taking risk aversion into account in the calculations, is to calculate the so-called certainty-equivalent values of the various cost and benefit components at different points in time, and use the risk-free interest rate for discounting. The resulting figure expresses a certainty-equivalent project profit that will, in the face of risk aversion, be lower than the expected profit, assuming that the project profit is positively correlated with the return on the national wealth. In theory, these two approaches should be equivalent. In practice, the calculation of certainty-equivalent cost and benefit values require detailed knowledge of the various components to be valued, and such calculation also needs to rely on a number of assumptions. All in all, this may imply that the approach involving the use of certainty-equivalent cost and benefit values is impracticable and characterised by low transparency.

interpreted in the widest sense, and shall in principle include everything that contributes to the welfare of the country. Using, for example, the national income figures of Statistics Norway will thus only give an approximation of this theoretical variable. By estimating how uncertain the return is relative to the return on an average private project, the pricing of project risk based on the Capital Asset Pricing Model can express the economic risk-adjusted alternative return against which the project can be evaluated.

However, two considerations, in particular, make it problematic to use the Capital Asset Pricing Model to determine discount rates for public projects. One of these is that the model, in its simple form, is valid for one period only. The other is that the model assumes that all assets are tradable and have a market price, whilst large parts of national wealth are not tradable.

In practice, it is common to assume a constant risk-free interest rate and a constant risk premium in the valuation of projects involving recurring cash flows, when applying a required rate of return calculated on the basis of the Capital Asset Pricing Model using market data. Both of these assumptions may be questionable for public projects with a long investment horizon.

With a long time horizon, it is reasonable to assume that interest rates, risk premiums and volatilities may all change. This makes the modelling of dynamic consumption and investment projects complex. The problem with uncertainty over time with regard to the so-called risk-free interest rate will be addressed later in the present Chapter. The classical solution to a portfolio choice problem over several periods, of which Mossin (1968), Samuelson (1969) and Merton (1969) have contributed one version each, is that the investment horizon is, under certain assumptions, irrelevant to optimal portfolio choice. One important assumption underpinning the irrelevancy result is that the return on risky assets is independent and identically distributed over time[7]. How the return on risky assets develops over time is a matter of debate. However, several empirical works suggest that equity returns are mean reverting, i.e. that returns tend to revert to a mean over time if they deviate, for various reasons, from such mean at a given point in time. A rational explanation for mean reversion is that risk premiums vary over time in tandem with business cycle fluctuations in the economy.

If the Capital Asset Pricing Model shall, nevertheless, be used as a framework for establishing a discount rate for public measures, the risk premium and beta estimates should, ideally speaking, both be based on national income. In practice, however, all price data are from the listed equity markets. National income figures are obtained from the national accounts, and include no information about risk considerations. This means that we need to believe that stock premium estimates express a correct price for the risk associated with public projects, in order for these to be used in determining a discount rate for public measures. This is probably justifiable from an opportunity cost perspective, provided that we accept that the risk aversion of stock market investors is reasonably representative of the risk aversion of those carrying the risk associated with public projects, cf. the discussion in the NOU 1997: 27 Green Paper. In addition, we need a method for estimating the beta of public projects. This is difficult because figures on the net benefits of a public project – as opposed to on the return of an equity – are not readily available and based on market prices.

There also exist models for estimating the beta of non-tradable objects, see Minken (2005). However, such calculations are fairly complex, whilst data availability is poor. The analysis in Minken (2005) shows that the output from such calculations is highly sensitive to changes in the data.

5.3 Norwegian guidelines on choosing the discount rate

5.3.1 Historical guidelines

From 1967 to 1999, Norway used an approach where the discount rate was based on the Ramsey model. Based on a report by Leif Johansen in 1967, in which it was assumed that ρ = 1 percent, μ = 3 and g = 3 percent, the discount rate was put at 10 percent in circular R-3/1975. In circular R-25/78, the discount rate was changed to 7 percent.

When revising the cost-benefit analysis framework in 1998, the assumption of a small, open

7 The other assumptions are that investors have constant relative risk aversion and that they live on capital income only. The last one hundred years have seen large growth in per capita consumption and wealth that have not been accompanied by any long-term trend in interest rates and risk premiums. This suggests that the risk aversion of investors is not particularly dependent on wealth. Campbell and Viceira (2003) argue, against this background, that one can and should as a main rule assume that investors have constant relative risk aversion. The introduction of labour income will, according to Campbell and Viceira (2003), under normal circumstances increase the optimal portion invested in equities.

economy was held to be reasonable for Norway. The risk-free interest rate and risk premiums were deemed to be increasingly determined by international markets. Hence, estimates of the relevant discount rate were based on the so-called Capital Asset Pricing Model (see Chapter 5.2.2).

The recommendations in the NOU 1997: 27 Green Paper were based on the Capital Asset Pricing Model. The Ministry of Finance guides from 2000 and 2005 discuss, in more detail, how the model may be adapted to provide an expression for a reasonable discount rate for use in cost-benefit analysis. Circular R-14/99 stipulates that a risk-free real rate of 3.5 percent should be assumed for cost-benefit analysis purposes. Three different risk classes were defined, with a risk-adjusted rate of 4, 6 and 8 percent, respectively. Specific calculation of the risk-adjusted required rate of return was recommended for large projects or groups of projects.

5.3.2 Current guidelines

A new circular R-109/2005, replacing R-14/99, was issued following revision of the Ministry of Finance cost-benefit analysis guide in 2005. The risk-free rate for use in the cost-benefit analysis of central government measures was here put at 2 percent, and it was noted that a normal project will have a risk premium of 2 percentage points, and thus a risk-adjusted required rate of return of 4 percent. For measures where considerable systematic risk may reasonably be assumed, it is stated that a risk premium of 4 percentage points, and thus a discount rate of 6 percent, may be appropriate. Specific calculation of the risk-adjusted required rate of return continued to be recommended for large projects or groups of projects. This applies, in particular, to projects falling within the scope of the system for quality assurance of major public projects (QA1), cf. the discussion in Chapter 5.3.3 below.

The Ministry of Transport and Communications has initiated a project to examine the discount rate for projects within its areas of responsibility. Minken (2005) presents an analysis of transportation projects in Norway in which he recommends a discount rate of 4.5 percent for road and railway projects and 5 percent for harbours and airport infrastructure. The said rates comprise an estimated risk-free rate of 2 percent and a systematic risk premium of 2.5 percent and 3 percent, respectively. However, Minken (2005) notes that the analysis is highly sensitive to the data used in the analysis. Moreover, he notes that the absence of real price adjustment of those unit prices that depend on income (the value of time and life, in particular) may, when taken in isolation, suggest a 0.5 – 1 percent reduction in the resulting discount rate. The Ministry of Transport and Communications concluded by applying a discount rate of 4.5 percent to all projects within its area of responsibility, whilst for practical reasons not distinguishing between road, railway and aviation.

5.3.3 Current guidelines for projects falling within the scope of the quality assurance regime for major central government investments

In the autumn of 1997, the Government initiated a project to review and propose improvements to the systems for planning, implementing and following up on major central government investment projects. The quality assurance regime now encompasses choice of concept (QA1) and the basis for control, as well as the cost estimate, including uncertainty analysis of the chosen project alternative (QA2). The system for quality assurance of major projects applies to projects with an estimated overall investment cost in excess of NOK 750 million (Ministry of Finance, 2011).

QA1 concerns quality assurance of the basis for decision making with regard to the commencement of the planning phase. Specifically, six aspects are subject to quality assurance: a needs assessment, a general strategy document, a general requirement document, a feasibility study, an analysis of alternatives, as well as guidelines for the planning phase. The analysis of alternatives includes cost-benefit analysis of the "do-nothing option" and at least two alternative main concepts. Input data from dedicated uncertainty analyses are used, with expectation values and dispersion measures being calculated for the various uncertainty elements. The uncertainty analysis seeks to directly calculate the systematic uncertainty of relevance to society. It encompasses, *inter alia*, differences in systematic uncertainty relating to the investment expenditure, variations in the level of the systematic uncertainty relating to the benefits and, not least, variations in how the uncertainty relating to benefits is eliminated over the lifespan of the project.

The current guidelines note that this provides a more reliable indication of systematic uncertainty than does adding a standard risk premium to the discount rate. The general risk premium in the discount rate is therefore not made applicable to projects falling within the scope of the central government rules on external quality assurance. The analyses have consequently been based on the risk-free discount rate of 2 percent, adjusted for estimated systematic risk if applicable. It has proven difficult to thus adjust for systematic risk, and specific risk-adjustment for individual projects has only been estimated in a small number of cases. The outcome has therefore been that many major projects are only discounted at the risk-free rate of 2 percent, with no real adjustment for systematic uncertainty through a risk premium or certainty-equivalent values, whilst minor projects (outside the QA scheme) have relied on the general recommendation of the Ministry of Finances (2005) for a discount rate of 4 percent for projects with normal systematic risk (Vennemo, 2011).

5.4 Very long-run considerations in the face of uncertainty

The challenge in using market data to determine the discount rate is that the most long-term interest-bearing financial instruments being traded do not have maturities that match the lifespans of the very longest-term public projects. How uncertainty develops and influences the rate must therefore be considered from the perspective of economic theory. In Chapter 5.4.1, we take a closer look at uncertainty about general economic developments, and which consequences such uncertainty has for the discount rate and its time structure. The fact that the project return may also include systematic risk is disregarded at this stage. In Chapter 5.4.2, on the other hand, we discuss the relationship between the systematic uncertainty associated with the return on the project and discount rate developments over time. In Chapter 5.4.3, this is discussed from the perspective of the global environmental challenges, as discussed in the NOU 2009: 16 Green Paper.

5.4.1 Uncertainty about general economic developments

Cost-benefit analysis of global climate policies and climate measures necessitates analysis of effects in the very long run. This has initiated new research on which discount rate it is appropriate to use in the very long run.

A key aspect that is highlighted is the basic uncertainty about future global economic developments. A joint feature of analyses addressing this is the assumption that consumers are risk averse. One way of approaching uncertainty about future wealth developments is to start out from the Ramsey condition, presented in Chapter 5.2.1, and let economic growth be uncertain. Gollier (2008), for example, presents such an expanded Ramsey condition in which uncertainty about future economic developments gives rise to an insurance motive for savings, which is indicative of a lower discount rate. In the face of uncertainty, one will, all else being equal, invest somewhat more for the future to guard against unfavourable future outcomes with regard to one's economic situation. This approach implies, under certain assumptions relating to preferences and consumption developments over time, a stable rate for all years.[8] Given the uncertainty assumption that suggests a stable discount rate over time, Gollier (2011) takes a closer look at the magnitude of the precautionary element in the required rate of return. It is noted that the insurance element is moderate for rich countries as the result of relatively stable economic growth in these countries. Assuming an elasticity of marginal utility of 2, which is stated as being based on a discretionary assessment, he finds, for example, a rate for the United States that is reduced from about 3.5 percent (if not taking the uncertainty into account) to 3.35 percent (if taking it into account). If, on the other hand, one takes into account the large variation in income globally, he finds that the precautionary element is much larger, with the global rate being reduced from about 4.5 percent to 0.7 percent. This indicates that in examining issues that affect the entire planet, for example the formulation of a global climate policy, it is important to consider such precautionary element. Under other assumptions – especially that the uncertain consumption is positively correlated over time – Gollier (2008) shows that the required rate of return declines over time.[9]

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8 Gollier (2008) shows, with regard to the time structure of the discount rate, that if preferences exhibit constant relative risk aversion, and consumption developments follow a discrete stochastic process in which consumption changes are stochastically independent and identically distributed, the time structure of the interest rate will be flat in the sense that the discount rate will be independent of the time horizon. If, on the other hand, consumption growth is positively correlated over time, consumption uncertainty will, from the perspective of the investment date, increase the further into the future such consumption takes place. This will imply a discount rate that declines over time. If the stochastic process behind consumption developments is subject to so-called mean reversion, thus implying that consumption reverts to a normal level as the result of the business cycle, the reduction in the discount rate over time will be significantly less pronounced.

9 See footnote 8.

If examining measures in the very long run, it may also be argued that economic growth can be expected to decline over time. This will also, when taken in isolation, indicate a declining rate over time, cf. the Ramsey condition with a declining growth rate in consumption per capita. Such arguments may, for example, be linked to limited aggregate global resources and to economic growth in the history of humanity only having been the norm for the last 250 years.

Another approach to uncertainty about future economic developments is modelled in Weitzman (1998) as uncertainty with regard to the opportunity cost of capital, independently of uncertainty as to the actual return on the project. This is based on the premise of the discount rate as a price that reflects the forgone market-based alternative return on the capital invested in the project, cf. Chapter 5.2.2. This raises two issues. One of these is that when the alternative return is uncertain, the discount rate needs to take the form of a certainty-equivalent opportunity cost of capital. This raises the issue of the relationship between the certainty-equivalent rate and the expected rate.

Geometric discounting makes the net present value a convex function of the discount rate. This implies that uncertainty about the discount rate results in the expected net present value of future project profits being higher than the net present value calculated on the basis of the expected rate (cf. the so-called Jensen's inequality). Consequently, the certainty-equivalent discount rate is lower than the expected rate. The certainty-equivalent discount rate is implicitly determined by the expected value of the discount factors corresponding to the uncertain rates, and not by the expected value of the discount rates (cf. Weitzman, 1998, and Weitzman, 2012, Box 5.4).

Secondly, there is the issue of developments in the certainty-equivalent discount rate over time. Such time structure depends on how the uncertainty associated with the alternative return changes over time. Newell and Pizer (2003) undertake a more general analysis of discounting under uncertainty based on capital market returns, in which the assumptions concerning rate developments over time are discussed. It is there noted that developments in the certainty-equivalent rate over time depend on whether one assumes that the uncertain future rate tends to revert to a long-term mean (so-called mean reversion) or whether one has positively serially correlated market rates as the result of random macroeconomic shocks. In the former case, the presence of uncertainty has relatively minor implications for the discount rate. In other words, the certainty-equivalent rate is in such case marginally lower than the expected rate. In the latter case, the certainty-equivalent rate will be considerably lower than the expected rate, especially in the long run. Newell and Pizer (2003) look at historical interest rate developments for long-term government bonds in the United States over the last 200 years, and estimate developments in the certainty-equivalent rate on that basis. They find, under the assumption of random walk-based rate developments, that stochastic, macroeconomic shocks with persistent effects will imply positively serially correlated rates. This results in the certainty-equivalent rate declining from 4 percent to 2 percent after 100 years, to 1 percent after 200 years and to 0.5 percent after 300 years. This is in line with the approach in Weitzman (1998). However, a model assuming mean reversion indicates that the same historical data imply a certainty-equivalent rate that is in practice identical to the expected rate of 4 percent for the first 30-40 years, and that remains above 3 percent for the next 200 years. It only declines to 1 percent after 400 years. Newell and Pizer (2003) state that evidence based on standard statistical tests provides no clear answer as to which model best fits the data. The authors nevertheless note that random walk is the model that best fits the data in most attempts at splitting the historical data into two periods (so-called split samples), which is indicative of a declining rate over time.

Like Newell and Pizer (2003), Hepburn et al. (2009) start out with an analysis of variations in the historical risk-free rate, looking at Australia, Canada, Germany and the United Kingdom. Different specifications of the econometric model provide somewhat different outcomes with regard to the time structure of the long-term certainty-equivalent rate. Based on a risk-free rate in year 1 of 3.5 percent for the United Kingdom, they find, for example, a rate that varies between 3.54 percent and 3.31 percent after 40 years and between 3.42 percent and 3.22 percent after 100 years. The article notes that the model with the steepest decline in the rate enjoys the best empirical support.

Instead of seeking to estimate a discount rate from historical data, Weitzman (2001) shows the findings from a survey amongst a large sample of economists as to which real discount rate they believe to be reasonable, "everything taken into consideration", for assessing a long-term climate issue. The mean response is 4 percent with a standard deviation of about 3 percent. Weitzman (2001) uses this sample as a distribution of potential future discount rates and shows, in line with the more general observation in Weitzman (1998), how such a distribution suggests a declining certainty-equivalent rate over time. By using the findings to estimate a specific distribution for this certainty-equivalent discount rate, he notes that this suggests, given his approach, a discount rate of 4 percent for the first five years, thereafter 3 percent for the next 20 years, thereafter 2 percent for the next 50 years, thereafter 1 percent until year 300 and thereafter 0 percent. However, Freeman and Groom (2012) note that these findings follow from a specific assumption to the effect that the respondents in the survey gave their responses as a normative assessment as to what they believed the rate should be, and not as an estimate as to what will in fact be the average rate. If respondents did actually give their best estimates of an average future rate, it is the distribution of individual estimated averages that is relevant, whilst it is the distribution of the respondent's normative estimates that is relevant under the normative interpretation. In the latter case, the variance will be much higher than the variance of the future rate estimates, which will be given by the variation in the distribution of averages. If the responses are interpreted as each respondent's best estimate of the future rate, it will result in a much flatter term structure for the discount rate than follows from Weitzman's approach. Since there will always be an element of normative replies, Freeman and Groom (2012) can be taken to indicate that Weitzman's findings are toned down, but without the declining tendency being eliminated altogether.

Freeman and Groom (2012) note that it is not possible to know on what basis the respondents in Weitzman (2001) submitted their responses. The authors note that different interpretations of the responses reflect, to a large extent, approaches to discount rate recommendations in the United Kingdom, France and the United States. The United Kingdom and France have public recommendations for a time structure of the discount rate that resembles what would result from a normative interpretation of the responses from the respondents. Recommendations in the United States, on the other hand, with less dramatic rate declines, resembles what one would get by interpreting the responses of the respondents as estimates of expected averages.

The literature reviewed above suggests, all in all, that growing uncertainty about the market return is indicative of a declining discount rate as given by the opportunity cost of capital. The reason for this is that it does, when taken in isolation, become more attractive to realise the project as the uncertainty associated with the alternative return that can be obtained in the market increases. This results in a lower required rate of return, and thus a lower discount rate. The literature reviewed in the present Chapter has found support for the contention that uncertainty with regard to macroeconomic developments - and hence the alternative return as given by the market rate of interest – increases in the very long run, i.e., beyond the period in which market returns can reasonably be hedged in financial markets. Consequently, this literature suggests that the discount rate, as assessed on the date of analysis, will eventually decline over time.

So-called hyperbolic discounting, or bias towards the present, has also been invoked as an argument for a declining discount rate over time (Harstad, 2012). Hyperbolic discounting implies that people's degree of impatience is not constant, and that the present is accorded relatively more weight than would be suggested by exponential discounting at a constant rate. This means that the trade-off between utility in subsequent periods changes over time. This gives rise to dynamic time inconsistency, which implies that the profitability of a decision is dependent on when such decision is made, although the informational basis for the decision remains unchanged. However, a number of empirical studies show that a bias towards the present is commonly found in individuals, and therefore must be assumed to influence the population's willingness to pay for future consequences. See for example Laibson (1997), Frederick et al. (2002), Dasgupta and Maskin (2005), for a more detailed discussion.

5.4.2 Uncertainty as to the return on the measure

Chapter 5.4.1 addresses how uncertainty with regard to general economic developments influences which risk-free rate should be adopted. This is examined quite extensively in economic theory. Another issue is how uncertainty concerning the actual return on the project will influence the discount rate in the long run. Such uncertainty will influence the risk premium element of the discount rate, cf. Chapter 5.2.3, *Models for pricing uncertain financial claims*, and related fact boxes. The literature examining the very long-term time structure of such risk premiums is more limited.

Weitzman (2012) presents a theoretical approach to the problem. Based on a consumption-based, multi-period version of the Capital Asset Pricing Model, in which net consumption from a project is comprised of an unsystematic component plus a systematic component that varies proportionally with the uncertain aggregate consumption in the economy at a factor of $0 \leq ß \leq 1$, an optimal discount rate is derived. This is implicitly determined by the risk-adjusted rate corresponding to a discount factor that is a *ß*-weighted average of the discount factor calculated with the risk-free rate and the discount factor calculated with the expected return on the capital portfolio generating the value added corresponding to the uncertain consumption component. The one-period version of this model results in a risk-adjusted required rate of return that is concurrent with the required rate of return from the Capital Asset Pricing Model. Moreover, for any *ß* between 0 and 1, the risk-adjusted required rate of return will be declining with the time horizon and will approach the risk-free rate when the horizon becomes sufficiently long.

The world considered here is genuinely uncertain. Over time, any project with a return that is less uncertain than is the value added in the risk-exposed part of the economy, will represent a form of insurance in a long-term perspective. For such projects the unsystematic part of the value added will therefore become increasingly important over time, whilst the component exposed to systematic risk "discounts itself out". The discount rate for projects with a certain systematic risk shall therefore decline over time, according to Weitzman (2012). Projects without systematic risk will, in line with the theory, have a constant rate equal to the risk-free rate. The model in Weitzman (2012) is presented in more detail in Box 5.4.

The discount rate used in the evaluation of public projects must be assessed on the basis of the sum total of the risk-free rate and the relevant risk premium. However, different model approaches share the feature that increasing uncertainty over time with regard to the alternative market return implies a declining risk-adjusted required rate of return.

It has not previously been common practice to use a rate that varies over time for cost-benefit analysis purposes. It is therefore worthwhile to make two observations. Firstly, the basis for a declining rate, as presented above, is increasing uncertainty over time. In an assessment situation in which such a declining rate is to be used, it will therefore be appropriate to assume that the rate structure will apply from the *date of analysis*. Secondly, values in the same period shall be discounted at the same discount rate, since they are exposed to the same macroeconomic uncertainty. As an example, assume that a declining discount rate is made operational by applying one rate for the first 40 years and a lower rate for subsequent years. This means than an economic effect in year 50 shall first be discounted to year 40 by applying the low rate, and then discounted from there at the shorter-term rate. In other words, the value of an effect cannot be changed significantly by moving it from year 40 to year 41, etc.

5.4.3 Discounting and global environmental challenges

The NOU 2009: 16 Green Paper, *Global Environmental Challenges – Norwegian Policy*, includes an analysis of uncertainty and discounting in view of, *inter alia*, the above literature, based on the work published at that time.

It was noted that there are arguments in favour of long-term climate measures being evaluated at a lower discount rate. According to the report, these arguments can be divided into two groups. Firstly, it is uncertain whether we attach sufficient weight to later generations if we also apply a relatively high discount rate for long-term projects. Secondly, there may be doubt as to whether the information in observable market interest rates is also of relevance to subsequent periods.

The report illustrated the issue by assuming that both risk-free rates and risk premiums will continue to develop more or less in line with what we can estimate on the basis of available market data, and that the project we are examining is not sufficiently large to influence market prices. Effects in the distant future will in such case have a very low net present value. With a discount rate of 5 percent, the net present value of 1 krone in, for example, 50 years will be 8.7 øre, and in 100 years only 0.76 øre. It was noted that it is often argued, on this basis, that projects with effects in the distant future should be evaluated on the basis of a low discount rate out of concern for future generations. However, the NOU 2009: 16 Green Paper noted that it is not obvious that a lower discount rate addresses the problem we want to solve.

It was noted, assuming that it is not a problem in itself to value all income and costs in kroner, that the analysis should, in the usual way, identify

Box 5.4 Summary of Martin Weitzman (2012): Rare Disasters, Tail-Hedged Investment, and Risk-Adjusted Discount Rates

From the welfare effects resulting from a marginal investment project in a simple dynamic stochastic general equilibrium model, one can derive the optimal risk-adjusted discount rate schedule to be applied to the project's time-dependent pay-offs . That is, the investment will improve welfare if and only if the present value of its cost is less than the expected present discounted benefits calculated at these discount rates.

Assuming constant relative risk aversion, the investment opportunities of the economy may be depicted as consisting of two assets; one risk-free asset which gives a fixed unit of consumption in each period, and one risky asset which may be thought of as equity yielding some fraction of all future risky consumption pay-offs.

Net benefits from the investment are random variables that are assumed to be made up by two components, and given by

$$(1)\quad B_t = b_t\left((1-\beta_t)I_t + \beta_t\frac{C_t}{E[C_t]}\right)$$

In (1), $ß_t$ is the fraction of the pay-offs at time t that replicates the risk profile of the aggregate economy at that time, while the fraction (1 - $ß_t$) is stochastically independent of the aggregate economy. Hence, without loss of generality, the latter component can be normalised by setting $E[I_t]$ =1 for all *t*. That implies that expected net benefits at time t are given by b_t.

The role of the fractions $ß_t$ resembles that of the investment beta in the Capital Asset Pricing Model. However, in the present context the beta at time *t* reflects the correlation between the project's pay-offs in terms of net benefits and the aggregate consumption at t, which is here called the *real project beta*.

For simplicity, it is assumed that $ß_t = ß$ for all *t*.

The relationship between the instantaneous risk-free rate, *rf*, and the gross return on the risk-free asset is given by $r_f = \ln(R_f) \equiv \ln(e^{rf})$ and similarly for the instantaneous risky rate of return on equity, i.e. $r_e = \ln E[R_e]$

Assuming an investment at time 0 yielding a single pay-off at time *t* given by the expression for B_t as in equation (1), one can define X as the loss of consumption at time zero that makes the consumer precisely indifferent between accepting or rejecting this hypothetical project. The consumption loss X must then satisfy

$$(2)\quad U'(C_0)X = \alpha^t E[U'(C_t)B_t]$$

where α is the constant discount factor representing the pure time preference for utility. The corresponding discount rate for a project with a beta value = b must satisfy the equation

$$(3)\quad X = E[(B_t)]e^{-r_e t}$$

Relying on the simplifying properties of the isoelastic utility function, one can derive the critical value of X as given by

$$(4)\quad X = b_t\left(\frac{1-\beta}{(R_f)^t} + \frac{\beta}{E(R_e)^t}\right)$$

Using (3), this can be expressed in terms of discount factors as

$$(5)\quad e^{-r_t t} = (1-\beta)e^{-r_f t} + \beta e^{-r_e t}$$

Taking logarithms, (5) can be rewritten as

$$(6)\quad r_t = -\frac{1}{t}\ln\left((1-\beta)e^{-r_f t} + \beta e^{-r_e t}\right)$$

Hence, a marginal investment project will increase welfare if and only if the expected present values of its net benefits discounted by the discount rate given by (6), is positive.

Compared with the Capital Asset Pricing Model where the risk-adjusted discount rate is given by a beta-weighted average of the risk-free rate and the expected return on the market portfolio, the optimal risk-adjusted discount rate in the consumption-based investment model is implicitly given by the optimal discount factor being a beta-weighted average of the discount factors associated with the risk-free rate and the expected return on equity, respectively. Hence, the discount rate given by (6) represents a multi-period generalisation of the stationary Capital Asset Pricing Model.

The static Capital Asset Pricing Model relies on mean-variance preferences, whilst its multi-period investment counterpart relies on constant relative risk aversion preference, both of which yield portfolio separation.

For t = 1, the discount rate equals the beta-weighted discount rate in the Capital Asset Pricing Model and approaches the risk-free rate as t becomes very large. Thus, for any risk profile as represented by the fraction 0 < ß < 1 of the project's pay offs that correlates perfectly with total consumption, the appropriate discount rate will be declining over time and approach the risk-free rate as a limiting value.

which groups profit from the project, and which groups incur a loss from it. If the project has a negative net present value when not taking distribution effects into account, whilst those who would profit from the project are future generations, we are, generally speaking, dealing with a distribution problem, and not a discounting problem. Those conducting the project analysis must in such case identify the distribution effects, and the decision maker should consider whether the project should be implemented due to the positive effects for future generations. The present Green Paper discusses the distribution issue in more detail in Chapter 3.

Furthermore, the NOU 2009: 16 Green Paper noted that it is also necessary to properly address other prices than the discount rate when dealing with long-term projects. If, for example, environmental goods become scarcer over time, there is reason to believe that the value (the calculation price) of environmental goods will increase relative to the value of other goods. The implications of such changes in relative prices may, according to the NOU 2009: 16 Green Paper, outweigh the implications of discounting, and make projects economically profitable even though the income is realised in the distant future. The Committee discusses real price adjustment in more detail in Chapter 4 and specifically addresses real price developments with regard to the shadow price of greenhouse gas emissions in Chapter 9. Reference is also made to the committee on the valuation of biodiversity appointed by the Ministry of the Environment.

The NOU 2009: 16 Green Paper then addresses the issue of determining a discount rate for periods for which we have no observable market prices to rely on. It is noted in this context that we need to examine what determines the risk-free rate and the risk premium in the long run. A number of the models outlined above are presented, and some factors, in particular, are highlighted: changes in economic growth, changes in uncertainty, weakness in the available data and market failure.

The NOU 2009: 16 Green Paper concluded, *inter alia*, that the discount rate applied for cost-benefit analysis purposes should be a real rate calculated before tax, and with a maturity tailored to the project duration. One should, as a main rule, use market-based estimates for the risk-free rate and the risk premium. However, it was noted that there is considerable uncertainty associated with estimates of long-term risk premiums and, in part, also long-term, risk-free rates. The NOU 2009: 16 Green Paper proposed no changes in current practice for determining the discount rate for public projects in Norway, whilst at the same time noting that the risk associated with many public projects is low.

5.5 The level of the discount rate

By comparing the interest rates charged for short-term and long-term loans, one can get an impression of how market players consider trade-offs in the long run. However, this only applies to periods in which a certain volume of securities is actually traded. Developments in the wake of the financial crisis in 2008 and, in particular, since the last year's Euro crisis, have illustrated how unclear it is what can be considered a risk-free interest rate and what constitutes a risk premium. Generally speaking, all yield curves are upward sloping in the current market, i.e. the interest rate is higher the longer the maturity, as far as those periods for which liquid markets exist are concerned.

The current interest rate level in the market for securities that are presumed to be secure is, generally speaking, very low from a historical perspective. It is uncertain whether this can be considered a long-term tendency, or must be considered a special phenomenon. This may be due to the specific circumstances in the current international currency market, where the ability of banks to manage without central government support in Europe and the United States is associated with significant risk, in combination with weak confidence in the ability of some states to handle their explicit and implicit liabilities.

Assessments of returns in international financial markets in the very long run are of special interest to the Norwegian State, because the return on the Government Pension Fund Global comes from these markets. Report No. 17 (2011-2012) to the Storting provides a detailed discussion of both historical and future returns in the very long run. It is shown that the average annual real return on the Government Pension Fund Global of 2.7 percent is well within normal fluctuations around an expected return of 4 percent.[10] It is noted that current real interest rates are very low, also from a historical perspective. According to the said Report to the Storting, this is partly caused by the steep slump experienced by the

10 It follows from the Report to the Storting that this concerns return figures computed as geometric means (growth rates).

world economy since 2007, and partly by central banks wanting to stimulate economic growth. The Ministry of Finance is of the view that the extraordinary nature of the current situation suggests that one should be cautious about changing the estimates for the expected real return on the Government Pension Fund Global exclusively on the basis of today's low real interest rate levels. The expected real return on the Fund is based on an estimate of 2.5 percent for the mean return on the Fund's portfolio of government bonds and an estimate of 2.5 percent for the stock premium. Other investments are assumed to have a risk profile between those of government bonds and equities, respectively.

The required rate of return for public projects should be determined as an arithmetic mean[11] before tax. The expected long-term return on equities in the Government Pension Fund Global is determined net of corporation tax and represents a geometric mean. It therefore needs to be adjusted to allow comparison with the required rate of return for public projects. If one uses the 2.5 percent expected return on the government bond portfolio as the risk-free benchmark return, one arrives, through the numerical example in the NOU 2009: 16 Green Paper, Box 8.2, at a real risk premium (before tax) of 3.5 percent for an average project funded in the stock market, given the assumptions made in Box 8.2 in the NOU 2009: 16 Green Paper.[12] Alternatively, we could have disregarded an estimated maturity premium in the government bond portfolio and thus applied 2 percent as a risk-free benchmark interest rate, which would have put the relevant risk premium at 4 percent. Both of these approaches suggests that a real required rate of return of 6 percent for projects with about the same systematic risk as an average project funded in the global stock market is consistent with expectations as to the long-term return on the equity portfolio of the Government Pension Fund Global.

If we assume that an ordinary public measure, being a transportation measure, has a risk profile that is somewhat closer to a government bond than to an average project funded via the stock exchange, the calculations above suggest that a risk-adjusted real required rate of return (before tax) of about 4 percent is reasonable. This is indicative of a risk premium of 1.5 percentage points. Using the current recommendations on the direct calculation of risk premiums, as set out in the Ministry of Finance guide from 2005, has turned out to result in a lower risk-adjusted rate than would be suggested by such a reasonableness test.[13]

5.6 Social discount rates in other countries

Discount rate recommendations vary considerably between countries. One review identifies recommendations ranging from 1 to 15 percent (Harrison, 2010). We will present some selected recommendations below. Different countries attach weight to different considerations in their discussion and determination of discount rates. We have chosen to present the recommendations as set out in the documents that have been reviewed.

5.6.1 Recommendations for the EU area

A consortium lead by the German institute IER (University of Stuttgart, Institute of Energy Economics and the Rational Use of Energy) has over the period 2004-2006 prepared, *inter alia*, a proposal for harmonised guidelines for transportation infrastructure investments in Europe through an EU-funded research project called HEATCO (Harmonised European Approaches for Transport Costing and Project Assessment). It does not provide one uniform recommendation on the discount rate for infrastructure projects. It is instead noted that some countries start out from the "social rate of time preference" as expressed through the Ramsey condition, whilst others base themselves on estimates as to the opportunity cost of capital. The recommendation for analyses of cross-border transportation infrastructure investments is to use a risk-free rate or a weighted average of the required rates of returns in the various countries, weighted by the funding contribu-

11 The arithmetic mean, R_A, of the values a_1, a_2 and a_3 er ⅓($a_1 + a_2 + a_3$). The geometric mean, R_G, of the same values is.

$$\sqrt[3]{(a_1 a_2 a_3)}$$

If the values a_1, a_2 and a_3 are not identical, the geometric mean will be lower than the arithmetic mean. If successive return figures are statistically independent and identically distributed with a variance equal to σ^2, we find that $R_G \approx R_A - 0{,}5\sigma^2$. See for example Johnsen (1996) for a more detailed discussion.

12 The assumptions include a volatility relating to the real return on equity investments of 15 percent and normally distributed returns (log-normal equity prices). Further assumptions are an average corporation tax rate abroad of 25 percent and a 50-percent equity portion, as well as a 5-percent borrowing interest rate for enterprises.

13 See for example Dovre Group (2010).

tion of each country. It is not stipulated how the risk-free rate shall be calculated. The use of sensitivity analyses is recommended, applying a rate of 3 percent, which in the guidelines is explained by reference to the Ramsey condition, with p=1.5, μ=1 and g=1.5. For projects in countries that themselves recommend the use of a declining rate path in the long run, the recommendation calls for sensitivity analysis with a declining rate path for effects that occur from year 40 and beyond.

No special guidance is provided as to whether costs or discount rates should be corrected for risk aversion. It is, on the other hand, recommended that risk and uncertainty be highlighted through sensitivity analyses, scenario analyses and/or Monte Carlo simulations, depending on the available resources and data. The treatment of systematic and unsystematic risk is not specifically addressed.

5.6.2 Sweden

There exists no intersectoral national guidance on discount rate choice in Sweden. For the transportation sector, a committee appointed by the Swedish Transport Administration recommends using HEATCO and the recommendations in the United Kingdom (Swedish Transport Administration, 2012) in determining the discount rate. The Ramsey model is used as a starting point (see the above discussion). The pure rate of time preference and the elasticity of marginal utility of consumption are put at the same levels as in the United Kingdom (HM Treasury, 2003) and as referred to in the HEATCO guidelines. Annual economic growth in Sweden is estimated at 1.78 percent. Taken together, this suggests a discount rate of 3.28 percent. Reference is made to arguments in favour of a declining rate over time, but it is noted that the methodological tools used in the cost-benefit analysis of transportation measures in Sweden are not adapted to such a declining rate path. A somewhat lower discount rate than the 4 percent previously recommended is assumed to partially compensate for this. The discount rate was 4 percent until September 2012, but the new guidelines applicable from September 2012 recommend 3.5 percent.

5.6.3 Denmark

The Danish Ministry of Finance (Danish Ministry of Finance, 1999) assumes, on a discretionary basis, that the social return on capital in alternative use will fall within the 6-11 percent range. 6 percent is chosen as the discount rate on the assumption that public investments are likely to involve lower systematic risk than the average project on the stock exchange. It is noted in the Danish guidelines that the chosen level is also held to fall within the likely range of the social rate of time preference.

5.6.4 United Kingdom

In the United Kingdom the discount rate is based on the social rate of time preference and quantified at 3.5 percent in real terms (HM Treasury 2003). The British economic analysis guide, the "Green Book", was revised in 2003. The former discount rate of 6 percent included a risk premium for various risk elements. However, it was concluded during the revision that it was a better solution to address relevant risk specifically for each project through various risk analysis methods. Moreover, the British have prepared separate guidelines on how the authorities may correct, in their calculation of the expected cost and benefit flows, for a tendency to be overly optimistic in assessing projects, the so-called optimism bias, with a view to obtaining more unbiased estimates. The "Green Book" assumes that systematic risk is usually negligible for most individual projects, given their magnitude relative to national income.[14]

Due to uncertainty about the future, the British guide recommends a declining discount rate over time for projects with effects beyond 30 years. Reference is made to Weitzman (1998, 2001) and to an unpublished paper by Christian Gollier from 2002. The guidelines include a table specifying which discount rates shall be applied for effects at various time intervals, with the rate being 3.5 percent until year 30, thereafter 3.0 percent until year 75, and with successive reductions down to 1 percent for effects that occur in year 300 and beyond. It is not specified how one has arrived at the specific recommended rate path.

5.7 The assessment of the Committee

In cost-benefit analysis, it is necessary to compare effects that occur at different points in time. A systematic and transparent way of doing so is discounting by way of a discount rate, with all monetised effects being converted to the value they will

[14] No specific reasons or sources are invoked in this respect in HM Treasury (2003).

have in a given reference year, calculated at such rate, and therefore being comparable. When the reference year comes at the beginning of the lifespan of the measure, this is called a net present value calculation.

It is difficult to arrive at a universally valid answer to the question of what is the "correct" discount rate or how such a rate shall be estimated. However, it is reasonable to start out from the premise that a lower value is attributed to future values than to current values, from a current perspective.

A simple approach is to say that the required rate of return depends on a pure rate of time preference, the elasticity of marginal utility of consumption, which shows relative change in marginal utility divided by relative change in consumption, as well as estimated consumption growth. However, all of these variables are highly uncertain in the long run, and Chapter 5.2.1 notes that different estimates for these key variables have resulted in estimated discount rates that range from 1.4 to 8 percent. The United Kingdom and Sweden recommend a short-term rate of 3.5 percent based on a set of assumptions that are held to be reasonable there.

Likewise, the required rate of return in the financial market reflects the return on private investments, assuming well-functioning markets. Theoretically, the required rate of return for corresponding investments abroad represents the opportunity cost of a public measure, and is consequently the discount rate for a small, open economy. The NOU 1997: 27 Green Paper notes that Norway is a small, open economy, and especially so since the liberalisation of the capital market. Such developments have been reinforced since 1997, which suggests, when taken in isolation, that the arguments from the NOU 1997: 27 Green Paper about using a rate model based on an alternative assessment of the price of capital remain equally valid.

The real risk-adjusted discount rate (before tax) should reflect the risk-free rate and the risk associated with the project, and thus reflect the opportunity cost of the project. From an opportunity cost perspective, it will generally speaking make sense to adjust the discount rate to be applied to each measure on the basis of the systematic risk of such measure. The systematic risk depends on whether the country is performing well or not when the return from the project is expected to materialise. If the economy is performing well, one can expect a lower value to be attributed to the project's contribution to the country's value added. This may be reflected in the analysis by applying a higher discount rate.

However, it is not obvious how such a project-specific risk premium shall be estimated. A correct calculation of the risk associated with individual measures is complex, whilst the availability of data is poor. Experience from such project-specific calculation of the risk premium has shown that calculations like these have only been carried out to a limited extent, and in those cases where they have been carried out the findings are sensitive to modified assumptions and minor changes in the data used. As noted in Chapter 5.5, direct use of the approach in the Ministry of Finance guide from 2005 has also resulted in a lower risk premium than would be indicated by a reasonableness test. Chapter 5.2.4 discusses theoretical weaknesses associated with applying the Capital Asset Pricing Model to estimate the risk premium for public measures. The present Chapter has noted weaknesses in the Capital Asset Pricing Model, both with regard to the identification of the systematic risk in the stock market, and as a basis for estimating the relevant risk premium for a public project. The Committee therefore holds the view that this model does not constitute a good basis for determining the discount rate for public projects.

Theoretical developments, especially in view of the climate debate, have generated much new and interesting analysis of the valuation of effects in the very long run. In summary, we may say that the theory reviewed suggests that the risk-free rate shall be declining over time if the uncertainty pertaining to growth rates in the economy accumulates over time. If such uncertainty does not accumulate, one can nevertheless argue in favour of declining rates over time on the basis of an expected decline in growth rates over time. Hyperbolic discounting is an alternative argument in favour of declining rates. However, there is no corresponding consensus as to how the rate path should *specifically* develop over time, and the discussion in Chapter 5.4.1 shows that different assumptions give rise to different time profiles. There is, at the same time, an ongoing debate about how project-specific systematic risk in the long run affects the economically relevant risk premium. The contribution from Weitzman (2012) notes that one will, for projects with lower systematic risk than the market average, get a rate that declines towards the risk-free rate in the long run.

All in all, the literature reviewed above indicates that increasing uncertainty about the opportunity cost of capital suggests a declining discount rate. The economic reasoning behind this is that it becomes more attractive to realise the project as the uncertainty associated with the alternative market return increases. This results in a lower certainty-equivalent required rate of return, which means a lower discount rate. The literature review in the present Chapter has demonstrated support for the contention that the uncertainty associated with macroeconomic developments - and hence with the alternative return – is increasing in the very long run, beyond the period that can reasonably be hedged in the financial markets. Consequently, this literature suggests that the discount rate, as assessed per the date of analysis, should decline over time. The Committee is of the view, based on an overall assessment, that the discount rate for use in the cost-benefit analysis of public measures should reflect these arguments in favour of a declining discount rate, based on the theory presented in this Chapter, especially for very long-term projects.

When the Committee is to make recommendations on the discount rate for use in the evaluation of public measures, we also need to take into consideration the decision structure within which this will be applied. Considerable room for discretionary assessments with regard to estimates as to project-specific risk, the time structure of the discount rate and the lifespan of the project may offer incentives to choose assumptions that may influence the outcome of the analysis in the direction favoured by various interested parties. In addition, experience from previous practice with several risk classes suggests that many project analysts have been uncertain about the technical criteria for choosing the risk class, and that such choices may therefore at times seem somewhat arbitrary. These circumstances suggest that it may be preferable to recommend simple and transparent rules that capture the most important aspects of the matter, without being too complex to understand or to apply. Simple, but rigid, rules will, on the other hand, necessarily limit the scope of the analyst for taking more specific knowledge about each project into account, for example with regard to systematic risk.

There is no one correct way of providing specific estimates for the risk-free market interest rate, the risk premium and the time profile of interest rate developments. However, a reasonable approach may be to assume that it will, under normal market conditions, be possible to secure a risk-free real interest rate of 2.5 percent within a time span of 40 years through investments in the international financial market. This is on a par with the unconditional expected return on government bonds in the Government Pension Fund Global. Beyond 40 years, it is reasonable to assume that one cannot secure a long-term interest rate in the market, and the discount rate should be determined on the basis of an assessment of the certainty-equivalent rate. A certainty-equivalent discount rate of 2 percent may be in line with reasonable assumptions as to developments in the uncertainty associated with future economic developments.

Furthermore, the discount rate needs to reflect the fact that ordinary public measures, like a transportation measure, will to some extent be sensitive to changes in the general economic situation (systematic risk). The Committee is of the view that the Capital Asset Pricing Model is not a good starting point for determining which risk premium will reflect this in a good manner. In line with the principle that the discount rate shall reflect the opportunity cost of capital, and moreover being a simple and transparent rule, the Committee believes that it is reasonable to look at the expected return on the Government Pension Fund Global, which owns a small portion of the world's production capacity and debt. The estimated expected mean return on government bonds for the Fund's portfolio is 2.5 percent, with a risk premium for equities of 2.5 percent. Chapter 5.5 explains that a required rate of return for an ordinary public measure, like a transportation project, of 4 percent is consistent with these expectations. Table 5.2 outlines a discount rate structure for such an ordinary project on this basis.

It is the recommendation of the Committee that the structure outlined in Table 5.2 normally be used for the discounting of all types of public measures. Consequently, the Committee has decided, based on an overall assessment, not to recommend the establishment of several risk classes with different risk-adjusted discount rates. For measures that quite obviously involve low or negative systematic risk, like for example labour market measures, it will be appropriate to apply a lower discount rate. For measures that quite obviously involve higher systematic risk it will, correspondingly, be appropriate to apply a higher discount rate. If one would otherwise like to conduct a sensitivity analysis to examine how the net benefits from the project will be influenced by other assumptions as to systematic risk, it will be appropriate to do so as a supplement, thus retaining a basic analysis that ensures comparability in the decision-making process. For projects where it is

Table 5.2 Discount rate structure for an ordinary project

	Discount rate		
	Years 0-40	Years 40-75	From year 75 (i.e. largely environmental effects)
-risk-free rate	*2.5 percent*	*2 percent*	*2 percent*
-premium	*1.5 percent*	*1 percent*	*0 percent*
Risk-adjusted rate	4 percent	3 percent	2 percent

primarily the costs that are quantified, the evaluation of sensitivity to business cycle fluctuations must focus on the cost aspect. For commercial public sector operations in direct competition with the private sector it will, however, be appropriate to use a risk premium faced by corresponding private enterprises.

It has not previously been common practice to use a rate that varies over time for cost-benefit analysis purposes. It is therefore worthwhile to make two observations. Firstly, the basis for a declining rate, as presented above, is increasing uncertainty over time. In an assessment situation in which such a declining rate is to be used, it will therefore be appropriate to assume that the rate structure will apply from the *date of analysis*. Secondly, values in the same period shall be discounted at the same discount rate. Assume that a declining discount rate is made operational by applying one rate for the first 40 years and a lower rate for subsequent years. This means than an effect in year 50 shall first be discounted to year 40 by applying the lower rate, and then discounted from there at the more short-term and higher rate. In other words, the value of an effect cannot be changed significantly by moving it from year 40 to year 41, etc.

For the time being, there is an ambition for the pricing of systematic risk to be handled individually for projects that fall within the scope of the central government scheme for quality assurance of concept choice (QA1). Under the current guidelines, this applies to projects with an expected cost in excess of NOK 750 million. The Committee notes, however, that it appears to be more difficult than previously assumed to identify the risk premium that reflects, in a correct manner, the systematic risk associated with individual projects, and, more specifically, that the method recommended thus far, based on the Capital Asset Pricing Model, has weaknesses. This suggests, when taken in isolation, that no requirement for a project-specific risk premium should be applied. Moreover, the Committee holds the view that it would produce a more predictable system if the discount rate is determined in the same way for all public measures, irrespective of whether these fall within the scope of the scheme for external quality assurance of the choice of concept (QA1).

Finally, the Committee highlights the importance of correct valuation of the effects included in the analysis, *before* discounting. The recommendations made by the Committee in the present Report will to a large extent contribute to more correct valuation of the effects in the analysis before discounting, cf. Chapter 4 on real price adjustment and Chapter 9 on carbon pricing. Where the effects of the measure are subject to major uncertainty, considerable weight should be attached to ensuring unbiased estimates and the best possible examination of the uncertainty, preferably through separate sensitivity analyses of such effects. The uncertainty analyses performed in preparing choice of concept reports and QA1 are valuable, *inter alia*, through their contribution to obtaining more unbiased estimates for cost and benefit effects.

5.8 Summary recommendations

- In principle, the real risk-adjusted discount rate should reflect the risk-free interest rate and the risk associated with the project and, consequently, reflect the project's risk adjusted opportunity cost of capital. The discount rate applied in the assessment of public measures should, however, nonetheless be based on simple rules that address the main aspects of the matter.
- For commercial public sector operations in direct competition with the private sector, it will

be appropriate to use a discount rate faced by corresponding private enterprises.

- A real risk-adjusted discount rate of 4 percent will be reasonable for use in the cost-benefit analysis of an ordinary public measure, such as a transportation measure, for effects in the first 40 years from the date of analysis.
- Beyond 40 years, it is reasonable to assume that one will be unable to secure a long-term rate in the market, and the discount rate should accordingly be determined on the basis of a declining certainty-equivalent rate as the interest rate risk is supposed to increase with the time horizon.. A rate of 3 percent is recommended for the years from 40 to 75 years into the future. A discount rate of 2 percent is recommended for subsequent years.

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Chapter 6
Lifespan, analysis period and residual value

6.1 Introduction

From the terms of reference of the Committee:

> The guide published by the Ministry of Finance does not prescribe the analysis period for a measure. The discrepancy between the analysis period and the technical lifespan is in certain sectoral guides dealt with by calculating a residual value as per the end of the analysis period. The Committee shall assess how the analysis period and the residual value should be determined.

A cost-benefit analysis should seek to capture all relevant effects of the measure under consideration. This suggests that if the measure will have effects into the distant future, such effects should also be captured. Cost-benefit analysis tends to focus on the net present value of the effects, such as to ensure the comparability of effects arising at different points in time. A discount rate is used to calculate the net present value, cf. the discussion in Chapter 5. This implies that effects in the distant future are accorded a low net present value, thus being, in relative terms, of minor importance to the overall assessment. At the same time, the uncertainty associated with the effects increases the further into the future these are expected to occur. If the measure under analysis has uncertain effects in the distant future, it may be appropriate to estimate any effects arising after a certain year on a rule-of-thumb basis. Chapter 5 on the discount rate also discusses the evaluation of measures with a particularly long time horizon.

In line with established terminology within the literature on cost-benefit analysis, as a specific method of analysis, we will define the analysis period as the period for which the effects of a project are analysed in detail. If the lifespan is expected to be longer than the analysis period, we may use the term residual value period to designate the remaining time period. The residual value is defined as the economic net present value a project is expected to generate after the expiry of the analysis period, estimated on a rule-of-thumb basis. The sum of the net present value from the analysis period and the residual value should provide the best possible estimate for the overall effects of the measure throughout its entire lifespan. Chart 6.1 illustrates the relationship between the project lifespan, the analysis period and the residual value period.

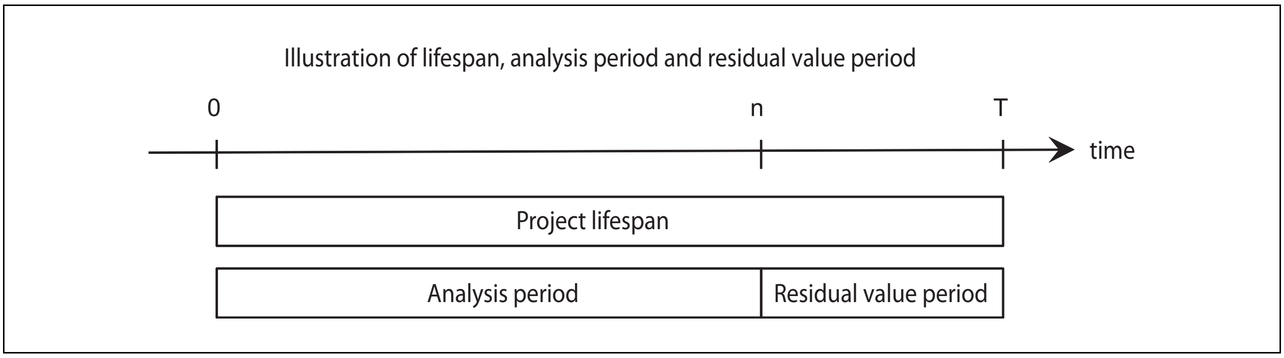

Figure 6.1 Illustration of lifespan, analysis period and residual value period[1]

[1] A cost-benefit analysis should capture effects throughout the entire lifespan of the project. If the lifespan is T years, and precise cost and benefit estimates are only prepared for n years (the analysis period), one should calculate a residual value that captures the estimated net present value for the remaining part of the project's lifespan (the residual value period). Hence, the net present value of the *sum* of the costs and benefits from the analysis period and the residual value represents the estimated net benefits of the project

In the present Chapter, the Committee will start out by discussing the lifespan of a project in Chapter 6.2 and principles for determining the analysis period in Chapter 6.3. Thereafter, we will, in Chapter 9.4, address various methods for estimating a residual value. In Chapter 6.5, we then present the methods recommended in sectoral guides in Norway and in foreign guides. Finally, the assessment of the Committee is presented in Chapter 6.6 and its recommendations in Chapter 6.7.

6.2 Lifespan

The lifespan of a measure may be defined as the period during which the measure under analysis will actually be in use or of service to society. The lifespan of a measure will depend on the specific nature of the project and the sector in question. This may be estimated using different approaches.

One approach is to start out from such lifespan as results in the maximum positive net present value. This may be termed the optimal lifespan of the measure.[1] If one examines an investment involving operational and maintenance costs that increase over time, whilst the benefits do not increase correspondingly, one may find a point where annual costs exceed the annual benefit flow from the project. If the project is economically profitable with such lifespan, this will define the optimal lifespan of the project. However, use of an optimal lifespan in the analysis is conditional upon it being reasonable to expect that the operating period of the facility will in actual fact be determined on the said basis. Such is not always the case with public sector projects. Any significant non-priced effects from the project should also be taken into consideration in evaluating what is the optimal lifespan of the project. The same applies to any significant costs associated with closing down the project at the end of its lifespan. In an international context, such is for example the case when analysing a nuclear power plant. Although the concept of optimal lifespan has its limitations, it may offer a basis for assessing what is an appropriate lifespan for projects within the relevant sector.

A related term is the technical or physical lifespan of an investment. This will be the lifespan of physical elements of the investment until they can no longer be used and will need to be replaced in their entirety. Although this term may seem objective, elements of discretionary assessment will be involved here as well. Operational and maintenance costs must always be expected during an operating phase, and there will not always be a clear distinction between what constitutes maintenance and what should be classified as reinvestment. How high operational and maintenance costs one believes to be reasonable to keep an investment in use will also be a matter of discretionary assessment. For many facilities, different components will have different lifespans, thus in any case requiring reinvestment in such components within the period defined as the overall technical or physical lifespan of the facility.

Some public sector measures do not comprise physical investments, but services and regulations. For such measures it is appropriate to consider how far into the future one expects the measure to have major effects.

If comparing projects with different lifespans that are intended to realise the same social objective, it will not be correct to compare their net present values directly, unless none of the projects can be implemented again in future. One approach is to show the costs and benefits of the various projects within the same time horizon. If one then chooses the project with the longest lifespan as the point of reference, reinvestments need to be taken into consideration for projects with shorter lifespans. In order to make the analysis sufficiently detailed, it is appropriate to include any operational, maintenance and reinvestments costs required to keep the functionality of the measure at a defined and adequate level within the time horizon of the analysis. Another approach, which should in theory give the same answer, is to focus on the annuity of each project, given its expected lifespan and the discount rate used. Such annuity is the fixed annual cash flow that has the same net present value as the project over the project lifespan. Annuities are comparable between projects with different lifespans. If one wishes to rank the projects based on their priced effects, one will rank the projects based on their annuities.

The lifespan of a given investment may often be subject to considerable uncertainty, as the result of uncertainty with regard to developments in demand, trends, technology, etc. This applies, *inter alia*, to ICT projects, for which it is difficult to know with any certainty when the solution becomes outdated and reinvestment becomes necessary. Where this can be expected to be a key issue, one may for example highlight it by making use of sensitivity and scenario analyses.

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1 The discussion of optimal lifespan adheres to the approach in the Danish cost-benefit analysis guide; Danish Ministry of Finance (1999).

6.3 Analysis period

The analysis period is the period for which annual costs and benefits are estimated in detail in the cost-benefit analysis. In order to capture all relevant costs and benefits, the analysis period should as a main rule be identical to the lifespan of the measure.

However, there are some reasons why the analysis period may be shorter than the lifespan of the measure:

- Mounting uncertainty about the magnitude of the effects in the long run, and thus also about the lifespan itself, may suggest that one might want to highlight for what time period one has a reasonably good basis for the precise modelling of effects, and for what time period this would not be particularly meaningful.
- Estimates for key input data may not be available for the entire lifespan of the project (e.g. GDP growth, population growth).
- The resources that would have to be devoted to preparing precise estimates for the distant future are disproportionate to the contribution such estimates would make to the cost-benefit analysis as a basis for making decisions.

If the analysis period is shorter than the lifespan of the measure, the calculation must be supplemented by the economic net present value one expects from the project after the expiry of the analysis period, estimated on a rule-of-thumb basis. Such an economic net present value estimated on a rule-of-thumb basis is defined as the residual value of the project. It is noted in the NOU 1997: 27 Green Paper that such an approach may be justified on two grounds:

> Firstly, one may assume that the effects will from a certain point in time have become stable and remain at the same level in all eternity. In such case it will be simple to arrive at an expression for the residual value of the project and include it on the income side. An alternative reasoning may be that it is conceivable, if the purpose of the analysis is to rank mutually exclusive alternatives, that such ranking based on net present values will not be affected by what happens after a certain point in time. The reason for this can be that effects in the distant future may «disappear» through the discounting. It will in such case be adequate to choose an analysis horizon that ends at that point in time.

If one defines an analysis period that is shorter than the project lifespan, and estimates a residual value, the economic net present value of the project can be expressed as follows:

$$NNV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+k)^t} + \frac{R_{n+1}}{(1+k)^{n+1}}$$

where NPV is the net present value, *B*t is economic income in year *t, C*t is economic cost in year *t* (including any cyclical reinvestment and upgrading costs), *k* is the discount rate, *n* is the number of years in the analysis period and is the residual value measured in year *(n+1)*. Various methods estimating such a residual value are discussed in Chapter 6.4.

6.4 Residual value

The residual value is defined as the economic net present value one expects the project to generate after the expiry of the analysis period, as estimated on a rule-of-thumb basis. In the private sector one can expect a correlation between the market value of invested capital at a given point in time and the income flow one can expect from said capital after such point in time. There is not necessarily any such correlation for public sector projects. Consequently, it is necessary to perform an explicit assessment as to how the residual value can reflect expected future net benefits in the best possible manner.

The following requirements may be stipulated with regard to the calculation of a residual value:

1. The residual value should be capable of being calculated on the basis of readily available information, for example information available from the calculations pertaining to the analysis period.
2. The assumptions underpinning the calculation of the residual value should be readily comprehensible.
3. The residual value should provide the best possible estimate, based on available information, for the total economic net present value expected from the project from the expiry of the analysis period and until the project lifespan has come to an end.

Below, we will discuss alternative approaches for estimating a residual value for a project. The approaches are based on methods that are recommended either in Norway or in other countries.

Market value of capital equipment

As far as concerns used capital equipment for which a market exists, it will be appropriate to use an estimate for the sales price as per the end of the analysis period. In some cases, various circumstances may indicate that the investment is not saleable in practice, i.e. that its real market value is zero. Using market value is a simple method that meets the first two of the above criteria. However, the method will only meet the third criterion if a clear alternative use for the equipment/investment exists as per the end of the analysis period, and there is no significant market failure in the market in which the equipment can be sold. For most types of transportation infrastructure, for example a road, it is obviously difficult to envisage any secondary market, but for much of the materiel acquired by the armed forces, e.g. any weasels that have been procured, it may be more realistic to calculate the residual value on the basis of the market value.[2]

Straight-line depreciation

As far as concern investments for which it is difficult to envisage a secondary market or an alternative use, one will often use an alternative method based on the investment cost. Assume that the project lifespan is estimated to be 40 years, and that the analysis period is put at 25 years. The analyst will then need to estimate the remaining economic net present value; the residual value, of the project for the last 15 years of the project lifespan.

If one assumes that there is a correlation between the project cost and the economic value of the project, one may use an estimate for the residual value of the physical investment as an approximation for the residual economic value of the project. If one assumes that the value of the investment declines on a straight-line basis throughout the entire lifespan of the project, 15/40 of the investment value will remain after year 25. Such value may then be used as the residual value of the project for purposes of the analysis.

This method meets the first two criteria outlined above. The extent of the correlation between project cost and net economic benefit may, however, vary from project to project. There may often be little or no correlation at all. If, on the other hand, such correlation can be assumed to exist, the third criterion will also be met. If one has no reason to believe that such a correlation exists, the method will offer a poor estimate for the actual residual value of the project.

Residual value based on the net benefit flow in the last year of the analysis period

Another method may be to start out from the flow of net benefits generated by the project towards the end of the analysis period. The residual value may then be estimated on the basis thereof.

There may, as noted in the NOU 1997: 27 Green Paper, be cases in which one assumes that the effects of a measure will become stable towards the end of the analysis period, and remain at the same level for all eternity. In such case it will be simple to arrive at an expression for the residual value.

However, the lifespan is defined on the basis of for what length of time the measure under analysis will actually be in use or of service to society. This suggests, if one disregards non-valued elements, that the net benefit will have been reduced to zero in the last year of the lifespan. In such case the residual value may be based on the assumption that the annual flow of net benefits during the residual value period is gradually reduced to zero towards the end of the lifespan. One approach can be to assume that the flow of net benefits declines on a straight-line basis, in which case the residual value A will be defined by

$$A = \frac{NN^* * (T - n)}{2}$$

where NB* is net benefits in the last year of the analysis period, n is the analysis period and T is the lifespan. This is illustrated in Chart 6.2.[3]

This method also meets the first two criteria outlined above. Whether it meets criterion number three depends on whether there is reason to believe that the flow of net benefits in the years from the end of the analysis period until the end of

[2] A cost-benefit analysis may also be expanded by estimating the “scrap value” as per the end of the project lifespan. Such scrap value is fundamentally different from economic residual value discussed above, and will only include such values or claims as might remain in the project when the project is no longer providing any service for society or is no longer in use. It will be appropriate to use the expected market value as per the end of the project lifespan to calculate such “scrap value”.

[3] Assume a lifespan of T years, an analysis period of n years and annual net benefits that are negative during a start-up period, and thereafter remaining stable at a positive level NN* for the remainder of the analysis period. Since the lifespan is defined with reference to when the project is no longer in use or of service to society, the residual value can be calculated as the area A on a rule-of-thumb basis.

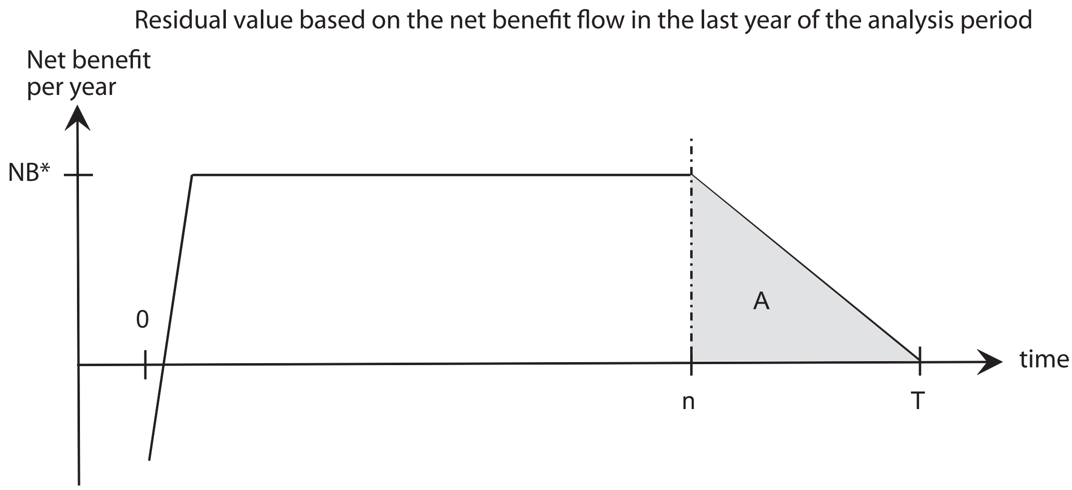

Figure 6.2 Residual value based on the net benefit flow in the last year of the analysis period

the project lifespan is determined by the flow of net benefits in the last year of the analysis period and then gradually reduced to zero towards the end of the lifespan.

One reason why the flow of net benefits in the years from the end of the analysis period until the end of the project lifespan may only to a limited extent be determined by the flow of net benefits in *the last year* of the analysis period could be cyclical changes in the net benefits from the project, for example due to reinvestment costs that recur at intervals of several years. This may be dealt with by adjusting the residual value for any cyclical or other expected variations in the time interval from the end of the analysis period until the end of the project lifespan, caused by for example major upgrading or reinvestment needs.

Scenario analysis

If the analyst believes that well-founded estimates are available for developments in key variables in the years from the end of the analysis period until the end of the project lifespan, one may envisage a model in which cost and benefit flows are extrapolated until the end of the project lifespan, as adjusted for different estimates for the said variables. One may, for example, operate with three scenarios, representing a low, a medium and a high alternative. The net present value of the net benefit flow, calculated for the years from the end of the analysis period until the end of the project lifespan in each scenario, will then represent the residual value of the project for use in the calculation of total estimated net benefits for the relevant scenario. The variation in net benefits between the various scenarios will in such case also illustrate how dependent the net benefits from the project are on developments towards the end of the project lifespan. The ambition should be for the mid scenario to reflect the expected value.

It may be more difficult to perform a scenario analysis in such a way that it meets the first two criteria for a residual value outlined at the beginning of this Chapter. It will be necessary to estimate developments in the key variables over the years after the end of the analysis period. This may require further analyses to supplement those carried out for the analysis period. It may furthermore, in view of mounting uncertainty associated with effects in the distant future, be more difficult to establish clear and unambiguous assumptions on which such estimates can be based. It may, on the other hand, be argued that the information about the net economic benefit from the residual value period, as estimated through a scenario analysis, is more suited for shedding light on the total economic net present value one expects the project to generate from the expiry of the analysis period and until the end of the project lifespan. This will imply improved compliance with the third residual value criterion. Since the approach will not provide one estimate, but several different estimates, for net economic benefits for the entire lifespan of the project, this approach may result in a more complex and equivocal basis for making decisions. It should be supplemented by assessments of the probabilities assigned to the various scenarios. This approach may be of particular relevance in cases where the residual value period is long and the uncertainty is high.

6.5 Current recommendations on analysis period and residual value

At present, the Ministry of Finance guide does not, as noted in the terms of reference, specify the analysis period for a measure. The NOU 1997: 27 Green Paper provides a brief discussion of the issue, as recapitulated in Chapter 6.3 above, but makes no specific recommendations either. Consequently, each sector in Norway has been left to choose its own approach to this issue. A review of recommendations in various sectoral guides in Norway and cost-benefit analysis recommendations in other countries identifies a broad range of approaches to the issues of lifespan, analysis period and residual value, cf. Tables 6.1 and 6.2 below. The tables will not necessarily convey all nuances of the various recommendations, and readers are referred to the sources for additional details.

The Swedish Transport Administration discusses analysis periods and residual values in a draft new cost-benefit analysis guide circulated for consultation (Swedish Transport Administration, 2012). The issues raised in the said draft are to a large extent the same as are addressed by the present Committee, and we will therefore add a brief summary to the observations made in the table below. It follows from Swedish Transport Administration (2012) that Sweden introduced a 40-year analysis period for investments within the transportation sectors with effect from the previous revision of its guide in 2008, whilst prior to that no specific analysis period had been stipulated. The reasons given at the time were the uncertainty associated with estimates for the very distant future, and that this is in line with practice in other countries and the recommendations emanating from the EU project HEATCO. It was recommended that any effects beyond this 40-year period be captured through a residual value. The method recommended for the calculation of residual value in the guide from 2008 was straight-line depreciation, as presented in Chapter 6.4 above. Swedish Transport Administration (2012) maintains the recommendation for a 40-year analysis period, but recommends, for projects with a lifespan in excess of 40 years, that the residual value of net benefits until the end of the project lifespan be estimated on the basis of the net benefit flow from the project in year 40. Swedish Transport Administration (2012) also presents recommendations with regard to economic life for different types of measures and elements, with a maximum economic life of 60 years.

6.6 The assessment of the Committee

A cost-benefit analysis should seek to capture all relevant effects of the measure throughout its lifespan. However, developments in terms of effects, and thus also in terms of lifespan, may be uncertain. It should therefore be the ambition of the sectors that the lifespan used in the analyses reflects the period during which the measures under analysis will actually be in use or of service to society.

However, the further into the future an estimate seeks to reach, the more uncertainty will be associated therewith. There will in many cases be a point beyond which it is no longer meaningful to prepare detailed cost and benefit estimates for use in cost-benefit analysis. Cost and benefit flows should be estimated as precisely as possible until such point in time. This is termed the analysis period. If the expected lifespan of the project exceeds the analysis period, the analysis needs to be supplemented by a residual value that shall provide the best possible representation of the remaining net economic benefit, based on readily available information. If there is considerable uncertainty associated with the lifespan, including whether it does exceed the analysis period, the residual value may be included in the analysis by way of a sensitivity analysis.

The duration of the analysis period is a matter of discretionary assessment. A review of recommendations within the transportation sector in Europe, HEATCO (2006), notes that it has turned out to be very difficult to provide specific estimates more than 40 years into the future. The Swedish Transport Administration has recommended, subsequent to the publication of the HEATCO report, a 40-year analysis period for transportation projects, based on the same reasoning. The transportation sector in Norway has used models with a shorter analysis period than this; 25 years. It is noted by the transportation bodies, in their proposed National Transport Plan 2014-2023, that such practice has been continued for road projects, whilst an analysis period of 75 years has been used for railway projects, with reinvestment costs being included in the analysis (Avinor et al., 2012). The Committee is of the view that it seems reasonable to expand the analysis period of these models, such as to provide

Table 6.1 Recommendations on lifespan, analysis period and residual value in Norwegian sectoral guides

Norwegian sectoral guides	Lifespan	Analysis period[1]	Residual value
Norwegian Public Roads Administration (2006)	Refers to functional lifespan. Lifespan fixed at 40 years, unless otherwise indicated by special circumstances.	25 years.	Straight-line depreciation.
Norwegian National Rail Administration (2011)	Technical lifespan of the facility, or how long the service affected by the measure can be expected to have a market. Technical lifespan for different types of investment specified in the guide. Varies between 30 and 75 years.	25 years; express reasons required for shorter or longer analysis periods.	In principle, the net present value of expected cash flow after the analysis period. Straight-line depreciation is the approach used for the time being.
Norwegian Water Resources and Energy Directorate ("NVE") (2003)	Economic life is the period over which the facility is depreciated for accounting purposes. Physical lifespan is the period during which the facility is expected to perform a function. (Ex. ordinary physical lifespan: hydropower (60 years), gas power and wind power (40 years)).	Normally same as economic life. (Ex. normal analysis period: hydroelectric power (40 years), gas power (25 years) and wind power (20 years)).	Straight-line depreciation.
Statnett (2007)	Discusses lifespan for different types of facility (ex. overhead power line, steel poles (70 years), overhead power line, wood poles (50 years) and control facility (15 year)).	Normally 25 years.	Ideally speaking, the residual value shall express the net present value of having the facility in operation after the expiry of the analysis period, inclusive of necessary reinvestments. Straight-line depreciation used in practice.
Norwegian Armed Forces (2010)	Separate analysis.	Often shorter than lifespan.	Market value.

[1] The specified period length often refers to the operating period only. In such case, a construction phase must be added. If, for example, the construction phase is 5 years and a 25-year analysis period has been specified, effects from a period of 30 years will be included in the detailed cost and benefit estimates.

Table 6.2 Recommendations on lifespan, analysis period and residual value in guides from other countries

Guides from other countries	Lifespan	Analysis period	Residual value
Sweden (Swedish Transport Administration, 2012)	Economic life. (Specific list for different types of measures. Maximum lifespan 60 years.)	40 years.	Continuation of net benefit flow from the last year of the analysis period.
Her Majesty's Treasury (HM Treasury, 2003)	Refers to "useful lifetime of the assets encompassed by the options under consideration".	Should be the same as the lifespan. May deviate if public-private partnership.	Market value. Shall reflect any remaining value upon the expiry of the project lifespan (alternative use, market value or scrap value). Should be tested for sensitivity.
UK Department for Transport (2011)	Most projects: indefinite. Some: finite.	For projects with indefinite lifespan: 60 years. For projects with finite lifespan: appropriate analysis period up to 60 years.	Analysis of projects with indefinite lifespan and 60-year analysis period described, in practice, as the scenario analysis in Chapter 6.4, but with only a mid-alternative being used. Any additional residual value after 60 years not estimated, but may be included in the form of a sensitivity test. For projects with finite lifespan: use the HM Treasury method, cf. the above table row.
EU, HEATCO (2006)	Expected technical lifespan.	Investment period + up to 40 years' operation. If several projects are compared: joint analysis period to end 40 years after the opening of the last project.	Straight-line depreciation. Alternative depreciation may be used if relevant (for example convex function for rolling stock).
Danish Ministry of Finance (1999)	Economically optimal lifespan.	Normally same as economic life or the number of periods for which the service is to be provided. Sufficient length to capture relevant differences between alternatives under assessment.	Market value.

detailed cost and benefit estimates for as much as possible of the project lifespan. However, the Committee agrees with the assessment of HEATCO and the Swedish Transport Administration that estimates into the very distant future will be highly uncertain, as well as with their recommendation that one should not seek to engage in detailed analysis of costs and benefits beyond a certain period. 40 years does, for example, seem a more appropriate analysis period for road projects than the 25 years used thus far. For other projects, both lifespans and analysis periods may be considerably shorter, e.g. in the region of 5-15 years for many ICT projects.

The presentation in Table 6.1 shows that most sectors in Norway use straight-line depreciation of the *investment cost* as a method for calculation of the residual value. Cost-benefit analysis is conducted in a highly uncertain world, and there are good reasons for choosing a simple rule-of-thumb model for effects in the very distant future. The straight-line depreciation method currently used in several sectors is an example of this. The Committee notes, however, that if there is little correlation between economic profitability and the actual prioritisation of projects, there will not necessarily be any close correlation between project investment costs and the net economic benefit generated by such projects when completed. Straight-line depreciation of investment costs does not, for such reason, seem a good calculation method for residual value.

The Committee therefore recommends that transportation bodies and others that currently calculate residual value on the basis of straight-line depreciation change their practice to calculating residual value based on knowledge of the specific cost and benefit flows estimated for the analysis period. One is then left with a choice, in line with the categorisation in Chapter 6.4 above, between estimating residual value on the basis of benefit flows from the last year of the analysis period and a scenario analysis. The reason for adopting an analysis period that may be shorter than the project lifespan is increased uncertainty, lack of estimates for key variables and a trade-off between the resources devoted to, and the benefits from, additional analysis. Since a scenario analysis may require a fair amount of resources, it may be inappropriate to choose scenario analysis as the primary approach. The Committee will therefore recommend that residual value be primarily estimated on the basis of the net benefit flow towards the end of the analysis period. For projects where most effects are valued, it should be assumed that the flow of net benefits approaches zero in the last year of the lifespan. It will therefore be reasonable to use, unless there is specific knowledge to the opposite effect, a calculation based on a gradual decline in net benefits, towards zero, from the end of the analysis period until the end of the lifespan, for such projects, cf. Chart 6.2.

This residual value must be adjusted for known variations, if any, that must be expected during the time interval from the end of the analysis period until the end of the project lifespan. These variations may, for example, relate to cyclical needs for major upgrades or reinvestments, and in such cases it may be more appropriate to focus on the average net benefit flow in the last cyclical period than on the net benefit flow in one single year for purposes of estimating the residual value. The specific approach should be made operational in future cost-benefit analysis guides, with a view to ensuring that the residual value is reasonably simple to estimate. The analysis may be supplemented by a sensitivity and scenario analysis, using different estimates for trend developments in the key drivers behind the cost and benefit flows. If there exist knowledge and documentation, including market value estimates, suggesting that a different method for estimating the residual value of the specific measure in question would be better, the best possible method should be used.

6.7 Summary recommendations

- A cost-benefit analysis should seek to include all relevant effects of the measure throughout its lifespan.
- The lifespan used in the analyses must reflect the period during which the measures under analysis will actually be in use or be of service to society. The lifespan therefore needs to be discussed for each project, or in sectoral guidelines within sectors where a large number of similar projects are implemented. It is appropriate for the approach within each sector to be as uniform as possible to ensure comparability between projects.
- The main principle should be to bring the analysis period as close to the lifespan as practicable. It would, for example, seem more appropriate to apply 40 years as the analysis period for road projects than the 25 years applied until now.

- If the analysis period is shorter than the lifespan of the measures, it will be necessary to calculate a residual value that estimates the total economic net present value the project is expected to generate from the end of the analysis period until the end of the project lifespan.
- Residual value should principally be calculated on the basis of the net benefit flow over the last years of the analysis period. It should be adjusted for any cyclical or other expected variations during the time interval from the end of the analysis period until the end of the project lifespan, for example due to a need for major upgrades or reinvestments. For projects where most effects have been valued, it should be assumed that the flow of net benefits will approach zero in the last year of the lifespan.
- The best possible method should be used in the event of any knowledge and documentation, including any market value estimate, suggesting that a different method for calculating the residual value of the specific measure in question would be better.
- If the residual value period is assumed to be long and the effects (and thus the lifespan) are subject to considerable uncertainty, sensitivity analysis and scenario analysis should be used as supplementary analysis methods to shed light on the importance of particularly uncertain estimates.

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Chapter 7
Net wider impacts of transportation projects

7.1 Introduction

From the terms of reference of the Committee:

> The Committee shall assess how gains from, for example, transportation investments should be dealt with in cost-benefit analysis, including benefits that are currently often not assigned a price tag in cost-benefit analysis, such as productivity effects from increased geographic density, increased labour supply, as well as the interaction between transportation services and land use. The Committee shall assess how the framework may potentially be made more specific when taking into consideration any net contribution from wider impacts of a public transport measure.

A cost-benefit analysis will normally summarise, in monetary terms, the effects for economic agents that are directly affected by a measure. It is therefore appropriate to limit the analysis to effects in the market where the measure is implemented. However, certain projects may have wider impacts of some importance in other markets. If these wider impacts contribute to net value added, and not only represent a redistribution of such value added, one should examine how such effects are to be dealt with in cost-benefit analysis, both as a specific method and in the broader sense attributed to that term in this Report.

A general definition of net wider impacts is provided in Chapter 7.2. Later in the Chapter, however, the Committee will focus, in line with the terms of reference, on wider impacts in the transportation sector. Wider impacts of transportation projects are the subject of ongoing economic research, and the Committee will in this Chapter review current research and discuss the implications for the cost-benefit analysis of transportation projects. The Committee also refers to the general discussion of wider impacts in the NOU 1997: 27 Green Paper.

The Chapter starts out by clarifying some concepts (7.2). This is followed by a presentation of the theoretical (7.3) and empirical (7.4) basis for the analysis of net wider impacts. In Chapter 7.5, we review recommendations from other countries with regard to the treatment of wider impacts in the analysis of transportation projects. Chapter 7.6 provides a brief discussion of other sources of deviations between actual benefits and economic effects as typically estimated. Finally, we present the assessment (7.7) and recommendations (7.8) of the Committee.

7.2 Some concepts

Generally speaking, wider impacts of public projects may be defined as effects in other markets than those directly affected by the measure under analysis. Wider impacts may be both positive and negative. If we use the term primary markets for markets in which the project has direct effects and the term secondary markets for markets in which the project has indirect effects, we may define wider impacts as changes in resource use caused by changes in secondary market equilibria. As far as transportation infrastructure investment is concerned, the transportation markets are the primary markets, whilst the labour market, the property market and the markets for those goods and services that make use of, or are otherwise affected by, transportation services are examples of secondary markets.

Net wider impacts

The Committee will focus the discussion on wider impacts that are of net *economic value* to the country, and we define these as "net wider impacts".[1] These will involve, in line with the definition above, situations in which the changes in the secondary market equilibria have an impact on economic efficiency. Assuming an economy without market failure, it follows from the welfare theorems that all economic effects of a marginal project will be captured by a well-specified ordinary cost-benefit analysis in the primary markets.[2] In order for a wider impact to be of net economic value there must, in other words, be a market failure in the secondary markets that implies under- or overconsumption of resources, relative to the economically optimal resource allocation, in the situation prior to the implementation of the measure.[3] If such under- or overconsumption is affected by the measure under analysis, there is a net wider impact from the said measure that may have economic efficiency implications.[4] This is often termed "wider economic impacts". In the present Report we will stick to the term "net wider impacts". See Chapter 5 of the NOU 1997: 27 Green Paper for a more detailed discussion of various reasons for market failures, as briefly summarised in Box 7.1.

Wider impact or simply redistribution?

One will in many contexts be interested in the wider impacts of a project *locally*. This may for example relate to the impact of a transportation project on a specific area. If these wider impacts in one area are mirrored by corresponding, but reverse, wider impacts elsewhere, such wider impacts represent a pure *redistribution effect*, and not a source of added economic profitability in a cost-benefit analysis context. If goods and services affected by the measure are priced correctly, and there is no market failure in the secondary markets prior to implementation of the measure, effects in other markets will only represent the redistribution of the original effect of the measure, and a well-specified ordinary cost-benefit analysis will capture all relevant economic effects in the primary market. In other words, there will be no net wider impact. If the redistribution effects are considerable, they may nonetheless be of relevance to the assessment of the decision maker, and should therefore be discussed in the analysis if possible; see Chapter 3 on distribution.

Box 7.1 Market failure

Different reasons for market failure are discussed in Chapter 5 of the NOU 1997: 27 Green Paper. The green paper discusses a main finding in economic welfare theory, called the first theorem of welfare economics, to the effect that an economy with free competition in all markets will, under certain assumptions, provide a resource allocation that results in efficient resource use. If the assumptions are not met in any given market we may, generally speaking, conclude that there is market failure in such market. The NOU 1997: 27 Green Paper notes the following causes of market failure:

- Public goods
- Externalities
- Imperfect competition
- Taxation
- Disequilibrium
- Asymmetric access to information.

7.3 Net wider impacts: Theoretical background

The terms of reference identify three categories of benefits that are currently often not assigned a price tag in the cost-benefit analysis of transportation projects: productivity effects from increased geographic density, increased labour supply in the presence of distorting taxes or involuntary unemployment, as well as the interaction between transportation services and land use.

As discussed in Chapter 7.2, one is only faced with a net wider impact if the measure under analysis has an impact on any under- or overconsumption resulting from a market failure. It is therefore necessary to look at what types of market failure may give rise to these potential additional efficiency effects. In the present Chapter, we will

1 The term "wider economic benefits" is used in many contexts within the transportation sector, but no unambiguous meaning has been attributed to the term. One definition of the term is "benefits that are not included in standard cost-benefit analysis within the transportation sector in Norway at present" (Minken, 2011). This encompasses a very wide range of issues, and will depend on how the analyses are carried out in practice at any given time. Most issues concern *direct* effects of a measure, which for various reasons are deemed not to be captured to a sufficient extent or with sufficient precision by market prices.. We have addressed some of these sources of error within the transportation sector in Chapter 4.6. The term may also include effects of transportation projects in other markets that have a net economic effect on the country.

2 This follows from the two main theorems of welfare economics. See e.g. Hagen (2005) for a discussion of these.

3 See for example Jara-Diaz (1986) for a more detailed discussion of this with regard to the transportation sector.

4 The presentation in the remainder of this section is largely based on Minken (2011).

examine how transportation projects in an area with unexploited economies of scale may give rise to productivity effects from increased geographic density (7.3.2), as well as how a transportation project in an economy with distorting taxes may give rise to an efficiency effect from increased labour supply that is not captured by the market agents (7.3.3). Thereafter, we will discuss the extent to which the interaction between land use and transportation measures may entail a net wider impact (7.3.4), as well as the effects of transportation projects in markets with imperfect competition (7.3.5). Finally, we will look at some estimation methods (7.3.6). However, first we will briefly outline, to put the discussion in context, what will already have been captured by a well-specified ordinary cost-benefit analysis in the transportation market. The main purpose of this is to highlight the fact that some effects that may be perceived as wider impacts will in actual fact already have been captured by an ordinary analysis of the transportation market.

7.3.1 What is captured by an ordinary cost-benefit analysis of a transportation project?

It may be useful, before the Committee addresses sources of net wider impacts in detail, to outline more specifically how analyses of the effects of a transportation project are currently conducted. In order to make the presentation as specific as possible, we will look at the Norwegian Public Roads Administration's cost-benefit analysis guidelines (Norwegian Public Roads Administration, 2006). These guidelines describe an approach under which all costs and benefits are distributed across four main stakeholder groups:

- Road users and transport users
- Operators (public transport providers, parking companies, road toll collectors and other private sector stakeholders)
- The public sector
- The rest of society (accidents, noise and air pollution, residual value, tax funding cost).

The economic effect of the measure is the sum of the effects for these four main groups. The effects are valued by using calculation prices. The effects may arise at different points in time, and are measured at net present value in order to make the values comparable. Any transfers between the groups will be zeroed out in the final sum, and one ends up with an expression for the net economic implications of the priced effects of the measure.[5] The non-priced effects are discussed separately.

In order to clarify this approach, let us look at the example of a road project that reduces the travel time between two locations. We assume, for the sake of simplicity, full public funding and no public transport. The costs faced by road users and other transport users when considering whether to travel are termed “generalised travel costs” and include time costs, fuel expenses, tolls, etc. (in addition to costs like bus tickets, ferry tickets, etc., when public transport is included). A transportation project reducing the travel time between two locations will produce an economic benefit effect through reduced generalised travel costs. In addition, lower costs may result in somewhat higher traffic, inasmuch as road users who previously thought, for miscellaneous reasons, that the journey was not worth the cost will now want to take the journey. The overall effect of the transportation measure will depend on the magnitude of the change in travel costs, the number of road users prior to the implementation of the measure and how the road users change their behaviour as the result of the change in costs. If the appropriate calculation prices are used, this will represent the changes in the consumer surplus of users. These benefits on the part of users must be balanced against the direct costs associated with the measure and the valuation of the effects for the rest of society. This latter category includes, for example, the value of the change in the number of expected accidents, the value of emission changes and the economic cost of taxation. Since different effects occur at different points in time, the values are converted into a net present value.

The method described above analyses the effects of a measure through its direct effects in the transportation market and some specific effects for the rest of society; what are termed the primary markets in Chapter 7.2. The effects may over time also be reflected in other markets, i.e. the secondary markets. However, unless one is facing a market failure in the secondary markets that may give rise to net wider impacts, this is only a reallocation of resources – i.e. a redistribution effect, as explained in Chapter 7.2. If one includes both the direct benefits in the transportation market and the effect of such redistribution of benefits between the primary and the secondary markets, one is going to count the same thing twice. This is discussed is more detail in Box 7.2.

[5] The principles behind such gross calculations are presented in more detail in Minken and Samstad (2005).

Box 7.2 Redistribution of benefits under perfect competition

Chart 7.1 provides a schematic representation of the economic benefits from a road project. This pertains to a project that reduces the generalised travel cost for individuals by shortening the distance travelled, thus delivering travel time savings. We analyse the issue in a partial equilibrium model under the assumption of perfect competition.

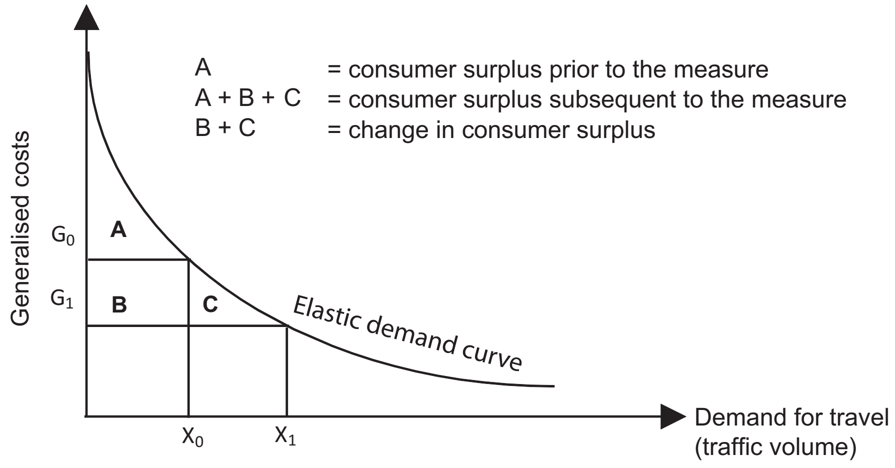

Figure 7.1 The effect of a road project for road users and transport users.

The demand curve indicates the private marginal willingness to pay for the relevant journey. The horizontal axis shows the demand for travel and the vertical axis shows the total cost per journey faced by the road user, including expenses associated with the means of transport and the value of time lost (generalised travel costs).

Source: Norwegian Public Roads Administrations (2006), Handbook 140.

The cost of taking the journey is measured along the vertical axis. The benefit to an individual from taking the journey is reflected by the demand curve, which shows the private marginal willingness to pay. An individual will take a journey if her benefit exceeds the cost she is facing. At travel cost G_0, X_0 journeys will be completed. The project we are analysing will reduce the cost of taking the journey from G_0 to G_1. Those who were already taking the journey prior to the implementation of the project will see a reduction of their travel costs of exactly G_0- G_1. This will result in a higher user surplus on their part. Moreover, some people who did not travel prior to the project will now be taking the journey, since the cost has declined. The number of new journeys is represented by the change from X_0 to X_1. The result will be an overall increase in consumer surplus, represented by the area between the marginal willingness to pay curve and the new travel cost. For the first new traveller, the benefit will be slightly less than (G_0-G_1), whilst the benefit will be just above zero for the last new traveller. The point (G_1, X_1) is the new equilibrium subsequent to the implementation of the project.

We note from such a partial analysis that the change in generalised travel costs reflects an *upper limit* with regard to individual willingness to pay for a transportation project. This implies that, for example, the benefit of improved proximity to one's customers upon the construction of a new bridge will be represented by the decline in generalised travel costs. We note, by reference to Chart 7.1, that it is necessarily the case that a firm's benefit cannot exceed the change in such firm's generalised travel costs resulting from the project. If the benefit had been higher, the trade would have taken place also before the bridge was constructed. The resulting benefit on the part of both the firm and the customers is the reduced generalised travel cost included in an ordinary cost-benefit analysis. If one had included a value attached to improved proximity to customers, in addition to the benefits to road users resulting from reduced generalised travel costs, one would have double counted the benefits.

The reasoning outlined immediately above is equally valid when the effects of a project are reflected in changes to other prices, for example land prices. Assume that the benefits from the above bridge project are mirrored by an exactly matching increase in housing prices on an island that has been linked to the mainland as a result of the new bridge. The overall benefits available for distribution remain unchanged, but will now accrue to island property owners rather than to road users. For cost-benefit analysis purposes, it will in this case be appropriate to calculate the project benefits on the basis of the benefits to road users from reduced generalised travel costs, irrespective of how such benefits are distributed. However, if the distribution effects are deemed to be significant, these may be outlined separately, cf. the discussion of distribution effects in Chapter 3. The interaction between land use and transportation is discussed in Chapter 7.3.4.

7.3.2 Productivity and geographic concentration of economic activity

Sources of increased productivity

Economic geography has provided new and specific insights into which mechanisms influence the interaction between economic activity and the location in which such activity is taking place. It is hardly a new observation that location is of importance to economic behaviour and efficiency. As early as in 1890, Alfred Marshall wrote about the economies of scale existing in towns and cities in his book *Principles of Economics*, as exemplified by the following quote:

When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously.

In addition to such dissemination of knowledge in networks, Marshall noted the advantages of a well-developed labour market and the beneficial effect of good interaction between manufacturers of finished products and their suppliers.

The effects noted by Marshall in 1890 are also the focus of current research into how productivity and employment are affected by geographic density. Such effects of the geographic concentration of economic activity may be termed agglomeration effects or proximity effects. Different theoretical models seek to explain how proximity between agents, most often expressed by a measure of functional town size, may influence productivity. A joint feature of these explanations is that they are predicated on various forms of market failure, which were also highlighted in the NOU 1997: 27 Green Paper as prerequisites for taking into consideration the resource reallocation resulting from a public measure. Special mention is made of various forms of economies of scale that are not fully utilised in towns.

Duranton and Puga (2004) provide an overview of the literature addressing the microeconomic mechanisms that may give rise to such economies of scale. The economic mechanisms that may create a causality between functional town size and productivity include:

- More well-functioning labour markets. Contribute to a better match between the knowledge and skills needed by employers and the knowledge and skills offered by employees.
- Linkages to both upstream and downstream markets. By linkages to upstream markets are meant better-functioning factor markets, whilst linkages to downstream markets are to do with more efficient markets for finished products.
- Dissemination of knowledge in networks. Co-location of enterprises in so-called clusters may contribute to enhanced productivity within the region.

Duranton and Puga (2004) believe the literature within the field to be sufficiently mature to allow a few general conclusions to be drawn. They note, *inter alia*, that a positive correlation between functional town size and productivity is consistent with a wide range of microeconomic models. This suggests that such a correlation is theoretically robust. It is, at the same time, difficult to empirically identify which specific mechanism produces the observed outcome.

Implications for cost-benefit analysis

Venables (2007) discusses cost-benefit analysis in a situation where a correlation between functional town size and productivity is assumed to exist. He notes that if an infrastructure investment in a town results in more employees being able to commute into town, the implication is a functional enlargement of that town. This will, according to the correlation presumed in theory, result in enhanced productivity, not only for the new arrivals, *but for all employees in town*. The value of the productivity enhancement will be additional to the sum total of changes in travel costs on the part of those travelling on the affected route. This represents a positive net wider impact of the transportation measure. The interaction with distorting taxes is also noted. This is discussed in more detail in Chapter 7.3.3.

There are three limitations to the above arguments, according to Venables (2007). Firstly, the reasoning applies to commuter journeys only, and such effects will, in a cost-benefit analysis that also includes leisure journeys, need to be weighted by the portion accounted for by commuter journeys. Secondly, the analysis has failed to examine the relationship between transportation improvements and negative externalities from increased crowding and queuing. Such effects will be the reverse of positive wider impacts. Thirdly, the model assumes that productivity outside the town remains unchanged despite labour being relocated to the town, which assumption is not necessarily correct. Caution is urged when it comes to making direct use of the findings to render policy recommendations, but one of the benefits of infrastructure investments in town may be overlooked by disregarding said findings.

7.3.3 Labour supply increase in the presence of distorting taxes

A tax on income implies that individuals make decisions based on their wages after tax, whilst the value of their production to society is its economic value, which in a well-functioning market will be reflected in wages before tax. This is a market failure with implications for the evaluation of transportation projects.

Reduced travel time may result in expanded leisure hours, expanded working hours or a combination of the two. It is conceivable that more people will enter the labour market when travel costs have declined. If a transportation project results in increased labour supply, it will be accompanied by higher production and more value added.

Part of the value associated with increased labour supply is captured in a well-specified ordinary cost-benefit analysis of the transportation market. Since the transport users who increase their labour supply will make their decisions on the basis of wages after tax resulting from such increased labour supply, this effect will be captured as the change in the consumer surplus of the transport users.

However, the value of the production increase resulting from the expanded labour supply is equal to wages *before tax*. In order for the entire value of expanded labour supply to be included in the analysis, one needs to add such part of the value of the production increase as is not captured by an ordinary cost-benefit analysis of the transportation market. Such additional element corresponds to the difference between the economic value of increasing production by one additional hour of work and the value received by individuals if they work for one additional hour. In practice, such difference is equal to the additional tax revenues resulting from the change in labour supply. This constitutes a net wider impact. See Box 7.2 for a graphic representation of this effect.

It is an empirical question whether transportation projects result in a net increase in labour supply, by more people entering the labour market or by people working longer hours, and we will revert to this in Chapter 7.4.

Venables (2007) also looks at how this labour market effect interacts with the productivity increase resulting from increased functional town size, cf. Chapter 7.3.2. In his model, the combination of lower generalised travel costs and enhanced productivity in town will result in more people choosing to work in town rather than in the surrounding rural areas. Individuals will choose to commute into town as long as the wage difference exceeds generalised travel costs. However, employees will make their decisions based on wages after tax, and not on the economic value of production, which is measured by wages before tax. Hence, the additional tax income resulting from employees choosing to commute into town to get more productive jobs reflects a production increase that would not have occurred otherwise. This pertains to the *change* in tax revenues from those employees who choose to commute into town as a result of the measure. The model in Venables (2007) assumes that labour supply in the country is fixed. However, higher wages in town may give rise to a countrywide increase in labour supply, and not only to a reallocation of labour from less productive jobs outside town. An analysis of overall increases in labour supply must, because of distorting taxes, take into account the fact that individuals make their decisions on the basis of the wage after tax, whilst the value of their production is its economic value. In a well-functioning market, the latter is reflected in the wage before tax.

7.3.4 Land use and transportation

A transportation project may result in price changes in the property market. This will, generally speaking, only represent a redistribution of the original direct benefits from the measure, as captured by the benefit to road users in a well-specified ordinary cost-benefit analysis. Hence, including both effects in the analysis would amount to double counting.

If a measure releases an area that was previously used for transportation, and such area has a positive scarcity value, its value in its best alternative use should in principle be included on the benefit side of the project. This is discussed by Minken (2011). It is there argued that this represents a real economic effect that is not captured in the direct user benefits from the project. It is emphasised that in order for such effect to merit inclusion in the analysis, the probability of such area being entered into use must be high, e.g. through serious expressions of interest. Minken (2011) notes that methods for such valuation are

Box 7.3 Economic value of increased labour supply

The tax wedge implies that if reduced travel costs result in increased labour supply, there will be an additional effect that is not captured by an ordinary analysis of the transportation market. This is illustrated in Chart 7.2.

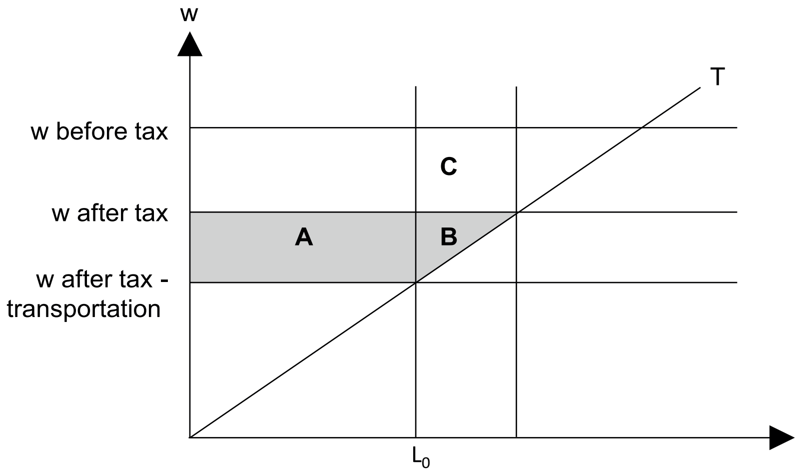

Figure 7.2 Economic effect of increased labour supply in an economy with a tax on income.

Chart 7.2 presents the difference between the economic effect of increased employment and such part thereof as will be captured by an ordinary cost-benefit analysis. The number of people in employment (*L*) is represented by the horizontal axis, and the wage (*w*) by the vertical axis. We assume that the supply of labour (*T*) is an increasing function of wage. This function represents the value of the leisure that must be forgone in order to participate in working life. In order to keep the illustration simple, we disregard the fact that wages can be expected to be a declining function of the number of people in employment, and assume that the wage curves are horizontal.

In deciding whether to participate in working life, an individual makes a trade-off between what she earns by working and the value of the leisure time she must forego when working. If the wage after tax, net of commuting costs, exceeds the value of leisure time, she will work. If the wage after tax, net of transportation costs, is less than the value of leisure time, she will not work. To begin with, labour supply will be L_0, given the wage after tax, net of transportation costs. If we implement a project that eliminates the transportation cost, the labour income of individuals will increase by the amount of the eliminated transportation cost. The new labour supply is L_1.

What is the economic effect of the transportation measure? The disposable income of those who were already participating in the labour market will be higher after the elimination of the transportation costs. This is represented by area *A* in Chart 7.2. Moreover, the increase in labour supply, either by those who participated in working life increasing the number of hours worked or by new people entering the labour market, will benefit the employees involved, inasmuch as what they earn from work exceeds their value of leisure. This is represented by areas *A* and *B* in Chart 7.2. These effects will be captured by an ordinary cost-benefit analysis. However, the value of the production generated by the increase in labour supply corresponds to the wage before tax. The difference between the economic value of increased employment and the value reflected in individual decisions is represented by area *C* in Chart 7.2. This corresponds to the value of the increase in tax revenues resulting from increased employment, and represents a net wider impact of increased employment in an economy with a tax on labour income.

available in Sweden[6], although these should not be used indiscriminately.

Another key aspect of the interaction between land use and transportation measures is how increased geographic density may entail enhanced productivity, cf. the discussion in Chapter 7.3.2. If one envisages that a transportation project will increase productivity in an urban area through the mechanisms discussed in Chapter 7.3.2, one may also be faced with a situation in which the value of enhanced productivity triggers higher property prices in the urban area. However, if one has sought to estimate the value of enhanced productivity directly, it would amount to double counting if one were to include the effect of the property market price changes in addition thereto.

If the *de facto* rationale behind a transportation measure under analysis is, for example, that it offers new urban development opportunities, such measure should be evaluated from that perspective in a cost-benefit analysis. It would be appropriate for the said analysis to examine which land use opportunities the measure will facilitate in both the short and the long run, and the potential economic effects resulting therefrom. In such case, economic effects in the transportation market will be only one aspect of the analysis. A recent example of an urban development project is the rearrangement of the traffic system at Bjørvika in Oslo, which project involved, *inter alia*, redirecting traffic underground. The net economic benefit estimate was here restricted to the actual road project only, which benefit was estimated at NOK -2.9 billion in the proposition submitted to the Storting in 2005, based on the priced factors. The expected cost of the project was about NOK 3.9 billion at 2005 prices. It was emphasised in the funding proposition to the Storting (Proposition No. 50 (2004-2005) to the Storting) that the benefits from the project's facilitation of urban development were not included in the net economic benefit estimates. One may say that the Storting, by giving the go-ahead for the Bjørvika road construction project, valued the non-priced factors as more than compensating for the negative net benefits estimated from the priced factors.

7.3.5 Imperfect competition

Imperfect competition in the markets that make use of transportation services may also be a source of net wider impacts. Firstly, improved transportation may increase competition between enterprises, which may narrow the gap between prices and opportunity costs. High transportation costs can be a main cause of geographic division in some markets, thus resulting in a large number of small, local markets. To the extent that a measure does actually have an impact on competition, the resulting economic effect will not be captured by ordinary cost-benefit analysis.

Secondly, there is scope for net wider impacts of increased production in markets with imperfect competition even in the absence of competition improvements. This is discussed in, *inter alia*, a report from the UK Department for Transport; SACTRA (1999). Its approach parallels the one discussed in Chapter 7.3.3, and focuses on effects of the under-consumption of resources as the result of market failure or distorting taxes.

Let us look at a firm operating in a market characterised by imperfect competition, which firm may therefore charge a price in excess of marginal cost. Assume also that the said firm is facing transportation costs that vary in proportion with its production level, thus implying constant marginal costs. In Chart 7.3, this is illustrated by a monopolist, and the profit-maximising price and output of the monopolist is given by the point P_m, Q_m. If a transportation project results in lower transportation costs for the firm, this will, all else being equal, mean lower marginal costs for the firm, illustrated by a shift in the marginal cost curve from *MC1* to *MC2*. The firm responds to the lower production costs by reducing its price and increasing its production to P_2, Q_2. The area *A+B* corresponds to the benefits captured as the value of reduced generalised travel costs for the business sector in an ordinary cost-benefit analysis. We note from Chart 4.3 that, since the firm is able to charge a price in excess of marginal costs, consumers' willingness to pay for one additional unit (as illustrated by the demand curve) exceeds the cost of producing such unit (the marginal cost curve). When production is expanded, this results in an efficiency benefit that is additional to that captured by an ordinary cost-benefit analysis. Such additional efficiency benefit is illustrated by the area *C+D+E* in Chart 7.3. This efficiency benefit is not captured by the firm and represents net wider impacts of expanded production in markets with imperfect competition.

[6] Specific reference is made to Chapters 17 and 18 of SIKA (2008), *Economic Principles and Estimates for the Transportation Sector: ASEK 4*. Swedish Institute for Transport and Communications Analysis.

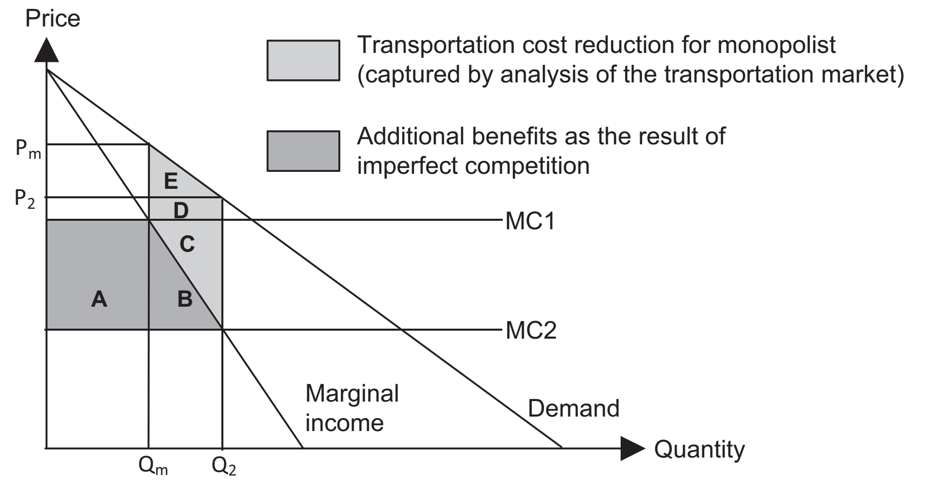

Figure 7.3 Efficiency benefits in markets with imperfect competition.

7.3.6 Estimation methods

The transportation sector in Norway has commissioned two reports that discuss the sources of net wider impacts (Heldal et al., 2009, COWI, 2012). The reports also outline potential methods for estimating net wider impacts, but emphasise the need for further improvement of estimation models, as well as the need for empirical studies and basic data for purposes of making actual calculations operational. The reports present some case studies highlighting the abovementioned need.

In principle, a study of a transportation project in a general equilibrium model will be an alternative to a partial cost-benefit analysis in which one seeks to take net wider impacts in other markets into account. If the general equilibrium model does comprise various forms of market failure, it may be able to capture any net wider impacts. Consequently, spillover effects between sectors through market interactions may result in government intervention and market failure in other parts of the economy than those where the measures are implemented having an impact on their economic costs and benefits (Fæhn, 2010).[7] Work has been conducted to expand general equilibrium models by adding realistic transportation networks. These are generally termed Spatially Computable General Equilibrium (SCGE) models. Hansen (2011) refers to a number of operational models of this type in other countries than Norway that can be used to estimate net wider impacts of transportation projects.[8] However, the level of detail required to model a complex transportation market within such SCGE models may make it difficult to identify the various effects in each market. On the other hand, not including sufficient details about the transportation system in the model may result in the model being unable to capture the relatively minor changes to the transportation system represented by many individual projects (Minken, 2011).

7.4 Empirical analyses

The NOU 1997: 27 Green Paper concluded, *inter alia*, that strict requirements must be met by the empirical basis in order for a cost-benefit analysis to capture net wider impacts. It was noted that improved underlying data, enhancement of econometric methods, etc., may over time enable the documentation of wider impacts in areas where such effects were difficult to identify at the time of the green paper, and that such might be the case within the transportation sector.

7 The general equilibrium model, MSG6 (Heide et al., 2004), models market failure as monopolistic competition in the domestic market for a number of goods, as well as direct and indirect taxation that gives rise to a discrepancy between the economic and the private returns on resources. Estimates from this model will therefore take several net wider impacts of a public project/measure into account. MSG6 does not model any detailed transportation network.

8 At present, Norway has a general equilibrium model that models the geographic distribution of activity; PINGO. However, this model assumes well-functioning markets, and consequently *cannot* be used to estimate potential net wider impacts (Hansen, 2011).

A considerable number of empirical studies of wider impacts have been conducted since 1997. Expanded data availability, enhancement of econometric methods and, not least, the possibility of processing large data sets quickly and cheaply by using more powerful computers, have paved the way for several interesting studies. Most of the relevant studies have been carried out outside Norway, and are reviewed in Chapter 7.4.1. Studies based on Norwegian data are reviewed in Chapter 7.4.2.

7.4.1 Studies of net wider impacts of transportation projects outside Norway

Productivity and economies of scale

The effects of larger functional town size on productivity within an area have been addressed by a number of studies. These studies typically seek to estimate by how many percent productivity in a town increases if actual town size is increased by one percent (the elasticity of productivity with respect to a measure of functional town size).

Melo et al. (2009) conclude, in a comprehensive review of available empirical research within the area, that the findings exhibit major variations.[9] The study shows that estimates vary widely depending on sector, country and how functional town size is measured. Besides, there are variations in the different methodological choices made in these studies. The mean elasticity reported by Melo et al. (2009) is 0.058. This suggests that if functional town size increases by one percent, productivity in such town will increase by 0.058 percent. Most of the elasticities fall within a range from -0.090 to 0.292.[10] The lowest elasticity identified by Melo et al. (2009) is -0.8, i.e. a negative correlation between town size and productivity, and the highest is 0.658, which shows that the estimates are widely dispersed. The mean elasticities reported in studies also vary between countries. The largest number of estimates is from the United Kingdom, where the mean elasticity is 0.102. A mean of -0.038 is reported for Europe as a region, whilst 0.039 is reported for France and 0.017 for Sweden. There are also considerable variations between sectors. The authors find a mean elasticity of 0.040 for the manufacturing sector, whilst the mean elasticity for services is 0.148. The article does not include any studies using Norwegian data.

Melo et al. (2009) conclude that the correlation between productivity and functional town size should be evaluated in the specific context in which the estimate is to be used. They take the view that there is no reason to expect elasticities to be the same across sectors, towns or countries.

The findings of Melo et al. (2009) are in line with a number of other studies within this field. Vickerman (2010) notes, for example, that such empirical studies will typically find elasticities ranging from 0.01 to 0.1, and highlight variations between sectors and regions. Furthermore, a more recent study of OECD countries (Égert et al., 2009) finds major variations in both the direction and the magnitude of the correlations identified between transportation investments and productivity, concluding that the effects are country-specific and depend on, *inter alia*, the level of infrastructure development in a country.[11] Graham et al. (2009) also find major variations between sectors in a study based on UK data, with an elasticity for manufacturing of 0.021, construction of 0.034, consumer services of 0.024 and producer services of 0.083.

There are also studies showing that the effects of proximity decline quite rapidly with distance. The question is how close different locations with economic activity need to be in order for economic activity in one location to influence such activity in the other location. Graham et al. (2009) has examined how rapidly the effect declines. Based on UK data, they find, for example, that the effect of the employment level in one area on productivity in another area declines by more than the inverse of the distance.[12] This implies that the effect from employment 10 kilometres away from the town centre is less than 1/10th of the effect from employment one kilometre away from the town centre. They have also distinguished between effects from economic activity on the basis of selected distance intervals, and find that correlations are positive and statistically signifi-

9 The study takes the form of an econometric meta analysis of 729 wider impact estimates obtained from 34 different studies.

10 These figures represent the 5th and 95th percentile, respectively, of the sample.

11 Crafts (2009) notes that Egert et al. (2009) find significant productivity effects from road and railway investments in the United Kingdom. This is interesting in view of the fact that the UK Department for Transport has promoted the inclusion of measures of such wider impacts in the analysis of major projects in urban areas, cf. guidance on this theme circulated for consultation (UK Department for Transport, 2009a and 2009b). As far as Norway is concerned, no unambiguous statistically significant correlation is identified in Egert et al. (2009).

cant between 0 and 25 kilometres, and then declining in the 25-to-50 kilometre interval. No statistically significant correlation between proximity and productivity is identified for distances in excess of 50 kilometres.

A review of the literature relating to agglomeration and public transport (Chatman and Noland, 2011) concludes that it is uncertain whether, and in which cases, public transport improvement may entail enhanced productivity as the result of efficient urban concentration. The review notes that very few studies have specifically addressed the effect of public transport.

There are methodological problems associated with identifying the effect of increased functional town size on productivity. It is noted that it is difficult to know whether enhanced productivity is caused by improved accessibility within an area, or whether it is the case that authorities and other stakeholders improve accessibility within an area characterised by productivity enhancement (see e.g. Vickerman, 2010). Furthermore, it is noted that the way in which a study is designed has a major impact on the elasticity estimates (Melo et al., 2009). Chatman and Noland (2011) note that it is not sufficient to identify a correlation between agglomeration and productivity, as many studies have done. What is relevant is the correlation between transport and agglomeration and, thereafter, how transportation-generated agglomeration influences productivity. It is noted that no empirical studies have examined such chain of causality. Chatman and Noland (2011) also note the need for examining any agglomeration effects in the context of the effects from any reduction in the density of economic activity elsewhere, since such a net effect is the relevant parameter at the national level. Graham and van Dender (2010) emphasise that even large projects have little impact on the overall functional town size of a given town, and argue that traditional approaches to estimating wider impacts are not paying sufficient heed to this. In addition to the methodological problems mentioned above, the correlation between productivity and functional town size is not necessarily linear. Graham and van Dender (2010) show that elasticity estimates vary with how geographically concentrated economic activity is to begin with, and that no correlation can be identified for certain segments. They therefore conclude that it is not possible to distinguish the effect of functional town size on productivity from other potential explanations[13]. It is noted that one direct implication for the cost-benefit analysis of transportation projects is that it would be highly misleading to use simple point estimates to represent wider impacts in such an analysis.

Employment

A number of studies carried out at macro level have also examined the correlation between road capital and employment. Vickerman (2008) notes that no systematic positive correlation has been found between employment and infrastructure, especially when distinguishing between different road types. It is also noted that what might at first glance seem to be a positive correlation may reflect methodological errors in the statistical analysis. One such example is Jiwattanakulpaisarn et al. (2009), which analyses the effect of varying freeway network densities in different counties in the US state of North Carolina. By looking at the relationship between freeway network densities and employment, they found a positive correlation, but when taking into account that the causality might be the reverse, and that employment in one period might be determined by employment in the previous period, they no longer found any such correlation.[14]

Imperfect competition

The UK Department for Transport (2005) discusses potential effects of transportation projects under imperfect competition. It is noted that there

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12 Graham et al. (2009) define efficient density in a location as. $A_i = \sum_{j=1 \neq i}^{n} d_{ij}^{-\alpha} z_j$.
In this equation d is a measure of the distance between location i and location j, whilst z_j is employment in location j, and a is the parameter indicating how rapidly effective density declines with distance. If $a = 1$, effective density is reduced by the inverse of the distance. Graham et al. (2009) have estimated that the mean value a is 1.65, and that it varies between different industries (1.1 for manufacturing, 1.5 for construction, 1.8 for consumer services and 1.7 for producer services). In a consultation paper, UK transportation authorities recommend that these values be used in calculations of wider impacts (Department for Transport, 2012b).

13 The findings suggest that the correlation between productivity and density is non-linear and that no positive correlation exists between productivity and density for a wide range of density measures.

14 In their study, the researchers used different econometric methods to examine correlations. They studied freeway densities and employment in 100 counties in North Carolina from 1985-1997, and controlled for other relevant variables that might explain employment. When taking into account the endogeneity of freeway investments and dynamic effects they found no statistically significant correlation between employment and freeway density.

is limited empirical material analysing the correlation between transportation investment and the degree of competition in the economy. One approach taken is to examine the competition implications of changes in barriers to trade; it is estimated, according to the Department for Transport (2005), that a five percentage-point reduction in the average rate of customs duties will result in a 4.5 percentage-point reduction in mark-ups in the economy as a whole. Assuming that transportation costs represent five to seven percent of the overall costs of firms, this finding suggests that a 70 to 100 percent reduction in transportation costs is needed in order for a transportation measure to have a corresponding impact on competition. In practice, transportation measures will have much less of an effect on transportation costs than do barriers to trade. It is concluded, on this basis, that one cannot normally expect a transportation project to have any net wider impacts as the result of enhanced competition.

Attempts have been made at quantifying net wider impacts resulting from increased production in markets characterised by imperfect competition. Under certain assumptions, the net wider impact resulting from increased production under imperfect competition may be captured by applying an "uprate factor" to the value of reduced generalised travel costs to the business sector in an ordinary cost-benefit analysis (Department for Transport, 2005). The magnitude of this "uprate factor" will depend on the size of the gap between price and marginal cost, as well as the elasticity of demand in the affected secondary market. If the gap between price and marginal cost is large and demand is elastic, this effect may be of importance. If the gap between price and marginal cost is small and demand is inelastic, the effect may be less important. It is emphasised that such a method of calculation can only be a rough approximation.[15] Based on studies of the average gap between price and marginal cost, as well as the mean elasticity of demand in the UK economy, the Department for Transport (2005) concludes that one will capture net wider impacts resulting from increased production under imperfect competition in the United Kingdom by adding 10 percent to the commercial transportation benefits in a cost-benefit analysis. It is noted that the simplification is only valid if the net wider impacts resulting from imperfect competition are the same for all sectors and the transportation project has the same impact on all sectors.

Other studies

The issue of whether infrastructure development stimulates increased value added has been analysed earlier. Aschauer (1989) compared production and productivity with infrastructure investment levels over time and in different regions of the United States. He noted a positive correlation. The NOU 1997: 27 Green Paper identified methodological weaknesses in the approach, as also emphasised by Vickerman (2010). He notes that doubt as to the direction of the causalities, in particular, means that the method used by Aschauer (1989) now inspires little confidence, and that the said approach is especially problematic as a basis for cost-benefit analysis. The studies also disregard the fact that economic agents may adapt to different transportation cost levels by changing their investments in homes and activities, or through expanding into new markets for finished products and inputs.

Some studies also look at behavioural changes at the micro level caused by transportation projects. As an example, Gibbons and Machin (2005) identify, according to Vickerman (2010), a systematic correlation between housing price increases and station access improvements on a new underground line in London (Jubilee Line). Such geographic rearrangement of activity as the result of an infrastructure investment is not a net wider impact in itself, but may give rise to the type of cluster effects and labour market effects discussed in Chapter 7.3.2.

A number of studies have also been conducted on the effect of the French high-speed trains. In summary, Vickerman (2010) notes, in a review of such studies, that the establishment of high-speed trains has resulted in increased traffic between the towns involved, whilst the overall economic effect is much more unclear. It is noted, as a general observation, that the establishment of the high-speed train links between Paris and surrounding towns cannot be said to have resulted in any net redistribution of economic activity between Paris and towns in its vicinity, or to have influenced overall economic growth in these towns. However, it is noted that the establishment of high-speed trains seems to have contributed to centralising economic activity around the cities located along the train routes.

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15 See Department for Transport (2005), paragraphs 191 – 225, for a complete presentation of the reasoning.

7.4.2 Studies on Norwegian data

Productivity, economies of scale and employment

Studies based on Norwegian data identify no general correlation between road investment and productivity. A macro study based on national accounts data for the period 1963 to 1997 did not, for example, generate findings that supported a hypothesis to the effect that infrastructure investments have improved productivity in Norway.[16] Nor does a new study, based on data specified by county from 1997-2005, find any statistically significant correlation between road investments and productivity (Eriksen and Jean-Hansen, 2008). The authors are of the view that the outcome may be caused by statistical problems, but also by the fact that transportation projects in Norway have only to a limited extent been given priority on the basis of their economic profitability.[17] Nor did Egert et al. (2009), which analysed the correlation between productivity and infrastructure in OECD countries, find any statistically significant correlation between road/railway investment and productivity in Norway.

Another study of 102 major road projects in Norway that were completed during the 1993-2005 period, finds a positive and statistically significant correlation between investment and population growth, but finds no statistically significant impact on employment, income level, commuting or industrial areas (Lian and Rønnevik, 2010).

The importance of road links between islands and the mainland in stimulating the local business sector is often highlighted in Norway. As a main rule, these effects will represent a redistribution of the regular first-order effects resulting from reduced generalised travel costs, cf. the discussion at the beginning of this Chapter. The Committee has not identified any studies uncovering any wider impacts beyond this, i.e. any net wider impacts. A qualitative study of four firms located in the vicinity of two fjord crossings (links between Giske and Ålesund and between Bergen and Askøy) was unable to identify any additional effect for the business sector in these areas, as the result of improved proximity between business networks (Bråthen, 2000).

The Committee is not aware of any detailed econometric studies of the correlation between town size and productivity on Norwegian data. In a report from 2011, Heum et al.[18] note, *inter alia*, that wage levels in some labour market regions, where regions are defined on a discretionary basis, are higher than in the rest of the country. However, the study is not an empirical study of any causality between geographic economic density and productivity in Norway. Consequently, the findings must be understood as providing an indication as to the hypothetical implications of such a correlation, provided that the assumptions in the said report are in fact met.

Imperfect competition

Klette (1994) found, in a study of imperfect competition in Norway, that the average gap between price and marginal cost within the manufacturing sector in Norway over the period 1980-1990 was five to ten percent. The study found relatively large variations between enterprises within the same industry. This finding indicates that one can only expect fairly minor welfare effects from policy aimed at enhancing competition. Furthermore, he found that no industries were encountering economies of scale.

7.4.3 Empirical evidence - summary

Many studies have been conducted on the correlation between functional town size and productivity. These are of relevance to transportation analysis, since urban transportation projects can be said to increase functional town size by reducing travel time. Most of the studies that have been carried out find a weak positive correlation. However, the consensus within the literature is that there is no uniform correlation across sectors, towns and countries. This implies, *inter alia*, that the local industrial structure is of major importance in determining which net wider impacts can be expected from a measure. It is also noted that the correlation between productivity and functional town size is not necessarily stable within the same town and sector. Consequently, it will not be correct to use one point estimate to represent the correlation between town size and productivity for cost-benefit analysis purposes.

It is also difficult to distinguish the impact of functional town size on productivity from that of other potential explanatory variables. In practice, this means that a correlation attributed to func-

[16] Eriksen and Christensen (2001), as reported in Eriksen and Jean-Hansen (2008).

[17] Odeck (1996) and Fridstrøm and Elvik (1997) are studies indicating that transportation investments in Norway are only to a limited extent accorded priority on the basis of economic profitability.

[18] Only a summary of the report is available as per the date of the drafting of the present Green Paper.

tional town size in the studies may in actual fact have other, unknown causes. This indicates that one should be cautious about making use of estimates to represent such correlation without having clarified these methodological problems.

The vast majority of the studies have been carried out on UK data, and the correlation found appears to be stronger in the United Kingdom than in other countries. The cause of this is unclear. The Committee is not aware of any studies of such correlation on Norwegian data, but findings from Sweden show a weaker correlation than in the United Kingdom.

Studies on Norwegian data have examined the correlation between road investment and productivity, without specifically addressing functional town size. These studies find no general correlation between road investment and productivity.

A number of studies have also focused on the correlation between road capital and employment at the macro level. There is nothing in the literature to support a general systematic positive correlation between employment and infrastructure. Nor do empirical findings merit a conclusion to the effect that transportation projects will increase competition.

7.5 Recommendations in other countries

Only a small number of countries recommend the inclusion of estimates for net wider impacts in their cost-benefit analysis guides. The United Kingdom stands out by having developed a specific template for such calculations, for purposes of supplementing ordinary cost-benefit analysis. In Japan, the Netherlands, Germany and France, estimates for net wider impacts have been prepared in relation to a select group of very large projects.[19]

7.5.1 The United Kingdom

Her Majesty's Treasury recommends, in its general cost-benefit analysis guide (HM Treasury, 2003), examining both the direct effects of a measure and the potential wider impacts of such measure on other parts of the economy. It is noted that such wider impacts need to be clearly described and carefully assessed, since both benefits and costs may be involved.[20] The UK Department for Transport recommends, in its guidance materials (Department for Transport, 2012a and 2012b), that the calculation of any net wider impacts should be kept separate from the calculation of net project benefits for cost-benefit analysis purposes. However, calculations of net wider impacts may be included as supplementary information in the summary of the cost-benefit analysis of a measure. The UK Department for Transport has prepared valuation guides for such net wider impacts.

The UK Department for Transport guide discusses four elements relating to the valuation of wider impacts: enhanced productivity as the result of increased functional town size, reallocation of labour to more productive jobs, general labour supply effects and production changes in markets with imperfect competition. The UK Department for Transport notes that the resources devoted to such analysis must be commensurate with the scale of the project under analysis. Consequently, it is for the project owner to evaluate whether one should embark on a detailed analysis of net wider impacts. Production changes in markets with imperfect competition[21] and labour supply effects[22] are highlighted as net wider impacts that will be of relevance to most projects. Productivity effects caused by increased functional town size[23] shall be evaluated if the investment also improves the accessibility of an area included in a list of "functional urban areas" in the United Kingdom. The economic effects of the reallocation of labour to and from more or less productive jobs shall, according to the guide, only be examined if such

19 Summarised in a lecture Professor Roger Vickerman gave to the Committee on 21 October 2011.

20 Cf. paragraph 5.25 of HM Treasury (2003).

21 The effect one intends to measure here is the difference between the willingness to pay for the change in production resulting from the transportation project and the production cost. The recommendation is based on the premise that there is s certain element of market power and that the said difference is positive. Specifically, the recommendation calls for a ten percent increase in the direct user benefits originating from business travel and the conveyance of goods.

22 Here the UK Department for Transport presents a method for estimating the change in employment resulting from a reduction in generalised travel costs, and thereafter recommends including the tax wedge associated with the change in employment in the analysis, which according to economic theory (cf. for example Venables, 2007) will not be captured by the direct user effects.

23 Here the UK Department for Transport presents a method for estimating the effect. It calls for estimates to be prepared as to the change in efficient accessibility for a number of small zones in the area that is being studied, as well as for subsequent estimates as to the potential productivity effect thereof, with the economy being divided into four defined industries. The UK Department for Transport has prepared a table setting out recommended values for the elasticity of productivity with respect to efficient density.

reallocation is probable on the basis of a detailed, specific model, and shall in any event take the form of a supplementary analysis only, and not be included in the summary of net wider impacts.

In practice, specific attempts at estimating economic net wider impacts have only been made for very large transportation projects. One example is a railway line through London, the Crossrail project, with an estimated cost of about GBP 16 billion, or about NOK 150 billion. The UK Department for Transport estimated that net benefits from the project increased from GBP 12.8 billion to GBP 20.0 billion when including these effects.[24] Consequently, estimates for net wider impacts contribute to the project being considered economically profitable. However, Crafts (2009) notes that the Crossrail project in London must definitely be characterised as a project with an unusually strong correlation between infrastructure investment and productivity.

7.5.2 HEATCO (EU)

In its report from 2006, HEATCO, an EU project seeking to harmonise the valuation of transportation projects, discusses elements that may be labelled as wider impacts (HEATCO, 2006). These are referred to as indirect economic effects. The report emphasises that it is important to distinguish between the direct and the indirect effects of a measure in order to avoid double counting. Reference is made to a review of how this is dealt with in 26 countries.[25] The said review includes effects referred to as net wider impacts in the present Chapter, but also outright redistribution effects and other aspects of the analysis of transportation market effects. The issues discussed in one or more countries include land use, economic development, short- and long-term employment, interregional equalisation at both the national and the EU level, urbanisation, network effects, effects on government finances and social equality. Moreover, HEATCO notes that the gap between theory and practice within this area is wide, and that its recommendations reflect this. It is recommended that the cost-benefit analysis of transportation projects shall include, at a minimum, a qualitative assessment of potential indirect effects, and that light should be shed on the magnitude of any net contribution to economic profitability on the basis of studies of projects in a similar context. Furthermore, it is recommended to use an economic model to estimate the indirect effects where these are deemed to be of major importance. General equilibrium models featuring a realistic transportation network, so-called Spatially Computable General Equilibrium (SCGE) models, are considered the best alternatives for such an analysis.

7.5.3 Sweden

In Sweden, a committee has recently discussed cost-benefit analysis methods within the transportation sector (Swedish Transport Administration, 2012). A separate chapter discusses how to deal with any net wider impacts. The highlighted elements are largely concurrent with those presented in the present Chapter. It is recommended that no attempt be made at capturing any net wider impacts of small or medium-sized projects. For large projects it is noted that one may present, if needed, a supplementary analysis of any effects beyond those captured by an ordinary cost-benefit analysis. It is emphasised that the findings from such an analysis not be added to the findings from an ordinary cost-benefit analysis, but potentially be included as a supplementary part of the basis for making decisions. Such a supplementary study should, according to the guidelines, be carried out within a relevant transport economic model.

Recommendations are also made with regard to the inclusion in a cost-benefit analysis of any new housing and commercial property development opportunities resulting from infrastructure projects, referred to as "exploitation effects" in Swedish Transport Administration (2012). At the same time, the report notes weaknesses associated with the current approaches to the issue, and it is emphasised that the method must be used with caution to prevent double counting. The findings should under any circumstance not be included in the calculation of net benefits, but may form part of a sensitivity analysis.

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[24] Findings by the Department for Transport (2005), as reported by Crafts (2009).

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7.6 Other sources of discrepancy between realised benefits and estimated economic effects

Arguments relating to wider impacts are often occasioned by a wish not to omit any important effects in the evaluation of projects. The focus of the Committee in the present Chapter is on net wider impacts; effects in other markets than the transportation market with a net impact on economic efficiency as the result of market failure in the secondary market, cf. the discussion of concepts in Chapter 7.2. However, it is also important to discuss whether any aspects of the analysis of impacts in the primary market, which in this case is the transportation market, can be improved. We will therefore in the following examine some sources of discrepancy between realised benefits and estimated economic effects within the transportation market.

Since the benefits from a transportation project largely take the form of reduced travel time, incorrect traffic growth estimates will lead to incorrect realised benefit estimates. Planning takes place under uncertainty, and it cannot be expected that forecasts will always be correct. However, one should expect the forecasts to be unbiased and not, in the long run, to systematically over- or undershoot actual developments. Verification of the priced effects some time after the project has been entered into use, so-called ex-post analysis, may reveal whether the assumptions underpinning the original analysis were correct[26]. Other types of analysis are required to uncover whether the project triggered net wider impacts, also including other time horizons than would be appropriate for ex-post analysis purposes.

It follows from Kjerkreit and Odeck (2010) that the Ministry of Transport and Communications asked the Norwegian Public Roads Administration, in 2005, to continuously verify the priced effects of projects in progress, and that a guide on the implementation of such verification was issued thereafter. A review of the first eleven analyses conducted within this framework shows that net benefits realised five years after opening exceeded those estimated prior to construction (Kjerkreit and Odeck, 2010). The main reason was that traffic growth had been underestimated at the outset. Other sources of discrepancies between estimates and realised net benefits were over- and underestimation of costs, accident costs and changes in project design subsequent to the original net benefit estimates. Another study, performed by the Institute of Transport Economics, has delivered corresponding findings (Madslien and Hovi, 2007). It follows therefrom that the traffic growth estimates underpinning national transportation plans over the period 1996-2006 were, for the majority of projects, somewhat lower than actual growth. The period examined is too short to merit, in itself, a belief that the forecasting tool is flawed, especially since the global recession in the wake of the financial crisis in 2008 is not included in the data. Nonetheless, the study illustrates the importance of correct forecasts.

In analyses examining what changes have actually been brought about by a project, it is of particular importance to carefully discuss what may actually be considered to be ex ante (before the project has influenced the adaptations of economic agents) and ex post (after the project has influenced the behaviour of concerned economic agents). Many economic adjustments are made immediately upon it becoming realistic to expect the project to be implemented, and well ahead of its physical realisation. If incorrect assessments are made in such regard, one risks not capturing the entire change resulting from the project. One study examines such effects of London being awarded the 2012 Summer Olympics (Brücker and Pappa, 2011). Adaptations in the form of increased investment, consumption and production are identified already *prior to* the event.

Another source of incorrect evaluation is failure to include factors to which road users or other stakeholders in the analysis attribute value. Let us for example look at a perceived inconvenience associated with dependence on ferry transport to an island. Such inconvenience would then feature as a cost element in the utility functions of economic agents. If an analysis of a bridge or tunnel between the island in question and the mainland ignores such an element, it will have a direct impact on the assessment of costs and benefits, with the result that the benefits such measure will generate for transport users will be underestimated. In addition, it may result in incorrect traffic forecasts, inasmuch as the generalised travel costs faced by agents do not include all costs of relevance to transport users. Bråthen and Hervik (1997) have studied this by looking at five such road links between islands and the mainland. The study found that the realised responses to the projects suggested that the willingness to pay for

26 Such verification may also be considered in the context of the evaluation requirement stipulated in Section 16 of the Central Government Financial Management Provisions.

the new journeys exceeded the original estimates. The reason for this was held to be that transport users were facing an inconvenience cost of ferry transport that was not taken into account in the original analysis, and that one thereby underestimated the real cost reduction the project caused on the part of transport users. This illustrates how ex-post analysis may assist in the identification of omitted cost or benefit elements, such as to facilitate their inclusion in subsequent analyses. The cost element represented by the inconvenience of ferry transport has subsequently been estimated, and is now included in the analysis tool used by the Norwegian Public Roads Administration.

Many effects are, as discussed in Chapter 2, difficult or undesirable to quantify in a cost-benefit analysis. These should nevertheless be included in a systematic analysis of such non-priced effects. If not, relevant non-priced effects will be another source of incorrect evaluation. An example of the systematic analysis of non-priced effects is provided by the analysis of the Sotra link. The project concerns an upgraded road link between Bergen and the island of Sotra, located west of town. The project is accorded priority in the National Transportation Plan 2010-2019, with start-up in the first four-year period and completion in the period 2014-2019. Such priority is conditional upon approval for partial toll funding being granted. The quality assurance (QA1) process established that a concept involving a new two-lane bridge, which, when added to the existing bridge, would result in four lanes, entailed estimated net benefits of NOK -450 million. The quality assurance provider also presented a systematic analysis of the non-priced effects associated with the various alternatives. All in all, the quality assurance provider was of the view that non-priced effects associated with a new two-lane bridge, relating to, *inter alia*, preparedness for major accidents, as well as improved and more attractive options for pedestrians and cyclists, suggested that the project should be recommended. The reason for the recommendation was that the negative net benefits from monetised effects were deemed to be minor when compared to the overall investment. Moreover, the negative net benefits were held to be compensated for by the positive non-priced implications, especially relating to reduced vulnerability of the road link between the island and the mainland. Another concept involving a new four-lane bridge in the same location, offered net benefits of NOK -1,700 million. Here the non-priced benefits were deemed to be even higher, but not sufficiently high for the quality assurance provider to conclude that these compensated for the lower net benefits from monetised effects. However, the Government has chosen to proceed with the planning of both concepts. The local political choice between the two concepts is now largely focused on balancing the priced against the non-priced effects. The decision on the implementation of the project, and thus on the final choice of concept, has not been made as per completion of the work of the Committee.

Another source of error may be that a project analysis uses an estimate for the average value of time for the country as a whole, despite the journeys undertaken being systematically valued differently from the country average. This is discussed in more detail in Chapter 4.4.3.

In analyses of road pricing in urban areas, it may also be incorrect to use an average value for travel time savings for all road users in a single project. Individual road users are not, generally speaking, faced with the costs they impose on other road users in the form of delays caused by queuing. Road pricing may entail considerable net economic benefits as a result of individual road users being faced with such costs, thus internalising the externalities associated with queuing. However, this reasoning is premised on road users differing in their valuations of time. This means that those who for some reason put a high value on a specific journey at a specific point in time will find it worthwhile to take such journey, even with road pricing. Others will put a lower value on such journey and wait until the road price is lower, for example around mid-day or in the evenings. Anderstig et al. (2011) refer to Parry and Bento (2001), which have examined road pricing from the perspective of the theory on net wider impacts. According to Parry and Bento (2001), net wider impacts in the form of reduced labour supply will be negative when travel costs increase, as with road pricing. However, Anderstig et al. (2011) note that exactly the variation in the valuation of travel time between different road users and purposes of travel suggests that the direction of such correlation is not obvious from the theory. They estimate the effects of the road pricing scheme in Stockholm, and find that net wider impacts of road pricing there were positive.

7.7 The assessment of the Committee

The Committee emphasises that the cost-benefit analysis guidelines must be based on updated research and theoretical developments. It is, at the same time, important for the recommendations to be robust and based on a well-established empirical foundation. This ensures comparability over time and between projects, and confers legitimacy on the analyses.

The approach presented in the NOU 1997: 27 Green Paper with regard to wider impacts is still deemed to be valid. However, new theoretical and empirical research merits some clarifications.

Wider impacts of net economic value

The Committee has focused its discussion on wider impacts that are of *net economic value* to the country, defined as “net wider impacts”. In order for a wider impact to be of net economic value, there must be a market failure in the secondary markets that causes, in the situation prior to implementation of the measure, under- or overconsumption of resources relative to the economically optimal resource allocation. If such under- or overconsumption is affected by the measure under analysis, the said measure has a wider impact that may have an effect on overall economic efficiency.

If goods and services affected by the measure are correctly priced and there is no market failure in the secondary markets prior to the implementation of the measure, effects in other markets will only represent a redistribution of the original effects of such measure, and a well-specified ordinary cost-benefit analysis will capture all economic effects. Such a situation will, in other words, involve *no* net wider impact. If the redistribution effect is considerable it may nevertheless be of relevance to the assessment of decision makers, and should therefore be addressed in the analysis if possible, cf. the discussion of distribution effects in Chapter 3.

Productivity and economies of scale

It is well-established in economic theory that mechanisms exist that may in certain cases give rise to a positive correlation between productivity and functional town size. This suggests that if a transportation project in an urban area does increase town size in practice, it may result in enhanced productivity for everyone in town, i.e. a net wider impact.

In order to merit a recommendation for the inclusion of effects resulting from such a correlation in cost-benefit analysis, the Committee takes the view that a theoretical and empirical basis should exist for a simple rule that does not depend on a large degree of discretionary assessment in each analysis. This is the only way of ensuring that the analyses are comparable, irrespective of who performs the studies.

However, the review of empirical studies in the present Chapter shows that it is very difficult to identify such a general correlation between functional town size and productivity. Besides, no such studies exist for Norway. The figures reported on how many percent productivity will increase if functional town size increases by one percent vary markedly between sectors, towns and countries (cf., *inter alia*, Vickerman (2008) and Melo et al. (2009)). The figures also vary markedly depending on which methodological approach is adopted. In addition, a comprehensive overview published by the OECD and the International Transport Forum (Graham and van Dender, 2010) notes that the correlation is not stable and that no correlation at all can be identified for large segments. It is not possible to conclude whether the lack of empirical identification is caused by the theory not working in practice, or whether it means that one has failed to find the appropriate method for distinguishing the effect of town size from other effects that influence productivity.

Since it has turned out to be very difficult to identify a correlation between town size and productivity based on the available data, the Committee takes the view that it cannot *generally* be recommended to assume such a correlation when preparing estimates for future effects of a project in a cost-benefit analysis context. Part of the difficulty with such identification is that it may take a very long time for the effects to be realised. A cost-benefit analysis should nevertheless discuss, where relevant, whether the type of wider impacts we see discussed in economic theory may arise.

Since economic theory gives reason to believe that there may be positive wider impacts of transportation projects in urban areas, the Committee takes the view that the cost-benefit analysis of large projects related to an urban area where it can be shown to be probable that productivity is systematically higher than in the neighbouring areas may be expanded by a *separate* discussion of net wider impacts resulting from increased functional town size. It must follow clearly from such an analysis which assumptions the assessments are premised on, and the uncertainty associated with any net wider impacts must be highlighted by way of sensitivity analyses, illustrating the effects of changing the assumptions. The Committee is of the view that any quantitative findings from such a supplementary analysis should not be included in the calculation of the ordinary net economic benefits from a project. This is, firstly, because such effects are highly uncertain and may depend on measures that do not constitute part of the project under analysis. Secondly, including such effects would reduce the comparability of different transportation studies, because the findings from an analysis of net wider impacts will be critically dependent on discretionary assumptions that need to be made in respect of each analysis.

The theoretical arguments in favour of net wider impacts through enhanced productivity resulting from increased functional town size apply to measures in urban areas. This suggests that the theory predicts that any net wider impacts from the construction of a stretch of road in rural areas would be minimal. The empirical review in the present Chapter indicates that the effect of proximity declines steeply with distance, and that no effect can be demonstrated for distances in excess of 50 kilometres from a town centre. When performing a cost-benefit analysis of such projects there is consequently no need to believe that there are net wider impacts as the result of increased functional town size. As far as road links between islands and the mainland are concerned, the situation is so different from place to place that no general recommendation can be made. As with general state aid for industry, it will be difficult to identify which projects may trigger positive net wider impacts. The Committee is not aware of any studies that provide any empirical basis for concluding that integration of housing and labour markets outside urban areas results in any positive net wider impacts for society as a whole.

Labour supply

A tax on labour income means that the economic value of one additional hour worked is higher than the wage referred to by individuals in determining their labour supply. If a project affects overall labour supply in Norway, the additional tax revenues will correspond to the economic value of the net wider impact resulting from distorting taxes. However, it is difficult to know whether individuals will convert reduced travel time into increased labour supply or make other adjustments over time, like for example taking the opportunity to acquire a cheaper home further away from work or to choose a workplace that is further away from their current home. If the benefit is converted into anything other than increased labour supply (and thus increased production), there is no net wider impact as the result of distorting taxes. Moreover, it is not necessarily the case that transportation costs have in practice contributed to individuals not participating in the labour market, and thus that reduced transportation costs will result in increased employment. These are empirical issues. Neither foreign, nor Norwegian, empirical studies exhibit any systematic correlation between overall long-term employment and infrastructure investments. This indicates that one will not be making a major error in excluding such labour supply effects when assessing the economic profitability of transportation projects. As with productivity effects, the identification of such effects may be difficult because it could take a very long time for said effects to be realised in full. A cost-benefit analysis should nevertheless discuss, where relevant, whether the type of wider impacts we see discussed in economic theory may arise.

For major projects where it can be shown to be probable, on an empirical basis, that the project will affect overall labour supply in the country through longer working hours or increased labour force participation, a cost-benefit analysis may, however, be expanded by a separate discussion of these effects. It is in such case important to avoid double counting of the benefits from the project, and the appropriate approach will therefore be to only take into account the tax effect resulting from the change in the value added caused by the increase in employment. However, in order to ensure comparability and in view of the uncertainty, any quantitative findings from such a supplementary analysis should not be included in the calculation of the net economic benefits from a project. The effect of the tax wedge must also be taken into account when valuing the effects of enhanced productivity as the result of increased functional town size.

Land use and transportation

As a general rule, price changes in the property market as the result of a transportation project represent only a redistribution of the original direct benefits from such measure. Consequently, including both effects in the analysis would amount to double counting. If one envisages that a transportation project will enhance productivity in an urban area through the mechanisms discussed in Chapter 7.3.1, one have a situation in which the value of enhanced productivity is reflected in higher property prices. However, if one has sought to calculate the value of enhanced productivity directly, it will also in this case amount to double counting if the effect of the property market price changes is included.

If a measure releases areas that were previously used for transportation, typically by traffic being redirected below ground level, and such areas have a positive value, their value in the best alternative use should in principle be included on the benefit side of the project, inclusive of any option values. However, in order for such an effect to merit inclusion in the analysis there must be a high probability that the areas will actually be used, e.g. in the form of clear expressions of interest from serious stakeholders. Sweden has developed methods for such valuation, but it is recommended that these be used with caution. In any event, the Swedish method recommends that such valuation take the form of a sensitivity analysis, and not be included in the calculation of expected net benefits from the project. The Committee assumes that the Norwegian transportation bodies are monitoring this process closely in their work on cost-benefit analysis guides within their respective areas.

Imperfect competition

Imperfect competition may also be a source of net wider impacts. However, the Committee is of the view that changes in transportation facilities in Norway will in most cases not have any material impact on the degree of imperfect competition. Hence, this should be a limited source of net wider impacts of transportation projects in Norway at present.

In Chapter 7.3.5, it was noted that reduced transportation costs will, when taken in isolation, result in increased production in markets with imperfect competition. This may be a separate source of net wider impacts, also if the competition situation itself is not affected. The magnitude of such an effect will depend on the gap between prices and marginal costs in each sector, and on how the consumers of goods from the affected sector react to the price changes. Individual enterprises will often not have complete information about market conditions and the demand curve in their sector, which suggests a high degree of uncertainty as to whether the market power will be exploited in full and how long time such adjustment will take. Moreover, this will vary from sector to sector. In Norway, there is reason to believe that the composition of commercial transportation will vary considerably between different types of transportation projects, which is an argument against using one single factor to capture such an effect. To the extent that gaps between prices and marginal cost are of some significance, and a firm is facing a downward-sloping demand curve, it is in any event not necessarily the case that reduced transportation cost will in its entirety accrue to the owner, as opposed to employees or subcontractors. This would in such case result in a smaller reduction in the marginal cost of the enterprise than would be indicated by the travel time savings in themselves. On the other hand, if the employees and subcontractors are Norwegians, the portion of the cost savings accruing to them will represent part of the national gain from transportation cost savings. Generally speaking, such a benefit incidence analysis can only be carried out within the framework of a general equilibrium model.

This implies, all in all, that the Committee is not in a position to conclude whether the effect of imperfect competition is of any material importance to the net economic benefits from transportation projects. Besides, it demonstrates that it is difficult to establish a simple method for capturing such an effect in a robust manner based on a firm empirical foundation.

Miscellaneous

It is an important principle that market imperfections should be corrected by policy measures that are as well targeted as possible in addressing the primary cause of such imperfections, such as not to promote enhanced efficiency in one area through measures that give rise to inefficiency in another area. This pertains to imperfect competition, in particular, where the authorities have a more direct policy measure available in the form of addressing market power through the competition legislation and the enforcement thereof. Using transportation investments to increase competition would at best be a second-best solution.[27] Valuation in a sensitivity analysis of any net

27 Vickerman (2008) notes that the competition effect of transportation investments can under any circumstance be expected to be neutral. On the one hand, reduced transportation costs may expand the market, thus introducing new competitors. On the other hand, such increased competitive pressure may in practice lead to some firms being bankrupted and thus reduce the number of firms competing in the market in the long run. It is noted that the exception will be those cases where a road link does in itself contribute to “unlocking” a previously protected local monopoly. Vickerman believes that this will rarely be the case in modern economies.

wider impacts resulting from imperfections may in such case illustrate that there is a potential for more direct policy measures to address the imperfection.

Besides, the Committee takes the view that it is no less important to ensure that the specification of the cost and benefit elements is complete, and that there are no other sources of incorrect estimates within the traditional cost-benefit analysis framework. The various sectoral guides must ensure that the main factors in the utility functions of economic agents are included in the analysis and that the valuation takes place at an aggregation level that does not give reason to expected systematically biased outcomes. In choosing an aggregation level, the cost of additional specification must be balanced against the benefits one may derive therefrom. Non-priced effects of importance need to be discussed in a systematic manner.

In practice, cost-benefit analyses are often partial analyses of small projects. Whether a project is small depends on whether it will have a material impact on market prices, cf. the discussion in Chapter 2. If a reform or a measure has a material impact on market prices outside the transportation market, an analysis within a general equilibrium model featuring a realistic transportation network, and taking relevant market failures into account, will be more suitable. Such an analysis framework will not involve the same risk of double counting some effects and omitting other effects as one may run when conducting ad hoc analyses of wider impacts in secondary markets. However, general equilibrium models often operate at a fairly high level of aggregation, which makes them less suitable for capturing the effects of minor changes, for example in the transportation network. The Committee is of the view that the development of general equilibrium models that are better suited for the analysis of such minor changes in the transportation network, and which take the relevant market failure into account, may represent a useful tool for analysing the effects referred to as net wider impacts in the present Chapter.

7.8 Summary recommendations

Based on the discussion in the present Chapter, the Committee makes the following recommendations:

Productivity and economies of scale

- It has proven very difficult to identify a relationship between town size and productivity when evaluating the effect of a transportation project or a series of such projects subsequent to its or their implementation. According to the view of the Committee it cannot, therefore, be recommended to generally assume such a relationship when evaluating a project prior to its implementation.
- Since the literature gives reason to believe that there may be positive net wider impacts of transportation projects in urban areas, the cost-benefit analysis of large projects in connection with an urban area in which it can be shown to be probable that productivity is systematically higher, may be expanded to include a separate discussion of net wider impacts. Such an analysis may be both qualitative and quantitative, and should discuss whether such effects are likely to materialise. However, in order to ensure comparability across projects, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to a main analysis of the net economic benefit associated with a project.

Labour supply

- For major projects concerning which it can be shown to be probable, on an empirical basis, that the project will influence overall labour supply in the country through longer working hours, or through increased labour force participation, a cost-benefit analysis could be expanded with a separate discussion of these effects. Such an analysis may be both qualitative and quantitative, and should discuss whether such effects are likely to materialise. It is important to avoid double counting of the benefits from the project in such contexts, and the correct approach will in practice be to only take into account the change in tax revenues as the result of higher employment. However, in order to ensure comparability, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to the main analysis of the net economic benefits associated with the project.

Land use and transportation

- As a main rule, price changes in the property market as the result of a transportation project only represent a redistribution of the original direct benefits from such project. Including both effects in the analysis will therefore amount to double counting. If one has sought to estimate the value of increased productivity as the result of increased functional city size directly, it will also amount to double counting if the property market implications of such effects are taken into account. In those cases where a transportation project releases areas with a positive opportunity value, there may be a real economic effect that is not reflected in the direct user benefits of the project.

Imperfect competition

- Based on the available documentation, the Committee is not in a position to conclude as to whether the effect on imperfect competition is of any material importance to the net economic benefit of transportation projects. The review also shows that it is difficult to establish any simple method for identifying any such potential effect in a robust manner, and with a solid empirical basis. If it can be shown to be probable, on an empirical basis, that the project may influence the degree of competition, or that it will influence markets that are in particular characterised by imperfect competition, a cost-benefit analysis may be expanded to include a separate discussion of these effects. However, in order to ensure comparability, and in view of the uncertainty, any quantitative findings from such a supplementary analysis should only constitute a *supplement* to a main analysis of the net economic benefits associated with a project.

The ex post analysis of the primary markets

- The effort to analyse projects subsequent to their implementation should be continued. A systematic approach, like that adopted by the Norwegian Public Roads Administration, generates new knowledge about the analyses carried out, and makes it possible to use these findings to improve the estimates. The systematic follow-up of such studies and other approaches may contribute to ensuring that the specification of the cost and benefit elements is complete, that projections are correct in the long run, and that there are no other sources of incorrect estimates within the cost-benefit analysis framework.

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Chapter 8
Disasters and irreversible effects

8.1 Introduction

From the terms of reference of the Committee:

> The Expert Committee shall consider how cost-benefit analysis is to deal with catastrophic effects with a small, but not negligible, probability, as well as the matter of irreversible effects.

Disasters are events with a low probability of occurrence, but with very serious consequences. These may be natural disasters or man-made disasters, but also a combination thereof. Earthquakes, hurricanes, tsunamis and major floods are examples of natural disasters. Terrorist acts, major financial crises and industrial accidents are examples of man-made disasters. The degree of destruction will often depend on society's preparedness. In the long run, climate change caused by anthropogenic carbon emissions may, if sufficiently large, result in global disaster.

By irreversible effects we mean effects the reversal of which is either associated with high costs or, in the worst-case scenario, impossible. These may vary in nature. One type of irreversible effect is caused by exceeding threshold values in nature. In an economic context, it is often difficult to reverse investment decisions, thus implying that the investment costs are not recoverable. An example of this may be infrastructure investments in the transport sector.

Although irreversibility and disaster may occur in many areas of society, we will in the present Chapter place a special focus on environmentally-related issues. These represent a challenge for traditional cost-benefit analysis for a number of reasons. Relationships in nature are often non-linear, complex and characterised by uncertainty. The assessments and conclusions of the Committee will nevertheless apply more generally.

Catastrophic effects will typically be irreversible. However, irreversible effects need not be catastrophic. The two issues can in many respects be discussed separately. In Chapters 8.2 and 8.3, we examine the concepts of irreversibility and disaster, with an emphasis on their relevance to cost-benefit analysis. In Chapter 8.4, we discuss the precautionary principle and "safe minimum standards", which are key policy rule proposals in contexts of potential irreversibility and/or disaster. In Chapter 8.5, we outline the main features of the debate on potentially catastrophic climate change, which is presumed to have motivated this part of the terms of reference of the Committee. Chapter 8.6 sets out the assessment of the Committee, and Chapter 8.7 presents its recommendations.

8.2 Irreversible effects

Although the reversible/irreversible distinction is useful, it is not a straightforward matter to divide effects into two separate classes. We are faced with a continuum of potential situations, from completely or almost completely reversible effects, via increasing rigidity or inertia, to effects that it would be physically impossible or economically unviable to reverse. It is therefore important to be mindful of the many potential degrees of irreversibility in an analysis situation.

Global examples of irreversible environmental effects may be melting of the Greenland ice sheet due to global warming, or the large-scale release of methane locked into the Siberian tundra. A domestic example may be the damming of a watercourse. Investments in housing, transportation links and other infrastructure will have a lifespan that makes them irreversible in practice, with environmental effects not necessarily being the predominant causes of irreversibility.

It is a characteristic of irreversible decisions that they curtail the future freedom of action, and thereby also decision-making flexibility. This may be of importance if inadequate information about the future consequences of a decision is available at the time of making such decision. In principle, this means that there is an economic value associated with postponing the decision, or delaying its implementation. This value is called an option or quasi-option value, or alternatively a real option value, cf. Box 8.1. This is equal to the expected value of the possibility of reversing the decision if thus merited by updated information. In order for it to be profitable not to wait, the net present value of the net benefits from immediate implementation must exceed the option value of waiting.

Since it will often be difficult to calculate the (quasi-)option value, the NOU 1997: 27 Green Paper; Cost-Benefit Analysis, concludes as follows:

> ”It must in each relevant case be evaluated how much can be gained by performing calculations of the expected benefit from postponement. It is under any circumstance important to be aware that a positive risk-adjusted net present value does not necessarily suggest that projects should be implemented immediately if these are irreversible and can be postponed.” (page 81).

Another aspect of irreversible decisions is that their profitability depends on whether it is evaluated prior or subsequent to the implementation of such decisions. This is because costs that cannot be recouped after the decision (”sunk costs”) are of relevance to decision making prior, but not subsequent, to the implementation of such decision.

There are, as noted above, many types of irreversible effects. The guide “Dealing with Uncertainty in Cost-Benefit Analysis” (Norwegian Government Agency for Financial Management (“DFØ”), 2006) emphasises the importance of being conscious of the scope for real options, and of looking for ways of preserving freedom of choice. Real options are held to be especially profitable in relation to effects that are irreversible in the strict sense of the word, when there is very considerable uncertainty about future developments in critical factors – which may be the case with long-term effects. Moreover, there should be a likelihood that the uncertainty will be reduced later on, and that the freedom of choice will actually be utilised. The calculation of option values is often resource intensive and complex. Consequently, the guide emphasises that the mode of thought underlying the concept of real options, and the fact that decision makers take the option aspect into consideration, will often be more important than the precise valuation of such option.

8.3 Disasters

Bergstrom and Randall write, in their environmental and resource economics textbook, that economics is “all but silent when confronted with the need to analyze a decision involving, say, a truly catastrophic outcome with a very low probability at some future time” (Bergstrom and Randall, 2009). However, economists have devoted more attention to this issue in recent years, especially in the context of the risk of extreme effects from global warming. We will here present a brief and general discussion of disasters, before outlining main perspectives in the climate debate in Chapter 8.5.

A number of the fundamental issues in welfare economics are of relevance to the matter of potentially catastrophic outcomes. One such issue is discounting, which is discussed in Chapter 5. Another is the distinction between risk and uncertainty. If we are able to attribute a probability to a given outcome, we are dealing with a *risk*. Historical empirical data and/or theoretical knowledge mean that one will in many contexts be able to quantify probabilities, such as the probability of a river breaking its banks, or of a person suffering a car accident. In other cases we have no empirical basis for estimating such probabilities. It is, for example, difficult to estimate the probability of exceeding a threshold value in nature as long as we do not know what that threshold value actually is. This is referred to as *uncertainty*.

The fact that disasters are, by definition, very rare does in itself suggest that it will be difficult to estimate probabilities. Some disasters are also of such a nature that no one has been able to envisage their realisation prior to the event, cf. Box 8.2. In other words, the uncertainty does not only pertain to the absence of a probability distribution, but also to incomplete knowledge about the sample space.

Obviously, the definition of disaster depends on the level of analysis. A fatal traffic accident is a disaster for those affected. The probability of such an accident happening to a specific person is also low (although obviously not negligible). However, no single accident can be considered catastrophic for analysis purposes from the perspective of society. Traffic fatalities are a fairly frequent occurrence, and the term disaster would, if at all applicable, have to be reserved for a dramatic growth in the number of traffic fatalities.

Box 8.1 Option and quasi-option value

In an environmental economics context, the value of "wait and see" prior to making a decision is termed *quasi-option value*. The background is an article by Arrow and Fischer (1974), in which they discuss the industrial development of a nature area as an example of an irreversible decision. If the development takes place, the recreational value of the area will be irretrievably lost, and the decision makers have inadequate information about how such loss will be valued in future. This gives rise to a quasi-option value associated with postponing the intervention, and such value must be included in an adjusted net present value criterion. Other examples of irreversibility in an environmental context may be pollution by heavy metals or other substances that take a very long time to decompose in the environment, such as CO_2 in the atmosphere.

This economic decision-making problem has the same structure as financial contracts termed call options. Purchasing a call option means obtaining a right, but not an obligation, to purchase the underlying object, which may be a physical good or a financial instrument. This decision-making flexibility has a value, an *option value*, and the holder pays a premium for such value. If development in the price of the underlying object induces the holder to subsequently exercise the option, such exercise is an irreversible decision, and the option is said to be closed out. Options of this or similar types used on real investments are often also termed *real options*.

Pearce, Atkinson and Mourato (2006) note that it is unfortunate that environmental economics and financial theory use different terms (quasi-option value and option value, respectively) for what is in actual fact the same phenomenon. (Further confusion may arise because environmental economics also uses the term "option value", but in referring to the value of preserving an environmental good for later use, irrespective of any uncertainty and irreversibility.) Moreover, they emphasise that the quasi-option value is not a separate component of the "total economic value" of environmental goods (see Chapter 4.5.2), but "rather ... a reminder that irreversible decisions under incomplete information should be made rationally." Which decision is made will determine the degree to which the total economic value of an environmental good is taken into account.

A war or an occupation is obviously a disaster at the national level, and the same applies to a terrorist act like the one Norway experienced on 22 July 2011, or a pandemic with a large number of deaths. At the global level, even a terrorist act on Norwegian territory will fall outside the scope of the term disaster. Major wars, like the World Wars, are global disasters. Large-scale famines, or worldwide pandemics with a high mortality, will be characterised as disasters. The immediate background to this issue being mentioned in the terms of reference must be assumed to be the climate problem, which is characterised by effects that are uncertain, but potentially enormous.

The definition of the term disaster will have social and political dimensions – not only, or primarily, economic ones. Delimitation is difficult, but would have to focus on events that are rare and unique. In principle, the discussion invited by the terms of reference may be pursued without setting out a clear definition of what constitutes a catastrophic effect. In practice, one will, as with irreversibility, be faced with a continuum of effects characterised by increasing seriousness, with the most extreme ones being defined as catastrophic.

At the level of the individual, financial safeguards are available. Enterprises and households may take out insurance against events that are catastrophic or serious, in order to reduce the economic consequences (even if the human costs cannot be averted). The authorities may also choose to "socialise" the consequences. The National Fund for Natural Disaster Assistance is an example of society absorbing the natural peril costs of individuals above a defined, normal level.

As far as disasters at the national level are concerned, the relevant issue is to determine the scale and scope of measures to reduce the real risk of such disasters, and/or to bolster society's ability to withstand them should they nevertheless occur.

Cost-benefit analysis may contribute to uncovering whether the risk of death, disease, injury or

Box 8.2 Taleb's "The Black Swan"

According to Nassim Taleb's book "The Black Swan" (2010), it is characteristic of the major disasters that their occurrence is a matter of complete surprise, like the terrorist attack in New York on 11 September 2001 or Hurricane Katrina, which hit New Orleans especially hard in 2005. Professor Taleb refers to this type of disaster as "Black Swans" or "unknown unknowns" because no one (or a very small number of people) had in advance even considered the possibility that such events could occur.

However, one problem with "Black Swans" from the perspective of prevention is that history rarely repeats itself, thus implying that it is difficult to draw direct lessons from such unique historical experiences. Professor Taleb writes that there is a tendency to underestimate the probability of unknown disasters ahead of the event (ex ante), and that one overestimates the probability of the recurrence of a disaster that has already materialised (ex post). Spectacular accidents, in particular, attract the attention of the general public, with the consequence that disproportionate resources are devoted to preventing their future recurrence – to the detriment of risk reduction in other contexts.

material loss is implicitly valued on a par across various sectors. Using cost-benefit analysis for regulatory purposes may, generally speaking, contribute to making the decision maker aware of the extent to which risk reduction resources are allocated efficiently across various sectors, as measured on the basis of the priced effects (Hagen and Godal, 2011).

Regulations proposed in order to enhance safety may, in the same manner as investments, be subjected to a cost-benefit analysis, as a basis for decision making. Any effects with a known probability distribution and consequences may be included in the analysis in the usual manner when calculating the expected value, thus enabling an ordinary cost-benefit analysis of the risk-reducing measure to be carried out.

Farrow and Shapiro (2009) note that the number of safety-motivated investments and regulations in the United States has increased considerably in the wake of the terrorist attack on 11 September 2001. Safety regulations have, by and large, escaped serious economic analysis. Admittedly, cost-benefit analysis of such decisions is difficult, especially because it is difficult to estimate the benefit side of such measures. The benefits will take the form of costs that were expected, but are avoided as the result of the decision. This involves both probabilities and consequences of the events focused on by such regulations.

However, the literature within the area is evolving. The authors emphasise "reverse cost-benefit analysis", also termed "break-even analysis", where the idea is to identify critical values for certain unknown probabilities. For example, an analysis of minimum requirements with regard to identity documents may indicate by how much the new requirement would have to reduce the probability of a terrorist act in order for the net benefit from the measure to be zero or positive. Farrow and Shapiro (2009) note that analyses based on available data cannot be expected to deliver clear policy rules, and propose improvements in the form of replacing hidden assumptions by explicit modelling and knowledge. Such models will under any circumstance involve an element of subjective or assumed probabilities, because some potential events will be very rare.

8.4 The precautionary principle and safe minimum standards

A traditional cost-benefit analysis may, in its calculation of the expected net present value, attribute relatively minor importance to a possible future disaster with major economic implications. This is because the product of even a very high cost and a low attendant probability could be a small number, which number will also have to be discounted. This is the basis for scepticism about the treatment of such events in economics, and the development of policy rules that focus more explicitly on uncertainty, irreversibility and potential disasters. The two best known of these are the precautionary principle and the principle of safe minimum standards.

The precautionary approach is a key environmental policy principle, often cited both internationally and in Norway. The most commonly used definition is set out in the Rio Declaration on Environment and Development from 1992: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (Report No. 13 (1992-1993) to the Storting). It is often said that this approach "shifts the burden of proof" in cases where irreversible or serious damage may occur. The environment shall be given the benefit of the doubt in case of uncertainty.

This principle focuses explicitly on potentially irreversible effects. One will note that it encompasses the risk of disaster, but also the risk of "serious damage" that will not necessarily be defined as catastrophic. The cost-effectiveness requirements may be interpreted as a reasonable reservation to the effect that the approach does not justify any given preventive action.

The term Safe Minimum Standard ("SMS") was introduced by Ciriacy-Wantrup (1952). The term is based on the idea of minimising the maximum loss in connection with a project. A simple interpretation is that one should reject changes that entail a risk of irreversible loss of natural resources. A weakness of the said interpretation is that no form of economic assessment is involved.

Bishop (1978) remedies this by proposing that safe minimum standards may be introduced unless the cost to society is unacceptably high. He introduces a measurable benefit component associated with preservation (B), to be deducted from the net economic benefits from a measure exclusive of environmental effects (A). Hence, Bishop's modified SMS criterion implies that the investment is economically profitable when $A - B > 0$, based on the valued effects. However, Bishop notes that the decision-making criterion should also include potential irreversible loss of environmental capital that is not yet considered valuable resources (C). The probability y of losing C as a result of the measure is unknown. Since we are unable to calculate the expected value yC, a cost-benefit analysis of the valued effects associated with a measure will have to be balanced against the non-valued (and unknown) component yC.

Since we do not know the value of yC, Bishop (1978) notes that the authorities may introduce a threshold value X representing what society considers an acceptable cost of preserving those environmental goods that are irreversibly threatened by a project. Consequently, the decision-making rule is to implement the project in question if $A - B > X$.

Neither the precautionary principle, nor safe minimum standards, will in itself tell us what is an optimal or appropriate level of ambition, and these approaches therefore necessitate specific trade-offs in each individual case.

8.5 The climate challenge

Global warming is a man-made process with irreversible effects, which may turn out to be catastrophic. The Committee will here outline the current debate amongst economists relating to economic analysis of the climate problem, and particularly the special challenges posed by the inherent uncertainty. The presentation may be considered an example of the economic analysis of uncertain, irreversible and potentially catastrophic effects. It is, at the same time, the climate challenge that has stimulated a vigorous debate on these issues in economic literature. This is the background against which the Committee examines the issue here.

The climate challenge is described in Chapter 9. There are two basic types of uncertainty associated with greenhouse gas emissions. One of these concerns the relationship between the concentration of greenhouse gases in the atmosphere and the corresponding temperature increases. We may term this climate sensitivity. The UN climate panel, the IPCC, has defined climate sensitivity as the average global warming resulting from a doubling of the CO_2 concentration in the atmosphere when compared to preindustrial times. The probable climate sensitivity range is 2 – 4.5 ^oC, with a best estimate of 3 ^oC. It is very unlikely that global warming will be less than 1.5 ^oC, and it cannot be excluded that it will exceed 4.5 ^oC (IPCC, 2007).

The other uncertainty concerns the impact of such temperature increase on the natural environment, production, consumption and welfare. The uncertain relationship between the CO_2 concentration in the atmosphere and the climate response, and between the climate response and material welfare, means that it is very difficult to estimate specific damage functions for the greenhouse gas emissions in economic models. In addition, there is considerable uncertainty associated with, *inter alia*, future technological developments and costs associated with reductions in greenhouse gas emissions.

8.5.1 Integrated Assessment Models

So-called Integrated Assessment Models ("IAM") are often used to analyse the climate challenge and climate policy at the global level. Such models combine climatology and economics, and can estimate both the costs associated with global emission-reduction measures and the global welfare effects of the attendant greenhouse gas emission levels. In principle, IAM models may be used to analyse what is an optimal global level of ambition for climate policy, or to analyse climate policy requirements for reaching a specific target (for example a two-degree path, cf. Chapter 9).

Many of the IAM models are based on standard economic growth theory, where society invests in capital, education and technology, thus refraining from consumption at present for the purpose of expanding future consumption opportunities. Society will seek to optimise its consumption over time, based on its current and future consumption needs. The level of the discount rate is of major importance to these trade-offs. Professor William Nordhaus (Yale University) has developed the best known IAM model, the so-called DICE model (Nordhaus, 2007). The model expands the traditional growth theory approach by also including investments in "natural capital". By investing in natural capital today, future reductions in consumption opportunities as the result of climate-induced deterioration are curtailed.

In the DICE model, Nordhaus (2007) studies the trade-off between traditional production investments and climate investments. His findings show that it is profitable to make relatively large investments in traditional activities in an early phase, which incidentally also include improved technologies and additional intellectual capital, and some investments in designated climate measures. This can be achieved by introducing general, harmonised CO_2 taxes at relatively low rates in this early phase. In the longer run, the environmental costs are expected to increase as greenhouse gases accumulate and global warming commences. It will then become profitable to shift investments to much more aggressive, emission-reduction measures. This can be achieved through a steep increase in the tax rates in the intermediate and long run. This gradual approach to the climate challenge has been termed the "climate policy ramp" (see, *inter alia*, Dietz, 2009).

Many IAM-based calculations lead to such a "go slow" conclusion, with a moderate emission reduction effort in the short run (Ingham and Ulph, 2003, and Ackerman et al., 2009). According to Ackerman et al. (2009), this conclusion depends on debatable choices of assumptions to underpin the analyses, including the choice of discount rate. Since the climate-induced damage materialises in the distant future, and the benefits of introducing clean-up measures at present therefore also materialise in the distant future, a high discount rate will attribute a lower value to climate-induced damage in the net present value calculations than would a low discount rate. This contributes to the conclusion that emission reductions should be modest to begin with. Whilst Nordhaus (2007) applies a market-based discount rate in his calculations, Stern (2007) uses a much lower discount rate in his calculations (1.4 percent). This contributes to Stern (2007) arguing in favour of starting early with relatively large, global emission cuts, in sharp contrast to Nordhaus (2007) and many other IAM-based calculations. Reference is also made to Box 5.4. of the present Report for a more detailed outline of the discussion between Nordhaus and Stern concerning the discount rate applied in climate-related calculations.

Ingham and Ulph (2003) cite additional criticism to the effect that the IAM-based model computations ignore the possibility that there may exist threshold values in nature, beyond which additional impact may trigger dramatic and irreversible processes. It is, for example, possible that global warming beyond a certain level may trigger rapid melting of the Greenland ice sheet, thus resulting in a steep increase in the sea level. Ackerman et al. (2009) emphasises that it is better to base analysis of the climate issue on an insurance-based approach, since the main consideration is to safeguard against a potential climate-induced disaster with a low probability, than to base it on a comparison of costs and benefits, as is the approach adopted by most IAM models.

8.5.2 Weitzman's "dismal theorem"

In an article from 2009 on the global climate challenge, Professor Martin Weitzman (Harvard University) has presented the so-called "dismal theorem". The theorem represents a criticism against traditional cost-benefit analysis of the climate issue, as conducted by using IAM models. At the core of the criticism is the observation that we do not know the probability of very serious consequences from global warming. The probability of climate-induced disaster, in the form of rapid global warming and large-scale feedback effects on production and consumption, may be non-negligible. Moreover, the shape of the social welfare function will be such as to make the willingness to pay for averting climate-induced disaster approach infinity with increasing temperatures. When this cost is multiplied by a non-negligible probability, the expected value is also infinite.

Weitzman (2009) is therefore of the view that we cannot perform a standard cost-benefit analysis of the climate problem and argues, against this background, in favour of an insurance approach that bears a resemblance to the precautionary principle discussed in Chapter 8.4. He believes there is much evidence to suggest that the probability distribution of climate-induced disaster has "fat" tails (see Box 8.3), because there is very considerable uncertainty associated with the future prospects for major temperature change, and because the global cost increases caused by temperature increases may be steeply progressive.

Weitzman (2009) highlights, *inter alia*, the uncertainty associated with the climate response occasioned by bringing the CO_2 concentration in the atmosphere to completely unknown levels. Since a temperature increase of, for example, 4.5 ^oC is outside the scope of our experience, we must rely on our views with regard to probability distributions, which must by necessity be subjective within the climate arena due to the lack of empirical data. Professor Weitzman also notes that potentially catastrophic feedback effects from increased CO_2 concentrations in the atmosphere are currently omitted from most IAM models. He furthermore criticises the damage function underpinning IAM analyses of the climate issue.[1] Such analyses find a relatively moderate effect on world production from large temperature increases. The special shape of the function, which measures the detrimental effects in terms of their impact on consumption, means that the economy can compensate for the welfare effects of higher temperatures through higher consumption. Another specification, which differs from the IAM models, might describe a situation in which the main effects of climate change affect goods that cannot be compensated for through material wealth, such as biodiversity and health.

The critical issue is, according to Weitzman, how rapidly the probability of disaster declines relative to the welfare effects of disaster. Although the probability of an outcome declines with the expected welfare loss associated with such outcome, it is not necessarily the case that the probability approaches zero rapidly enough for the expected value of the welfare loss to also approach zero. The answer depends partly on how "thin-tailed" the probability distribution is (see Box 8.3), and partly on how fast society's expected wel-

Box 8.3 Thin and fat tails

In statistics, one makes a distinction between probability distributions with so-called "thin" and "fat" tails, respectively. The bell-shaped normal distribution does, for example, feature a thin tail. This implies that most outcomes are centred around the expected value of such outcomes, whilst outcomes a long distance from the mean occur only very rarely. A "thin-tailed" probability distribution implies that the probability decreases exponentially or faster when one moves away from the expected value. Hence, there is a very low probability of outcomes that are far removed from such value. An example of a normally distributed variable may be female (or male) height at the national level.

However, many phenomena may have a probability distribution that deviates from this bell-shaped curve. One example may be stock market fluctuations. On 19 October 1987, the US stock market slumped by 23 percent, cf. Nordhaus (2011). If the stock market had adhered to a normal distribution, we would, according to Nordhaus, have observed a 5-percent change in prices only once every 14,000 years. However, historical stock market data show that major fluctuations happen much more frequently than would be indicated by a normal distribution. This is indicative of a probability distribution with "fat tails", i.e. that the probability declines towards zero more slowly than under the normal distribution. One example of such a distribution is the Pareto distribution, also called the "power law" distribution. This distribution is frequently used in both the natural and the social sciences. Even extreme outcomes will not be entirely improbable under such a distribution. Fat tails are often associated with events like, for example, the magnitude of an earthquake, a steep stock market contraction, or a major correction in housing prices at the national level.

[1] The standard CBA damage function reduces the welfare equivalent of production in the event of a mean global temperature increase T by a quadratic-polynomial multiplier expressed as $M(T) = \alpha T^2/(1+\alpha T^2)$, cf. Weitzman (2011). Instead of being multiplicatively separable, the negative utility from global warming may be additively separable. This will again, according to Weitzman (2011), imply stricter emission restrictions than would be suggested by the standard calculations.

fare loss increases with the climate effects. Hence, this is a race along the tail end of the probability distribution, between how rapidly the probabilities decline and how steeply the welfare effects from climate-induced deterioration increase. If the probability of catastrophic climate-induced damage is not negligible, this will serve to bring about a high willingness to pay for the prevention of such extreme climate change. It may therefore be difficult to determine an upper limit for this willingness to pay.

8.5.3 Criticism of Weitzman's findings

Nordhaus (2011) believes the dismal theorem to be important because it may assist us in determining when extreme outcomes are of relevance to our decisions. However, the theorem is only valid under special conditions: It assumes strong risk aversion in society, a very fat tail for uncertain variables and, moreover, that society is unable to learn and act in a timely manner. According to Nordhaus, the dismal theorem assumes, *inter alia*, that the marginal utility of consumption grows infinitely large when consumption approaches zero, as in the case of a disaster. This implies that society will have an unlimited willingness to pay to avert such a scenario, even if the probability thereof is very low. If this assumption is not met, the expected value of the welfare loss will not be infinitely large, and the premises underpinning the dismal theorem will be eliminated. That leads us, according to Nordhaus, back to standard cost-benefit analysis, such as the many IAM models.

The key question asked by Nordhaus is whether the international community does in actual fact have an infinite willingness to pay for avoiding a very low, but non-negligible, probability that the basis for human existence will be wiped out. He notes, by way of an example, that the probability of an asteroid hitting the Earth is about 10^{-8} per annum. If the dismal theorem was valid we would, according to Nordhaus, be willing to pay an unlimited amount for a tiny reduction in this probability. He notes that society does not, generally speaking, behave as if infinite negative utility is associated with catastrophic outcomes at the limit. Besides, Nordhaus maintains that the nature of climate change (unlike asteroid disaster) is such as to give us time to learn, and to postpone the large-scale emission reductions until more effective technologies have been developed.

Pindyck (2011) notes, as did Nordhaus, that Weitzman assumes a utility function exhibiting special characteristics, especially with regard to the shape of society's risk aversion. Pindyck believes that marginal utility may be very high when consumption approaches zero, but not infinitely high. If we introduce an upper cap, thus implying that marginal utility approaches a finite level, the willingness to pay will also be finite, according to Pindyck. However, he agrees with Weitzman that it is reasonable to assume that the relevant probability distributions are fat-tailed. He does not dismiss the possibility of an extreme climate-induced outcome, and notes that sufficiently fat tails justify swift action without any complex analysis, but he believes that steep emission reductions may also be justified even if assuming thin tails. In view of other potential disasters faced by the world, the shape of the tails will not provide much guidance as far as political decision making is concerned. The decisions must be considered in the context of other important social priorities, such as the cost of taking precautions against other potential disasters.

In a rejoinder to the criticism, Weitzman (2011) writes, *inter alia*, that the existence of other potential disasters does not eliminate the special cause for concern occasioned by climate change. He could also have chosen different specifications for society's utility function than those adopted in his original analysis. The key observation is that potentially fat tails should make economists less confident about cost-benefit calculations within this area.

8.6 The assessment of the Committee

As far as policy implications relating to irreversible effects are concerned, the Committee is of the view that no decisive theoretical or empirical developments have unfolded since the NOU 1997: 27 Green Paper. This would also appear to be confirmed by Pearce et al. (2006). When faced with irreversible effects, one should, if the project can be postponed and such postponement enables new information of relevance to decision making to be gathered, take into account the (quasi-) option value associated with a wait-and-see alternative. A positive net present value based on a cost-benefit analysis will not necessarily imply that it is profitable to implement the project immediately. The expected net present value of implementing the project immediately must also exceed the option value associated with the wait-and-see alternative.

It is often difficult or impossible to calculate the (quasi-)option value, but it is important to be aware of it, and to describe and assess the implications of waiting. Although the examples discussed here are principally obtained from the environmental arena, the Committee notes that there are also other types of irreversibility. Examples may be infrastructure investments, and decisions that influence the choice of technology. Whether (quasi-)option values of relevance to the analysis arise will depend on the scale, scope and duration of the effects, and on whether relevant, new knowledge can be gathered if the project is postponed.

If one is unable to conclude that the probability of catastrophic effects is negligible, the standard method of analysis for risky outcomes (where the probability distribution is assumed to be known) may underestimate, potentially to a considerable extent, the expected cost of society being exposed to an unknown degree of disaster risk. If such is the case, traditional cost-benefit analysis will not be a suitable tool for calculating an optimal safety level.

The Committee takes the view that one should in such cases, first of all, attach considerable weight to describing both what one knows about the possibility of catastrophic outcomes, as well as the knowledge deficiencies of which decision makers should be aware. There will be a difference between analyses where potentially catastrophic effects are the main focus, on the one hand, and analyses of measures involving some effects that may influence the probability of disaster, on the other hand. The level of ambition will usually, at least implicitly, be determined as a "safe minimum standard". Cost-effectiveness analysis may contribute to shedding light, for the benefit of decision makers, on what amount of resources is allocated to risk reduction within different sectors. It may, in such a context, be of interest to highlight whether more resources are devoted, on the margin, to reducing the risk of death or injury in catastrophic and/or dramatic scenarios, when compared to more "mundane" accidents that cause, in aggregate, the same amount of damage, and possibly more. The Committee does, however, acknowledge that certain disasters may involve aspects and dimensions that make such comparisons less relevant to decision makers. The Committee has not considered defining what qualifies as "catastrophic effects", and what does not, as falling within the scope of its terms of reference.

Generally speaking, the cost-benefit analysis of safety measures is at an early stage of theoretical development. Various types of break-even analysis may contribute to indicating how large a reduction in the probability of a terrorist act or similar incident must be entailed by a safety measure in order for such measure to be justified on economic grounds.

The Committee also refers to Report No. 29 (2011-2012) to the Storting, "Civil Security and Safety", in which the Government outlines various measures to strengthen civil protection efforts. The Report addresses practical matters relating to civil protection efforts within various areas of society, including the organisation of such efforts.

The debate amongst economists concerning the economic analysis of the climate issue reviewed in the present Chapter provides an illustration, at the global level, of the issues raised by disasters and irreversible effects. It may in this context be appropriate to examine whether the relationships under assessment are linear, or whether there may exist threshold values beyond which effects that are not only irreversible, but potentially catastrophic, could arise.

The fundamental lesson from the debate surrounding Weitzman's dismal theorem is the importance, in the cost-benefit analysis of situations involving potentially catastrophic outcomes, of assessing whether or not the probability of disaster is negligible. However, believing that the probability is low and/or approaches zero is, in this context, not sufficient to conclude that it is negligible.

Firstly, one needs to examine whether costs increase by so much in the event of more extreme outcomes that it will, in full or in part, outweigh the effect of a declining probability of such outcomes; cf. the above discussion. In other words, it is not only the level of probability, but also the costs, that determine whether the possibility of an improbable outcome can be ignored. Secondly, one needs to take into consideration how certain one is that the probability of a disaster is low. If, strictly speaking, one does not know very much about such probability, the actual uncertainty faced by society may potentially be much higher (than it would have been if the risk had been correspondingly low, but fully known). A traditional risk assessment in which the disaster probability is held to be low, but known, does in practice make active use of two types of probability information: firstly, its level, i.e. how probable one believes a disaster to be, and secondly, its precision, i.e. that the probability figure is certain – which implies, *inter alia*, an assumption to the effect that one knows that one is not mistaken, and therefore has not significantly underestimated the disaster risk.

If one is not certain that the disaster risk is negligible, the fundamental observation of Weitzman (2009) is that we should think along the lines of insurance against disaster, i.e. a precautionary principle. The two-degree target may be interpreted as reflecting such an approach, in the form of a "safe minimum standard".

8.7 Summary recommendations

- When faced with irreversible effects, it will at times be possible to get more information about the effects of the measures by postponing execution. In formal terms, this may be expressed as a (quasi-)option value. Such values may be difficult to estimate, but the advantages of postponing implementation should nevertheless be described and assessed.
- In the cost-benefit analysis of situations with a potentially catastrophic outcome, it is important to examine whether or not the probability of such catastrophic outcome is negligible. In order to safely ignore a disaster probability it is, in principle, necessary to know 1) that the level of the disaster probability is very low, 2) that the level of the disaster probability is well known (and therefore not uncertain in itself), and 3) that the cost increase in the event of more extreme outcomes is not sufficiently steep to (in full or in part) outweigh the fact that more extreme outcomes are less probable.
- If the probability is not negligible, or if one is unable to conclude that such is the case, the standard method of analysis may underestimate, potentially to a significant extent, the cost associated with society being exposed to an unknown degree of disaster risk. The Committee is of the view that one should in such cases attach considerable weight to describing both what one knows about the possibility of catastrophic outcomes, as well as the knowledge deficiencies the decision makers have to be aware of. The level of ambition will usually, at least implicitly, be determined as a "safe minimum standard".
- Cost-benefit analysis should be used to highlight the amount of resources used, implicitly or explicitly, for risk reduction within various sectors, in order to improve the basis for making decisions about sensible resource allocation. The theoretical literature within the area of safety regulation is in development. Various types of break-even analysis may provide information about the minimum probability of a terrorist act, or a similar incident, that may justify a safety regulation.

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Chapter 9
Carbon price paths

9.1 Introduction

From the terms of reference of the Committee:

> There is considerable uncertainty associated with future international climate negotiations, and consequently with future emission prices. By basing the cost-benefit analysis of public measures on uniform assumptions with regard to the future prices of greenhouse gas emissions, everyone preparing calculations for public investment projects will apply the same assumptions in such respect. This will contribute to projects being dealt with in a consistent and comparable manner. The NOU 2009: 16 Green Paper; "Global Environmental Challenges - Norwegian Policy", recommends that a carbon price path be included in the cost-benefit analysis circular of the Ministry of Finance, thus making this mandatory for all central government cost-benefit analysis. The Expert Committee shall assess the said recommendation and propose potential guidelines for the pricing of greenhouse gas emissions in view of two alternatives; one carbon price path that reflects current expectations with regard to future prices in the EU ETS, and one path that supports the 2-degree target supported by Norway.

Public investments and projects will often have an impact on greenhouse gas emissions[1]. Transportation projects or new investments in the defence sector may be good examples of this. Increased emissions result in undesired global climate effects and thus impose a cost on other economic agents, or on society. Projects that result in emission reductions will, correspondingly, entail a benefit. All changes in greenhouse gas emissions should be valued for cost-benefit analysis purposes.

Whilst Chapter 4 on changes in real prices focused on how environmental goods can be valued and subjected to real price adjustment for cost-benefit analysis purposes, the present Chapter will specifically address greenhouse gas emissions. A stable climate differs from many other environmental goods, principally, in its global nature and in the possibly irreversible and potentially serious effects of major changes. Emissions have the same impact on the atmosphere irrespective of whether these take place in Norway or elsewhere on Earth. The focus on international agreements and cap-and-trade systems is one of the reasons for discussing greenhouse gas emissions separately, and not together with other environmental goods, in the present Report. This is also in line with the terms of reference.

Because the detrimental effect of greenhouse gas emissions (the social cost of carbon) is independent of the geographic location of such emissions, a cost-efficient climate policy will involve all agents facing one identical price for such emissions. In a theoretical scenario where one joint carbon price is applicable worldwide (i.e. to all emissions), it would be appropriate to apply (the best estimate for) the social cost of carbon for cost-benefit analysis purposes in Norway. No such global carbon price exists at present, and slow progress in the international negotiations under the UN Framework Convention on Climate Change suggests that an international agreement resulting in one global carbon price is unlikely to be a realistic prospect anytime soon.

The absence of a global market for greenhouse gas emissions therefore implies that sufficient mechanisms are not in place to ensure that the marginal cost of reducing emissions (the marginal abatement cost) equals the marginal cost to

[1] The literature tends to talk about greenhouse gas emissions and a carbon price (not a "greenhouse gas price") associated therewith. In the first commitment period of the Kyoto Protocol, a total of six different gases were defined as greenhouse gases (see Annex A to the Kyoto Protocol, 1998). The number of gases (or groups of gases) was increased to seven in the second commitment period of the Kyoto Protocol. The term CO_2 equivalents is used in order to facilitate comparison between the gases, i.e. the gases are "converted" into CO_2.

society of increased emissions (the marginal social cost of carbon). Consequently, the abatement cost varies between sectors and across borders, whilst the global marginal social cost of carbon will always be the same. It may in practice be difficult to estimate the marginal social cost of carbon. It is therefore not obvious what calculation price for greenhouse gas emissions should be applied for cost-benefit analysis purposes in Norway.

A general cost-benefit analysis principle is that calculation prices for private goods should be identical to producer prices. This results in overall production efficiency when the private and the public sector are considered as a whole. However, we will see that carbon prices in Norway vary considerably between different economic agents. Large parts of Norwegian emissions fall within the scope of the EU Emissions Trading System (the "EU ETS") for businesses, where the carbon price is determined in the cap-and-trade system. Other emission sources are taxed, at tax rates that vary quite significantly between sectors, whilst for example the agricultural sector is exempted from carbon pricing. For public investments, however, it would be reasonable to envisage that all projects should be examined on the basis of identical calculation prices for greenhouse gas emissions. If the same effects are priced differently in different project alternatives, no meaningful profitability comparison is feasible. The current tax structure means that it is not possible to ensure that calculation prices for private goods are identical to producer prices whilst, at the same time, public projects are examined on the basis of identical carbon prices.

NOU 2009: 16 Green Paper; Global Environmental Challenges – Norwegian Policy, provides a comprehensive and thorough account of principles for an appropriate Norwegian climate policy. Chapter 13 of the NOU 2009: 16 Green Paper; *Key recommendations and implications for regulatory frameworks, etc.*, recommends, *inter alia*, that "*central government should formulate a carbon price path to be used for central government cost-benefit analysis purposes and to provide guidance for the regulation of greenhouse gas emissions … The carbon price path should be included in the cost-benefit analysis circular of the Ministry of Finance, and thus be made mandatory for all central government cost-benefit analysis*" (page 131). The terms of reference explicitly request the present Committee to consider the above mentioned recommendations from the NOU 2009: 16 Green Paper. Moreover, the terms of reference request the Committee to propose guidelines for the pricing of greenhouse gas emissions in view of the EU cap-and-trade system and the two-degree path.

The Committee will in the present Chapter discuss the issues raised in the terms of references with regard to determining a calculation price for greenhouse gas emissions for cost-benefit analysis purposes, with a focus on the recommendations from the NOU 2009: 16 Green Paper. A number of important topics within the climate area will be discussed rather briefly or not at all in the following. The Committee refers to the NOU 2009: 16 Green Paper for a more general approach and discussion of the climate challenges and Norwegian climate policy.

The structure of the Chapter is as follows: In Chapter 9.2 we briefly discuss the background to the pricing of greenhouse gas emissions, before presenting, in Chapter 9.3, an overview of Norwegian climate commitments and which carbon prices one can observe in Norway today. Chapter 9.4 discusses the current international cap-and-trade systems, as well as the two carbon price paths referred to in the terms of reference. In Chapter 9.5, we discuss principles of relevance to choosing which carbon price path should be use for the cost-benefit analysis of public projects. Chapter 9.6 provides a brief description of the use of carbon price paths in Norway and some other countries, whilst 9.7 and 9.8 present the assessments and recommendations of the Committee, respectively.

9.2 Background to the pricing of greenhouse gas emissions

Greenhouse gas emissions contribute to global warming and climate change. The basis for regulating the emission of CO_2 and other greenhouse gases is that these indirectly impose costs on the international community that the emitter does not take into consideration when making decisions. The emissions therefore represent a global *externality* (see Chapter 2 for a more detailed description). The "Stern Review on the Economics of Climate Change" (Stern, 2006), which was commissioned by the UK authorities, prepared by Sir Nicholas Stern and published in October 2006 (hereinafter referred to as the "Stern Review"), provided a thorough review of economic aspects of the climate challenge and drew considerable attention. The report refers to climate change as the *"greatest market failure the world has seen"*.

Box 9.1 Carbon prices and cost-effectiveness

As reduction of greenhouse gas emissions is costly to society, it is desirable for economic agents to internalise the negative external costs they impose on others. This may be achieved by introducing a carbon price that corresponds to such cost. There are two main ways of introducing such a price:

- Firstly, by imposing a *tax* on emissions. For each tonne of CO_2 equivalent (hereinafter referred to as "CO_2e"; see footnote 1) emissions, the emitter pays a tax to central government.
- Secondly, by introducing a *cap-and-trade system.* A cap-and-trade system comprises a fixed number of emission allowances. The overall allowance volume acts as an emissions cap for all agents in this market. The agents are required to hand over one allowance to the authorities for each tonne of CO_2 they emit. Because the allowances are tradable between the agents, an equilibrium price will be established for the allowances. Hence, the price of an allowance is what agents must pay in order to emit one tonne of CO_2.

Assuming that the tax rate is the same for everyone, that the allowance volume covers all emissions and that no agents have market power, both mechanisms will result in cost-efficient investment decisions: All climate measures that cost less to implement than paying the tax or the allowance price, will be profitable to the enterprise. Measures involving a cost in excess of such price will not be implemented. In other words, the cheapest measures will be implemented. If the tax rate or the allowance price established is equal to the social cost of carbon, the system achieves an optimal trade-off between the social cost of carbon and abatement costs.

Taxes and cap-and-trade systems may be designed in various ways, with partly varying effects. Hagen (2010) provides a discussion of the use of allowances and taxes under alternative assumptions.

The authorities have several policy measures at their disposal that may remedy this market failure. One way of getting economic agents to internalise the negative external costs they impose on others is to introduce an emission price that corresponds to such cost. Setting the same price for all greenhouse gas emissions will result in a cost-efficient climate policy, under the assumption of well-functioning markets. There are two main methods for introducing such a price: A tax on greenhouse gas emissions or a market for trading in allotted emission allowances (see Box 9.1). The present Chapter will refer to both taxes and allowance prices as "carbon prices".

The authorities may also influence emissions through other policy measures, like direct regulations (orders/prohibitions and quality standard requirements), subsidies (for e.g. the development of new technology) and the dissemination of information. In principle, although not always in practice, a marginal cost (or shadow price) of the abatement measures can be calculated in respect of such policy measures as well. In some situations, such policy measures can work well (for example if households have inadequate information), but it can also be the case that implications become difficult to ascertain when several policy measures are in use, and one policy measure may have a negative impact on the effects of another. In such case, the overall cost of achieving emission reductions may be unnecessarily high.

There are also other measures for preventing climate change apart from emission reductions. The technology carbon capture and sequestration seeks to capture CO_2 from, for example, coal power plants and sequestrate it instead of releasing it into the atmosphere. Geo-engineering is concerned with alternative methods for reducing temperatures on Earth (like, for example, making more clouds or removing greenhouse gases from the air). The Committee does not embark on a detailed examination of other climate-related policy measures than allowances and taxes.

9.3 Norwegian commitments and carbon prices in Norway

9.3.1 Norwegian commitments and targets

The UN Framework Convention on Climate Change (the "Climate Convention") and the Kyoto Protocol are the key binding international legal instruments within the climate area internationally today; see Box 9.2. The ultimate objective of the Convention is to stabilise greenhouse gas concentrations at a level that would prevent undesirable anthropogenic interference with the climate system. Norway has supported a target of limiting the increase in the global mean temperature to two degrees Celsius relative to pre-industrial levels.[2]

Box 9.2 The UN Framework Convention on Climate Change and the Kyoto Protocol

The UN Framework Convention on Climate Change (the "Climate Convention") was adopted in Rio de Janeiro in 1992. The ultimate objective of the Climate Convention is to stabilise greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system, and it sets out commitments on the curtailment of greenhouse gas emissions. The negotiations under the Convention resulted in the adoption of the Kyoto Protocol in 1997. The Kyoto Protocol was the first international agreement to include binding, quantified restrictions on greenhouse gas emissions and entered into force on 16 February 2005. The objective of the agreement was to reduce, over the period 2008-2012, overall greenhouse gas emissions from the industrialised countries by a minimum of 5 percent relative to 1990. The regulatory framework established by the agreement provides each industrialised country with a given number of emission allowances, permitting them to emit a specific number of tonnes of CO_2e during the period 2008-2012. The number of such emission allowances – or quotas – is defined as a percentage of the countries' greenhouse gas emissions in 1990, which varies from 92 percent to 110 percent of their 1990 emissions.

The provisions of the Kyoto Protocol imply that countries with binding emission commitments may meet these in four different ways:

a. reduce their own emissions;
b. purchase emission allowances from other countries with emission commitments;
c. implement climate projects in other countries with emission commitments (Joint Implementation, "JI"); and
d. implement climate projects in countries without emission commitments, like e.g. China or India (Clean Development Mechanism, "CDM").

Greenhouse gas emissions from Norwegian territory are estimated at 54 million tonnes CO_2e as an annual mean for the first Kyoto period, 2008- 2012 (National Budget, 2012). Norway was allotted a total annual quota (or emission allowance) volume that was 1 percent higher than its emission volume in 1990, i.e. 50.1 million allowances. As Norway's emissions have exceeded the allotted volume, it has been necessary for Norway to purchase allowances to cover part of the Norwegian emissions.[1] Norwegian authorities have only made use of b. and c. to a very limited extent.

The emissions of countries with commitments during the first commitment period of the Kyoto Protocol; 2008–2012, represent just below 30 percent of total global emissions. During the climate negotiations at the Conference of the Parties in Durban in South Africa in 2011, agreement was reached on a second commitment period under the Kyoto Protocol, from 2013. It is, for the time being, unclear how long such period will be, which countries will participate, and how ambitious the emission commitments will be. However, it would appear that the second commitment period will be much less comprehensive than the first one in terms of the number of participant countries.

[1] Norwegian enterprises encompassed by the EU ETS are already purchasing more EU allowances than is necessary to meet Norway's commitments during the first commitment period under the Kyoto Protocol. It is therefore, more precisely, Norway's objective of over-compliance with the Kyoto Protocol that necessitates central government allowance purchases. Norwegian authorities will be purchasing a total of about 20 million CDM credits in connection with the first commitment period under the Kyoto Protocol. See Report No. 1 (2012-13) to the Storting; National Budget 2012, Chapter 3.9 and Table 3.17 for a discussion and overview of Norway's Kyoto accounts. See also the Ministry of Finance website for an updated overview of concluded central government allowance purchase contracts.

Norway's commitments under the Kyoto Protocol (1998) play a key role in Norwegian climate policy. A basic premise of the Kyoto Protocol is that those industrialised countries which have ratified the agreement (the so-called *Annex B countries*) are required to hold a number of UN-approved emission allowances matching each country's total national emissions during the commitment period. In other words, the countries are subject to a *national* allowance requirement. If the total emissions of a country exceed the emission allowances such country has been allotted through the agreement, the authorities in the said country will have to acquire additional emission allowances.

In addition to the national emission commitments of Norway under the Kyoto Protocol, Norway also participates in the EU Emissions Trading System for businesses (the "EU ETS"); see Box 9.3. Norwegian enterprises subject to allowance requirements under the EU ETS (the "*allowance requirement sector*"[3]) must hand over allowances matching their emissions to the Norwegian authorities. The allowances submitted by such enterprises are used to meet the national allowance requirement under the Kyoto Protocol.[4]

Norway also has a long-term climate target that is not embedded in international agreements. In Report No. 34 (2006-2007) to the Storting; Norwegian Climate Policy (the first "*Climate Report*"), the Government formulated the following target (the "30-percent target"):

> Norway shall until 2020 make a commitment to reducing global greenhouse gas emissions by an amount corresponding to 30 percent of Norway's emissions in 1990.

In the same document, the Government also presented a domestic emission reduction target for 2020 as follows:

> Based on the analysis of measures carried out by the National Pollution Control Authority[5], the sectoral climate action plans, as well as existing policy measures, the Government is of the view that it is realistic to seek to reduce emissions in Norway by 13–16 million tonnes of CO_2 equivalents relative to the reference path as presented in the National Budget for 2007, when forests are included. This would imply that about half, and up to two thirds, of Norway's total emission reductions are effected nationally.

In addition, the Government called for Norway to be carbon neutral by 2050, i.e. that Norway shall ensure (global) emission reductions corresponding to Norwegian emissions in 2050.

In the Agreement on the Climate Report (2008) (the "*Climate Settlement*"), the Socialist Left Party, the Labour Party, the Centre Party, the Conservative Party, the Christian Democratic Party and the Liberal Party agreed "that the interval from the Government's Climate Report can be expanded to 15–17 million tonnes of CO_2e. … This would imply that about two thirds of Norway's total emission reductions are effected nationally." The parties also supported the 30-percent target. Moreover, agreement was reached on the following:

> As part of a global and ambitious climate agreement under which other industrialised countries also make major commitments, the parties agree that Norway should commit itself to achieving carbon neutrality no later than 2030.

In the wake of the Conference of the Parties in Copenhagen in 2009, Norway also submitted the following expansion of the 30-percent target to the UN:

> As part of a global and comprehensive agreement for the period beyond 2012 where major emitting Parties agree on emission reductions in line with the 2 degrees Celsius target, Norway will move to a level of 40 per cent reduction for 2020.

On 25 April 2012, the Government submitted a new Climate Report, Report No. 21 (2011-12) to the Storting; Norwegian Climate Policy (2012). The following is stated on page 14: "The climate

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2 The two-degree warming target was first proposed by the EU on the basis of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007). The target has subsequently been recognised as a joint, long-term objective at the Conference of the Parties to the UN Framework Convention on Climate Change in Cancún in 2010 (the Cancún Agreements, 2010, paragraph 4).

3 It should hence be noted that the term "allowance requirement sector" refers to Norwegian enterprises subject to an allowance requirement under the EU ETS, and not to the general Kyoto commitment (which pertains to overall Norwegian emissions).

4 See Report No. 1 (2012-13) to the Storting; National Budget 2012, Chapter 3.9.5., for a more detailed explanation of the relationship between Norway's Kyoto commitment and the EU ETS for enterprises.

5 Now the Climate and Pollution Agency ("Klif").

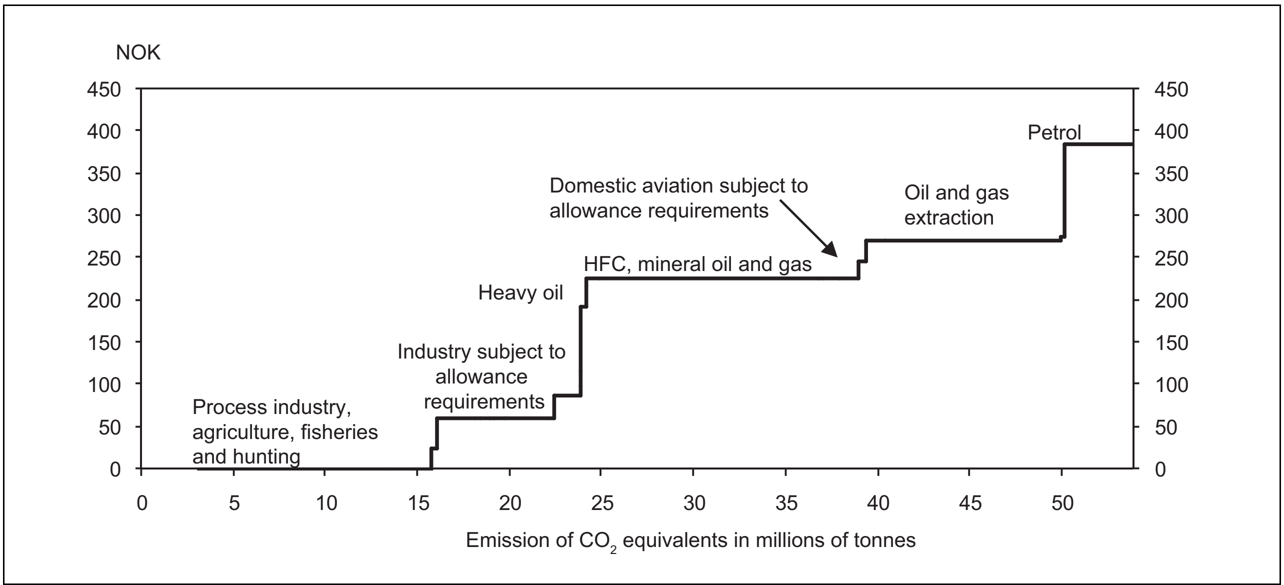

Figure 9.1 Carbon prices in various sectors. NOK per tonne of CO_2 equivalents in 2012. (Allowance price of NOK 61 per tonne of CO_2.) Emission figures from 2010.

Source: Ministry of Finance

targets as specified in the Climate Settlement remain unchanged."

Proposition No. 111 (2011-2012) to the Storting, submitted on 15 May 2012, states the following (page 74):

> The Government will establish, within the scope of the EU guidelines on state aid, a scheme for the reimbursement of indirect allowance costs in Norway, cf. the guidelines being drafted pursuant to Article 10a No. 6 of the revised EU ETS Directive. The Government will revert on how a Norwegian scheme shall be defined after the contents of the EU guidelines have been clarified.

9.3.2 Carbon prices in Norway

In 2012, about 70 percent of Norwegian greenhouse gas emissions will be subject to a carbon price. The prices faced by economic agents in Norway can be divided into two categories:

- CO_2 tax: CO_2 tax is payable upon the purchase of petrol, mineral oil and natural gas/LPG. In 2012, about 35-40 percent of Norwegian greenhouse gas emissions were liable to tax. Emissions from the Norwegian petroleum sector are additional thereto (about 25 percent), and are both subject to allowance requirements and liable to tax. (The majority of domestic aviation activities, as well as some uses of natural gas, are also both liable to tax and subject to allowance requirements.)
- Allowance price: Major parts of onshore manufacturing industry fall within the scope of the European cap-and-trade system for enterprises (the "EU ETS"). From 2012, greenhouse gas emissions from the aviation sector are included in the cap-and-trade system. The portion of emissions subject to allowance requirements will be just below 40 percent of total Norwegian emissions in 2012 (inclusive of the emissions from the Norwegian petroleum sector). From 2013, the cap-and-trade system will be further expanded to encompass more manufacturing industry enterprises (including major parts of process industry). The price of the EU allowances is determined within the cap-and-trade system. Enterprises subject to EU ETS allowance requirements may also make use of the Clean Development Mechanism ("CDM"); see Box 9.3.

One will note from Chart 9.1 that there are major variations in carbon prices in Norway. The CO_2 tax on petrol is the highest, at NOK 384 per tonne of CO_2 (NOK 0.89 per litre) in 2012. The process industry has been exempted from taxes and allowance requirements up and until 2012, but becomes part of the EU ETS from 2013. Agriculture, fisheries and hunting are exempted from tax, and are not included in the EU ETS either. The price of EU allowances is recorded in the chart, at NOK 61 per tonne of CO_2e. Additional information on the CO_2 tax structure in Norway is available in Chap-

Box 9.3 EU cap-and-trade system for enterprises

The EU cap-and-trade system for enterprises (the "EU ETS") was established in 2005. The first phase of the system is referred to as a test phase, and lasted from 2005 to 2007. The current phase runs from 2008 to 2012. The third phase will run from 2013 to 2020. It is expected that the cap-and-trade system will also be continued after that time. The cap-and-trade system encompasses greenhouse gas emissions from power plants, manufacturing industry, offshore petroleum production and aviation (from 2012) in all the EU 27 member states, as well as Norway, Iceland and Liechtenstein. Enterprises falling within the scope of this system are subject to allowance requirements, and must hand over allowances corresponding to their emissions to central government (which allowances are then used to meet the national allowance requirement under the Kyoto Protocol). Emissions from road transportation, agriculture, waste disposal sites and energy consumption in buildings are not included.

The total EU ETS allowance volume for 2013 is 2.04 billion tonnes, which represents somewhat in excess of 40 percent of greenhouse gas emissions in participating states and about 4 percent of global greenhouse gas emissions. Current policy calls for the annual allowance volume to be reduced by 1.74 percent every year after 2013 (EU Directive 2009/29/EC). This would imply an allowance volume in 2020 that is 21 percent below the 2005 emission level of the enterprises subject to allowance requirements. The third phase accounts for two thirds of the EU target of a 20-percent emission reduction in 2020, relative to 1990.

Enterprises subject to EU ETS allowance requirements may also use the Clean Development Mechanism ("CDM"). The two main purposes of the establishment of this mechanism were to assist developing countries in achieving sustainable development and to assist industrialised countries in meeting their commitments under the Kyoto Protocol (Article 12 of the Kyoto Protocol, 1998). The mechanism enables enterprises and countries to purchase allowances created through project activities in countries without emission commitments; for example India and China. Since the EU cap-and-trade system for enterprises permits enterprises to submit CDM allowances (instead of "ordinary" EU allowances) in respect of a portion of their emissions, the prices of these two types of allowances have been closely correlated.

ters 2 and 4 of Direct Taxes, Indirect Taxes, Customs Duties 2012 (2012).

A differentiated tax structure, like that illustrated by the chart, will increase the economic costs of reducing emissions, and is therefore, generally speaking, not cost-efficient. However, a desire to protect specific industries may lead to a conscious political choice to deviate from the principle that the price structure should be cost-efficiently designed. In Norway, we have for example noted that the agricultural sector is exempted from tax on CO_2 emissions. Traditionally, the prices of greenhouse gas emissions in energy-intensive industries exposed to international competition have been lower than in other industries. The latter may reflect carbon leakage considerations. An implication of a deeply integrated world economy is that measures which reduce emissions in Norway or Europe, may result in increased emissions outside Europe. It may thus be argued that industries particularly exposed to such leakage should be subject to less stringent climate regulations. Bye and Rosendahl (2012) divide the most frequently discussed carbon leakage effects into two categories:

- *The energy market effect* works via the market for fossil fuels. Climate policy in a group of countries will normally reduce their consumption of oil, gas and coal, which will typically also result in lower prices for these goods internationally. Countries that do not pursue a corresponding climate policy may thus increase their consumption of these fuels.
- *The competition effect* works via the markets for energy-intensive goods exposed to international competition (for example metals, cement and chemical products). If climate policy results in higher production costs in energy-intensive sectors, the profitability of enterprises in such sectors will deteriorate, and increase correspondingly in countries without a climate policy.

Generally speaking, the amount of carbon leakage is inversely related to the size of the geographic area introducing a higher carbon price. Macro-based analyses indicate 10-30 percent carbon leakage upon the introduction of a unilateral carbon price for large geographic areas like the OECD or the EU (i.e. that each tonne of CO_2 emission reduction due to climate policy in a specific area is accompanied by a 0.1–0.3 tonne emissions increase outside such area) (Bye and Rosendahl, 2012). For smaller areas, like each of the Scandinavian countries, leakage is much higher, and studies indicate that it may reach 60–90 percent (Nordic Council of Ministers, 2012). Micro-based studies tend to generate higher carbon leakage estimates than do macro-based studies (Nordic Council of Ministers, 2012). For energy-intensive industries like cement, iron and steel, such studies indicate 40–50 percent leakage even for large regions (Nordic Council of Ministers, 2012).

We will revert in more detail to criteria for the realisation of climate policy targets and principles for the valuation of greenhouse gas emissions in Chapter 9.5. Reference is also made to Chapter 9 of the NOU 2009: 16 Green Paper.

9.4 International carbon price paths

9.4.1 Current international cap-and-trade systems

Norwegian discussions on current international cap-and-trade systems tend to focus on the EU cap-and-trade system for enterprises. However, other systems are in existence: The Kyoto Protocol cap-and-trade system enables countries to engage in the purchase and sale of allowances between countries with commitments under the Kyoto Protocol. Such allowances are termed AAUs; see the discussion in Box 9.4. In addition, smaller cap-and-trade systems have been established, or are emerging, in the United States, Canada, New Zealand, Japan and Australia.

The allowance price under the EU ETS for enterprises, both for the current year and for the years until 2020, is determined in the market on a continual basis. The allowance price is quoted on a daily basis. There are several market places for trading in EU allowances, including, *inter alia*, the European Climate Exchange (ICE ECX), NASDAQ OMX (formerly Nord Pool), and the Nordic power exchange (Nord Pool Spot). Spot prices and futures prices are quoted for both EU allowances ("EUAs") and for approved allowances from CDM projects ("CERs").

Chart 9.2 shows developments in the spot price of EU allowances ("EUAs") and CDM allowances ("CERs") since 2009. Prices have fluctuated

Box 9.4 Different allowance types

The following abbreviations designate the various allowances (with each allowance representing one tonne of CO_2e emissions) under the Kyoto Protocol and the EU ETS for enterprises:

- *AAU:* Assigned Amount Units ("AAUs") are the allowances that the authorities in countries with commitments under the Kyoto Protocol may sell or purchase ("Kyoto allowances"). Norway was allotted 5*50.1 million such allowances for the 2008–2012 Kyoto period.
- *EUA:* European Union Allowances ("EUAs") are the allowances under the EU ETS for enterprises ("EU allowances"), and are principally available for purchase and sale between enterprises. Norwegian enterprises submit these allowances to the Norwegian authorities, which exchange these for AAUs, in order to use these to meet the Kyoto commitment.
- *CER:* Allowances from the Clean Development Mechanism (the "CDM") are termed Certified Emissions Reductions ("CERs"), and are issued by the UN on the basis of projects in developing countries that result in emission reductions in countries without commitments.

Other types of allowances also exist globally. New Zealand uses New Zealand Units ("NZUs"), whilst Voluntary Emission Reduction ("VER") is the term used to designate so-called *voluntary* allowances; see for example Hamilton (2010).

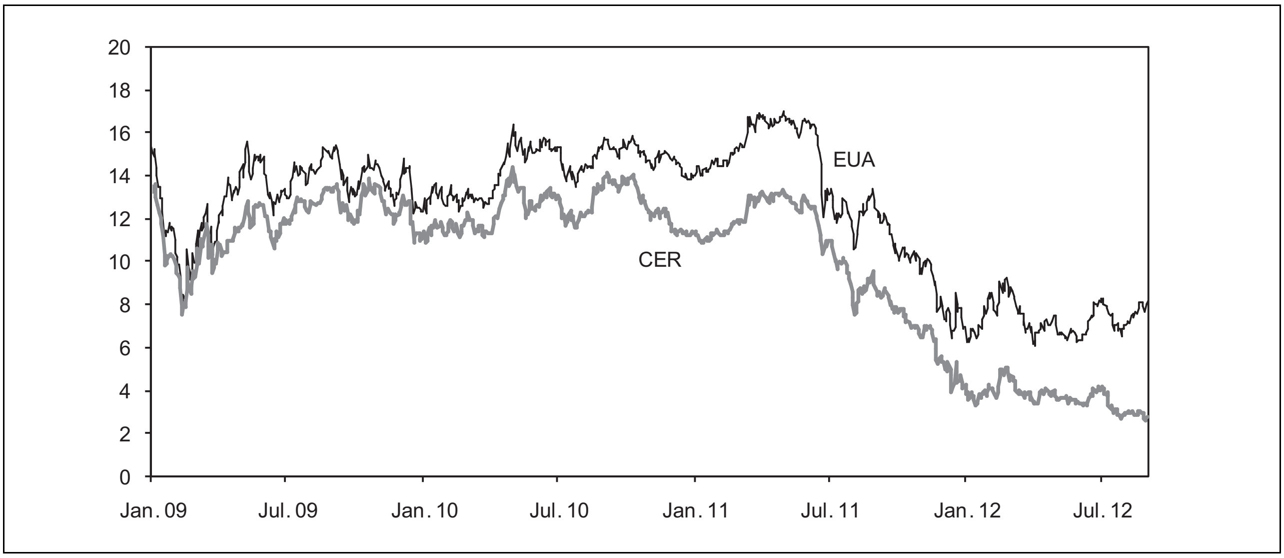

Figure 9.2 EU ETS spot price (“EUA”) and price of approved CDM allowances (“CERs”) from 1 January 2009 to 3 September 2012. EUR per tonne.

Source: Reuters EcoWin

considerably. The highest EUA quote during that period was on 2 May 2011 at EUR 17.03 euro per tonne, whilst the lowest quote was on 4 April 2012 at EUR 6.08 euro per tonne. Prices increased throughout 2009 in the wake of the rebound after the financial crisis in 2008, and contracted significantly again throughout 2011, primarily as the result of renewed cyclical downturn.

Political signals and pronouncements have, in addition to macroeconomic factors, energy prices and temperature fluctuations, had a major impact on the EU cap-and-trade system at times. The organisation of the cap-and-trade system and the determination of allowance volumes are key influences on what price clears the market. Expectations of changes in such factors may therefore affect allowance prices. One example of this having a major impact was the EU decision in the summer of 2011 *not* to increase, for the time being, emission reduction ambitions towards 2020, which resulted in a steep decline in prices. Germany’s decision to bring the phase-out of its nuclear power plant forward to 2022 had the opposite effect. A third example of market reactions to political statements came on 20 December 2011, when the price increased by more than 30 percent because an EU Parliament committee voiced its support for a draft legislative supplement to withhold “a significant” portion of allowances from the cap-and-trade system to bring about more scarcity and a higher allowance price (Wall Street Journal, 21 December 2011, page 4). Alberola and Chevallier (2009) study how the allowance price (during the first phase, 2005-2007) was influenced by various political decisions, especially the decision not to permit the saving of allowances from the first to the second phase.[6]

Although both EU allowances and CDM allowances have thus far been approved as EU ETS allowances, the CDM allowances have consistently carried a lower price tag than the EU allowances. The price difference may be caused by certain restrictions on the use of CDM allowances (see for example Mansanet-Bataller et al. (2010), which examines this price difference and its underlying causes in more detail).

9.4.2 Future carbon prices

The EU ETS and market prices for the submission of allowances

Future international carbon prices are subject to considerable uncertainty. Global economic devel-

[6] The market has also been characterised by statements from the European Commission that have at times been unclear or unfortunate. A well-know episode took place on 21 January 2011, when the Commission announced the outcome of a vote on which industrial gases should be permitted under the CDM. The announcement resulted in the price increasing to its highest level for three months. The Commission revoked the announcement only half an hour later, as the announced outcome turned out to be incorrect, which immediately resulted in an 11 percent price decline. A trader was quoted in The Guardian as having said that: “… [s]ome traders have lost a lot of money today. If I want a Mickey Mouse market, I'll go to Disneyland.” (The Guardian, 2011)

opments and the outcome of international climate negotiations in coming years may have a significant effect on the price of EU allowances. However, both economic theory and empirical studies may give us some indications as to how prices will develop in future.

The futures price is the price under a binding contract between two parties for the purchase/ sale of an emission allowance at a fixed future delivery date. Enterprises encompassed by the EU ETS are entitled to save allowances from a given year to future years. If we assume that the market is in equilibrium, investors must be indifferent between purchasing an allowance "now" (at the spot price) and purchasing an allowance for delivery in a later year (at the futures price).[7]

Futures prices for allowances under the EU ETS are quoted for a number of years ahead. Currently observed futures prices therefore provide a basis for estimating future EU ETS spot prices, all else being equal. As an estimate of allowance prices for the period for which no futures prices are quoted, it is possible to use the current spot price extrapolated at an interest rate that reflects the opportunity cost of capital (on the margin) of the investors in the cap-and-trade system (with the same risk).

Model simulations and studies of the cap-and-trade system can also be useful for purposes of obtaining information about future prices. The work relating to Climate Cure 2020[8] (2010) involved the preparation of a separate sub-report on future allowance prices (Climate Cure 2020, 2009). Three different scenarios for EU ETS allowance price developments until 2020 were presented due to a high level of uncertainty, based on calculations made by Statistics Norway and Point-Carbon; see Table 9.1.

The report also discusses allowance prices after 2020, but emphasises that uncertainty in that respect is so high that it chose to start out from prices that were compatible with the two-degree path (see below), rather than explicitly preparing its own allowance price estimates. Climate Cure 2020 assumes a carbon price of EUR 100 per tonne from 2030 onwards, based on the calculations from Point Carbon.

Table 9.1 Estimated future allowance prices from Climate Cure 2020. EUR per tonne of CO_2e

	2012	2015	2020
Low	16	18	25
Medium	17	26	38
High	20	40	60

Fixed prices. Unknown base year.
Source: Climate Cure 2020 (2009).

In practice, future allowance prices under the EU ETS are subject to considerable uncertainty. Prices will be influenced by the negotiations relating to a new commitment period under the Kyoto Protocol, which are to be completed by the end of 2012. Ambitious targets may, for example, signal higher prices in future (although it is unclear to what extent the negotiations concerning the second commitment period will have a direct impact on the EU targets).

The current EU emission target is to reduce emissions by 20 percent in 2020 relative to the emission level in 1990. Whether the target should be increased to 30 percent has been discussed internally within the EU for a long time. Low carbon prices for a protracted period of time, both as the result of the financial crisis and as the result of other climate measures introduced by the EU, have given rise to a concern that necessary restructuring desired by the EU is being implemented too slowly. In addition, very low prices may undermine confidence in the cap-and-trade system. One implication of the low prices is that it may be politically more feasible to increase the target, i.e. to lower the allowance cap. In late July 2012, the European Commission proposed that part of the allowances to be auctioned before 2015 be withheld in order to increase the market allowance price. Whether the allowances will be withheld temporarily (and auctioned later) or permanently is under discussion.

The future prospects of the market for CDM allowances are also subject to considerable uncertainty. In 2011, the EU decided not to accept the introduction of additional CDM allowances into the EU ETS from CDM projects registered by the UN after 2012, unless such projects originate in

7 Since the futures price is the *certain* price at which an allowance may be purchased and sold in future, risk considerations may result in differences between the futures price and the expected spot price.

8 The report Climate Cure 2020 was commissioned by the Ministry of the Environment and drafted by an expert group comprising the Norwegian Water Resources and Energy Directorate, the Norwegian Petroleum Directorate, the Norwegian Public Roads Administration, Statistics Norway and the Climate and Pollution Agency. The report was published in 2010. The report was to provide the basis for the Government's evaluation of climate policy and the need for changes to policy measures as announced in Report No. 34 (2006–2007) to the Storting; Norwegian Climate Policy (the first "Climate Report").

Box 9.5 Key outcomes from the climate negotiations in South Africa in 2011

At the Conference of the Parties to the UN Framework Convention on Climate Change in Durban in South Africa in 2011, countries reached agreement on, *inter alia*, the following:

1. A new commitment period under the Kyoto Protocol, with the EU (including new applicant countries), Norway, probably Switzerland, and possibly also Australia and New Zealand and certain other countries. Formal quantification of the commitments will take place at the Conference of the Parties in December 2012.
2. A decision to negotiate (a roadmap for) a legal agreement to encompass all countries. The negotiations shall be completed by 2015 and the agreement shall enter into effect in 2020 at the latest.
3. Establishment of the Green Climate Fund, which may potentially become a main channel of climate funding for developing countries.
4. A decision to define a new market mechanism under the Convention, as well as to embark on the effort to draft provisions to govern such mechanism. Work to develop standards on other market mechanisms also to be commenced.

one of UN-designated least developed countries ("LDCs") or in countries with a bilateral emissions reduction agreement with an EU country. The decision is expected to result in a considerable reduction in the overall demand for CDM allowances after 2012, because the EU countries have thus far accounted for the majority of the overall demand for CDM allowances and because a very small number of CDM projects have thus far been registered in the LDCs.[9]

The decision at the Conference of the Parties to the UN Framework Convention on Climate Change in South Africa in December 2011 concerning a new commitment period under the Kyoto Protocol for the EU countries, Norway and certain other countries (not clarified as per the date of the present Report) may, on the other hand, contribute to sustained demand for CDM allowances; see Box 9.5. Potential new types of mechanisms that may replace or supplement the CDM, and that may generate larger allowance volumes, are also being examined. It was agreed, at the Conference of the Parties to the Climate Convention in South Africa in 2011, to commence work on a new *sectoral* mechanism (by sectoral is meant that the mechanism will encompass entire sectors rather than individual projects). The commencement of such work was an important negotiation outcome for the EU. This suggests that one can expect more allowances from countries without commitments to become available in the longer run. Such supply increase may hold back international carbon prices, but may also result in the EU permitting the expanded use of such allowances, as well as introducing a stricter emission target.

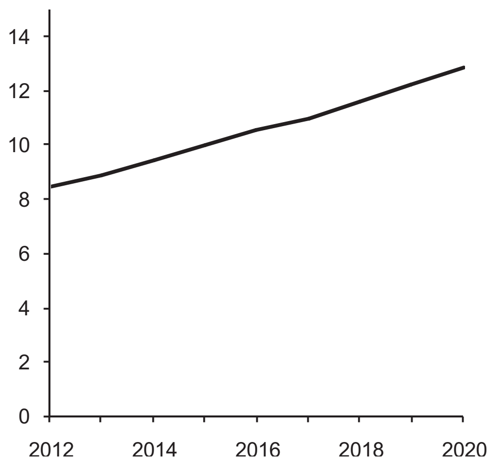

Figure 9.3 Futures prices under the EU cap-and-trade system as per 7 September 2012.

Market prices as per 7 September 2012 for the delivery of allowances in December each year until 2020. Euros per tonne of CO_2. Nominal prices.

Chart 9.3 shows the market price of EU allowances as per 7 September 2012 for the delivery of allowances in December each year for the years until 2020. Average annual nominal allowance price growth, as measured in Euros, is about 5.4 percent between now and 2020.

The two-degree path

The Intergovernmental Panel on Climate Change (IPCC, 2007) estimates that stabilising the concentration of greenhouse gases in the atmosphere at about 450 ppm will result in an expected

9 See http://cdm.unfccc.int/Statistics for an overview.

Table 9.2 Restructured summary of the ICCG overview of two-degree paths. Real prices (see note to the table). Euros per tonne of CO_2e

		Price estimate, Euros per tonne		
Author(s)	Model	2020	2030	2050
Tol (2009)	FUND	40	64	170
Bastianin et al. (2010)	WITCH	16	53	394
Nordhaus (2010)	RICE-2010	22	38	101
Bosetti et al. (2009)	WITCH	28	69	271
Paltsev et al. (2009)	EPPA	55	82	179
Mean		43	68	235
Standard deviation		*29*	*43*	*169*

increase in the mean global temperature of two degrees Celsius relative to pre-industrial times.[10] It is an overarching objective of Norway to contribute to the climate negotiations organised by the UN resulting in a comprehensive climate agreement that ensures developments in conformity with the two-degree target. Realising this target requires, according to the Intergovernmental Panel on Climate Change, global greenhouse gas emissions to be reduced by 50-85 percent by 2050, relative to 2000. By the two-degree path is meant the measure cost path (the carbon price path) defining, at any given time, the upper cost limit associated with the global measures necessary to realise the two-degree global warming target.

A number of organisations and groups of researchers have performed model-based calculations as to which carbon price paths are required to realise the two-degree target. A joint feature of these calculations is that they highlight the necessity of a future price that is considerably higher than suggested by the EU ETS allowance prices, both spot and futures prices. However, the resulting paths are critically dependent on the assumptions underpinning the analyses. Different estimates with regard to population growth, economic growth, technological developments, substitution opportunities in the event of price differences, as well as electricity consumption, are some of the elements that will influence the calculations. How large a portion of global emissions is facing any given carbon price is of particular importance to the price path. A cost-efficient approach would require all emissions to face the same price. It is debatable how realistic this is, but it remains the traditional approach adopted by most analyses. However, some studies have sought to estimate the cost of not covering all emissions. The authors tend to find a large increase in costs if adopting a non-efficient approach; see Hoel et al. (2009, p. 98) and the NOU 2009: 16 Green Paper (footnote 5, p. 32).

The Italian research initiative *International Center for Climate Governance* (ICCG, 2011) has prepared an overview of a number of model computations of carbon price paths from 2008–2010 that are consistent with stabilising the concentration of greenhouse gases in line with the two-degree path (450 ppm).[11] The paths vary in their assumptions as to which geographic regions participate, what type of climate policy is pursued, rules governing the cap-and-trade systems, expected GDP and population growth, technological improvements, energy types (for example use or non-use of nuclear power), etc. In Table 9.2 below, we have summarised some of the findings from recognised models. In addition, we include

[10] The concentration of CO_2 has increased from about 280 ppm prior to industrialisation to a level that is now in excess of 390 ppm. In addition, the concentration of other greenhouse gases, including, *inter alia*, methane and nitrous oxide, has also increased, thus implying that the concentration of greenhouse gases is currently estimated to be fairly close to 450 ppm.

[11] The table compiled by the ICCG is a summary of information from their report International Climate Policy and Carbon Markets, which is published on a regular basis. The table has been removed from their website in connection with a restructuring, but the ICCG has in an e-mail informed the Committee that the table may be used freely. The table is available from the Ministry of Finance upon request.

the ICCG mean and standard deviation for *all* model computations.

Mean and standard deviation are reported for all model computations presented by the ICCG (not the selection reported by the Committee). As far as the computations of Paltsev et al. (2009) are concerned, we report the mean across four model simulations with different assumptions as to technological progress. "Model" refers to the name of the model used in the calculations. The ICCG does not specify the base year of the various prices.

The models used in the studies included in the above table are so-called "Integrated Assessment Models" (integrated economy-energy-environment models). These integrate general economic equilibrium models with a detailed modelling of energy demand and production, as well as the pollutant emissions associated therewith. Some of the models also model costs associated with increased greenhouse gas concentrations. These models are used in the analysis of issues within energy economics and environmental economics, such as estimating the costs associated with various climate policy ambitions.

The mean estimated price in 2020 is EUR 43 at 2012 prices (about NOK 323 at an exchange rate of NOK 7.5 per euro). Corresponding figures for 2030 and 2050 are EUR 68 and EUR 235, respectively. There are substantial differences between the estimated price paths, especially for the distant future. The standard deviation in 2050 is EUR 169. All price paths feature a fairly steep increase in the real price over time. The average increase from 2020 to 2030 is 4.6 percent per year, whilst the increase from then until 2050 is about 6.4 percent per year.

The International Energy Agency ("IEA") publishes thorough analyses of the energy markets on a regular basis. Its most recent published computations (as per the date of the present Report) are presented in the *World Energy Outlook 2011* (IEA, 2011). The analysis presents different global climate scenarios. Their "450 ppm scenario" assumes that the EU carbon price will increase from USD 45 per tonne in 2020 to USD 95 dollar per tonne in 2030 and USD 120 dollar per tonne in 2035 (about NOK 260, 550 and 700, respectively). In the United States, Canada, Japan, South Korea, Australia and New Zealand, the price starts out at a somewhat lower level, before converging to the price calculated for the EU in 2035. For China it is assumed that the carbon price in all sectors will increase from USD 10 per tonne in 2020 to USD 65 per tonne in 2030 and USD 95 per tonne from 2035. For Brazil, India, Russia and South Africa, a carbon price in 2035 of USD 95 per tonne is assumed, but in these countries such price applies to the power sector and to manufacturing industry only. Moreover, it is assumed that many other developing countries will also put a price on major parts of their emissions. The IEA does not provide any carbon price computations beyond 2035.

The findings from computations generated by comprehensive, long-term models of the type presented above are debated extensively. Much of the debate on climate models in economic literature has been concerned with the discount rate. For projects and investments with long lifespans, it is especially important how costs and benefits at different points in time and, in particular, in the distant future are compared and traded off against each other. This will influence what is held to be an optimal emission target, but also the price paths for realising specific targets. In Chapter 5, the Committee discusses issues relating to the discount rate. In addition, a debate has arisen with regard to dealing with potentially catastrophic climate effects. This is discussed in Chapter 8.

9.5 Principles for the valuation of greenhouse gas emissions in cost-benefit analysis

9.5.1 Introduction

In order to reduce greenhouse gas emissions to what is, in global terms, an optimal level, marginal emissions should carry a price tag corresponding to the global economic cost associated with such emissions (hereinafter referred to as the "social cost of carbon"). If such price applies to all economic agents and to all emissions, and no agents have market power, the behavioural decisions of all will result in the marginal abatement cost (the cost of reducing emissions by one unit) being equal to the social cost of carbon. However, it is not particularly realistic, as mentioned above, to expect such a system to be established in the foreseeable future. Consequently, the pricing of greenhouse gas emissions for cost-benefit analysis purposes is a more complex issue.

The principles that should underpin the pricing of greenhouse gas emissions for cost-benefit analysis purposes therefore depend on which questions one would like the cost-benefit analysis to answer. These may depend, as we will note below, on both preferences and policy, including the current national and international climate policy situation and how it develops. It will, in particular, be decisive whether emissions from a project will result in increased global emissions or whether the increased greenhouse gas emissions are offset by emission reductions elsewhere.

We will here present and discuss various principles for the valuation of greenhouse gas emissions for cost-benefit analysis purposes. Two of these are based on the two-degree path and international carbon prices (EU ETS allowance prices), respectively, cf. the terms of reference of the Committee. In addition, we deem it relevant to discuss carbon prices derived from declared or actual climate policy in Norway at present. Once a principle for choosing calculation prices for greenhouse gas emissions for cost-benefit analysis purposes has been decided on, one needs to apply (best estimates) for such prices for all years of the analysis period. As discussed in Chapter 3, real prices (i.e. prices adjusted for inflation) are what should be used for analysis purposes.

As a first step towards discussing the principles behind various calculation prices, we will outline some carbon pricing principles. We will start out from the discussion in the NOU 2009: 16 Green Paper on how greenhouse gas emissions should be priced in Norway, based on various objectives and preferences.

9.5.2 Carbon pricing principles and findings from the NOU 2009: 16 Green Paper

The NOU 2009: 16 Green Paper discusses various potential objectives for Norwegian climate policy. One such objective is for Norway to comply with its international agreements and commitments at the minimum possible cost. However, formal compliance with commitments is not tantamount to making a contribution to reduced global greenhouse gas emissions. The NOU 2009: 16 Green Paper notes that carbon leakage issues (see Chapter 9.3.2 above) and challenges relating to the CDM mechanism may imply that actual emission reductions are less than would be credited under an agreement (see Chapter 9.5.5 below).

Another objective for the authorities may be for Norway to comply with its Kyoto Protocol and other commitments through measures that result in actual global emission reductions. The NOU 2009: 16 Green Paper concludes that this seems to be the most realistic objective, and its discussion is therefore based thereon.

The NOU 2009: 16 Green Paper also discusses whether the authorities may have other objectives beyond those resulting from international agreements and commitments. The first Climate Report (see Chapter 9.3.1) specified that it was realistic to aim for two thirds of Norway's contribution to global emission reductions in 2020 to take place domestically. The NOU 2009: 16 Green Paper briefly discusses the extent to which the said objective can be held to guide the use of policy measures in Norway.

The NOU 2009: 16 Green Paper concludes that taxes and tradable allowances are suitable policy measures for the regulation of greenhouse gas emissions. If the objective is to limit Norway's contribution to global emissions, and carbon leakage is disregarded, it will be cost-efficient to apply the same carbon price in all sectors. As large parts of Norwegian emissions fall within the scope of the European cap-and-trade system, this should define the "reference price", and emissions from other sectors should be subject to tax at a rate corresponding thereto. Furthermore, the NOU 2009: 16 Green Paper notes that since the price of greenhouse gas emissions for enterprises subject to allowance requirements will vary from day to day, it would however be particularly challenging to charge the same prices for greenhouse gas emissions both within and outside the allowance requirement sector.[12]

Carbon leakage considerations may suggest that sectors where major leakage is expected might merit a lower carbon price. However, the NOU 2009: 16 Green Paper finds that the "combination of inadequate information about technological possibilities and relocation costs and the paucity of effective policy measures mean that the environmental gains from a policy aimed at carbon leakage seem highly uncertain", and therefore recommends that all sectors be regulated with equal strictness.

The NOU 2009: 16 Green Paper also discusses separate domestic emission reduction targets. The following is stated at the beginning of such discussion:

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[12] A general finding from economic theory is that taxes are, as a main rule, a more efficient policy measure than allowances under uncertainty when abatement costs are highly dependent on the emission reduction level, whilst the social cost of carbon depends on aggregate emissions and hence does not vary much with short-term emission changes. This finding implies, according to the NOU 2009: 16 Green Paper, that "one should avoid major abatement cost changes from period to period as long as the costs associated with short-term emission reduction variations are fairly minor" (page 93). See Chapter 9.3.2 of the NOU 2009: 16 Green Paper for a discussion on how the non-allowance requirement sector can be regulated on the basis of the EU ETS allowance price. Weitzman (1974) discusses the choice between allowances and taxes; see also Hoel and Karp (2002) and Hagen (2010).

A domestic target implies that the authorities regulate domestic emissions more strictly than is required to achieve a cost-efficient solution. Any global agreement that reduces global emissions by an amount sufficient to materially reduce the risk of major and irreversible detrimental effects, will result in major domestic emission reductions as the allowance price increases, cf. the discussion in Chapter 4. Hence, the arguments in favour of domestic targets cannot rely exclusively on the need for domestic reductions to comply with a strict international agreement, because such reductions over time will also result from a cost-efficient policy. A domestic target must instead mean that domestic emission reductions shall be implemented earlier than would be the case under a cost-efficient policy.

Two possible reasons for having such targets are then discussed:

- One argument is that domestic enterprises and households are not paying sufficient heed to the fact that the carbon price will increase over time. Such a line of argument is based on the premise that the authorities have better information than private agents about which emission reductions should be implemented now. The report notes, however, that it seems less plausible that domestic emitters will generally fail to take note of expected long-term price developments in a situation where a large (and growing) portion of Norwegian greenhouse gas emissions is regulated via the EU cap-and-trade system.
- Another argument in favour of domestic targets may be that such targets make it easier to establish an international agreement. Early adoption of climate regulations may give rise to a form of positive externalities, in the same way as when an individual country devotes itself to important R&D measures. The report notes, however, that the effect of such initiatives on climate regulations in other countries is difficult to measure.

In the event that the authorities have such objectives, the NOU 2009: 16 Green Paper recommends that the domestic objective be formulated as a price target, and not as a quantitative target, in view of the uncertainty about costs. Moreover, it is recommended that the authorities announce how strict regulations will be over a certain period, thus relieving emitters of the risk of sudden changes in regulations. The NOU 2009: 16 Green Paper recommends, irrespective of whether the target is formulated as a price or a quantitative target, that tax be used as the policy measure (for enterprises in the allowance requirement sector this implies an additional tax imposed on top of the allowance price, such as to make the sum of these equivalent to the tax level outside the allowance requirement sector).[13]

In subsequent sections we will discuss in which situations and for which climate policy objectives the various carbon price paths should be used as calculation prices for cost-benefit analysis purposes. This is also discussed in the NOU 2009: 16 Green Paper. It is there noted that finding the optimal calculation price in a small, open economy is, generally speaking, simple if an international price exists and one does not value national emission reductions higher than global ones: "The international price should be used as the calculation price for all domestic decisions. With a global climate agreement resulting in a joint international carbon price, the international price will represent the cost of Norwegian greenhouse gas emissions, and thus the basis for all domestic use of policy measures" (page 90).

The NOU 2009: 16 Green Paper goes on to note that the decisive factor in the valuation of greenhouse gas emissions, in the absence of such a global agreement, is how Norway meets its emission commitments on the margin. For Norway this has, until 2012, been through internationally available allowances (primarily CDM allowances). The argument is that Norway is a price taker in the cap-and-trade system, and that the cheapest way of reducing greenhouse gas emissions is therefore to implement all measures in Norway that carry a cost below the allowance price, and thereafter to effect any additional emission reductions through allowance purchases abroad.

In subsequent sections we will discuss in which situations and for which climate policy objectives each carbon price path will apply. We will first discuss whether current producer prices for greenhouse gas emissions could or should also be used for public cost-benefit analysis purposes.

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13 The NOU 2009: 16 Green Paper also discusses other policy measures like subsidies for renewable energy, information dissemination and recommended or statutory standards. Reference is made to studies finding that price incentives may in certain situations have little effect, whilst facilitation may give rise to more behavioural change. See Chapters 9.3.4 and 9.4 of the NOU 2009: 16 Green Paper.

9.5.3 Differences in actual prices, identical calculation prices?

A general cost-benefit analysis principle is that calculation prices for private goods should be identical to producer prices. This results in efficient resource allocation between the private and the public sector. A project that features private goods only will thus be subject to the same profitability assessment in both the private and the public sector.

No further corrections shall, as noted in Chapter 7 of the NOU 2009: 16 Green Paper, be made in cost-benefit analysis in respect of externalities when such externalities are adequately reflected in producer prices (through taxes or allowance prices). In other words, in the presence of externalities (like greenhouse gas emissions) that are internalised in private decisions through the use of taxes (or cap-and-trade systems), the public sector cannot improve on the market solution by using calculation prices that differ from producer prices inclusive of tax.

Hence, whether a cost-benefit analysis shall disregard the taxes applicable in the various sectors, and instead apply one joint carbon price path for the valuation of emissions in all sectors, depends on whether one believes that current taxes adequately reflect external costs. One may argue, on the one hand, that the tax structure chosen by the authorities is in actual fact carefully "thought through" by the authorities and that, for example, carbon leakage considerations suggest that the differentiated taxes seek to meet the requirement that producer prices should adequately reflect external costs. In such case, these prices should be used as calculation prices for cost-benefit analysis purposes. It should be noted that a challenge under this approach is that information about future policy is required to prepare estimates for future carbon prices in Norway.

It may, on the other hand, be argued that the current tax structure is the result of political prioritisations that have nothing to do with the external cost of greenhouse gas emissions, and therefore should be excluded from cost-benefit analysis. In such case, the current tax structure should *not* be used for cost-benefit analysis purposes. It would in that case be preferable to discuss the implications of the measure in other policy areas in other ways suitable in the analysis context. For example, relevant distribution effects should be discussed separately, cf., *inter alia*, Chapter 2.3 and Chapter 3 on distribution.

If one uses calculation prices that differ from producer prices, one will have to estimate the actual overall changes in greenhouse gas emissions resulting from a project. Thereafter one will need to multiply ultimate net changes in emissions by the calculation price used, less any tax or allowance price already paid in respect of the emissions. The global and ultimate changes in greenhouse gas emissions resulting from an investment, as effected through market input-output mechanisms, can often be very difficult to calculate, and it will normally be necessary to introduce simplifications. If producer prices are used instead, the probability calculations can be based on observable prices.

9.5.4 Global marginal social cost of carbon

If we use a calculation price based on the marginal *social cost of carbon*; i.e. the global cost of emitting one additional tonne of CO_2e, cost-benefit analysis will measure the net willingness to pay for a project, provided that the greenhouse gas emissions from such project are not offset by other measures – and thus actually impose global climate-related damage. In addition, it is implicitly assumed that the willingness of persons in both Norway and other countries to pay to avoid climate change shall be taken into account in the assessment of Norwegian projects.

However, estimating this social cost of carbon is convoluted and complex. Firstly, the social cost of carbon depends on future emissions. If one does not succeed in curtailing emissions, it is likely that the marginal social cost of carbon will be higher. Other issues relate to the discount rate (see Chapter 5), risk aversion and so-called "tipping points" or catastrophic events (see Chapter 8). In addition, there are challenges associated with how to interpret the global willingness to pay as a measure of the welfare effect of preventing damage, since the poorest part of the world's population will have little scope for signalling its interests via its willingness to make monetary payments. A particularly thorny issue is, for example, the valuation of lives lost in poor countries.

A recent attempt at estimating a global marginal social cost of carbon was carried out at the behest of the authorities in the United States in 2009 (Interagency Working Group on Social Cost of Carbon, 2010). The estimates are strictly dependent on the discount rate used. The point estimates for 2010 (the first year presented by the working group) vary between USD 4.7 and 35.1 at

2007 prices (as per 2010). See also Bell and Callan (2011) for a discussion of this and other estimates.

9.5.5 Necessary cost of realising a given emission target

A physical emission target means that Norwegian emissions are subject to a binding cap, and that it is not permissible to exceed such cap.[14] If a project or measure results in emissions, emissions in the remainder of the economy must therefore be reduced correspondingly. Alternatively, the question may be posed as follows: What is the net willingness to pay for the project, provided that emissions must be reduced correspondingly elsewhere?

It should be noted that the global marginal social cost of carbon (discussed in 9.5.4) is not of relevance to this question, because it is assumed that total emissions will not increase, thus implying that the project will not give rise to any change in global damage. This question may then be differentiated on the basis of what emission target is being considered. The stricter is the emission target, the higher will be the abatement cost in the economy to begin with, and the higher will be the cost of reducing emissions elsewhere.

Necessary cost of realising the two-degree target

At present, there is a consensus that the international climate negotiations shall proceed on the basis of the two-degree target. Norway has, as previously mentioned, expressed its support for this target. The target necessitates, according to the Intergovernmental Panel on Climate Change (IPCC, 2007), global emission reductions of 50–85 percent by 2050, relative to the 2000 level. The reduction in overall emissions from rich countries must be 25–40 percent by 2020 and 80–95 percent by 2050, relative to the 1990 level.

Several attempts have been made, as we noted in Chapter 9.4, at calculating what prices are required to enable the world to realise this target. If one chooses to apply such prices for cost-benefit analysis purposes in Norway, it implies that one poses the following question: What will be the net willingness to pay for the project, provided that emissions from the project are offset by emission reductions elsewhere in the economy, in a situation where Norway's domestic greenhouse gas emissions are determined by a hypothetical international agreement in conformity with the two-degree target?

In other words, the valuation of greenhouse gas emissions we use to answer such a question will be determined by the costs necessary to comply with a given emission target (in this case Norway's "share" under a hypothetical agreement), and not what it will cost the world if one does *not* realise such target. The latter question concerns the social cost of carbon; see 9.5.4. Only if it turns out that the two-degree target implies an optimal trade-off between the social cost of carbon and abatement costs, will the prices implied by the two-degree path and the prices implied by the estimated marginal social cost of carbon be identical.

One may envisage several reasons for using a price path for Norwegian cost-benefit analysis purposes that is premised on the two-degree target. Firstly, the above question will be of interest if we are in a situation where an international agreement in line with the said target does actually exist, and where the Norwegian authorities intend to comply with such agreement. In that scenario, such a carbon price will represent the actual and necessary cost of offsetting the emissions from the project elsewhere in the economy. In such a scenario it is also quite conceivable that this price path will be reflected in international cap-and-trade systems, and that the Norwegian tax level will be calibrated with such target in mind. In such case it will be appropriate to apply this price path for cost-benefit analysis purposes.

No such agreement exists for the time being. Another reason for applying such price path for cost-benefit analysis purposes might be that Norwegian authorities would like to act *as if* such an agreement existed. It may, for example, be that Norwegian authorities would like to send political signals with regard to credible climate policy by acting as if Norway was encompassed by such an agreement, or because they believe that it may contribute to other countries also choosing to act in the same manner. In such case on should also change the tax level (and not only calculation prices for cost-benefit analysis purposes) in line with a hypothetical agreement of this nature.

Thirdly, it is conceivable that the authorities may wish to analyse potential projects as if such an agreement existed, even though taxes and other policy measures are not calibrated to realise

[14] Chapter 9.5.2 of the NOU 2009: 16 Green Paper discusses the implementation of domestic targets. It is there noted that the target should be flexible – rather than absolute – since the cost of reducing greenhouse gas emissions domestically is subject to considerable uncertainty, and that a domestic target should therefore preferably be implemented as a price target (with the price exceeding the price under the EU cap-and-trade system).

any such target in practice. This may be interesting as a hypothetical exercise, but will imply that project assessments are made on the basis of principles that are not in conformity with the other practical policies pursued by the authorities.

It should be noted that, as long as no international agreement exists, the basis for using prices in line with the two-degree path must either be defined national targets, or assumptions to the effect that a group of countries that includes Norway will face an allowance price resulting from analyses of the type presented in Table 9.2.

Necessary cost of meeting existing emission targets

Although much remains to be decided about Norway's next commitment period under the Kyoto Protocol, as per the date of the present report, it has been established that Norway will also after 2012 be seeking to comply with an international emission commitment (until and including 2017 or 2020). In addition, objectives have already been formulated with regard to the limitation of domestic greenhouse gas emissions by 2020.

A question of obvious interest from a cost-benefit analysis perspective is therefore what is the net willingness to pay for a project, provided that emissions will have to be reduced correspondingly elsewhere to meet existing binding emission targets?

If "existing binding emission targets" is here taken to include climate policy considerations that have not been incorporated, or that are in the process of being incorporated, into practical policy, one will be faced with the question of the legitimacy of such targets, and of whether calculation prices shall be based on said emission targets or on the policy measures in actual use. Consequently, additional clarification as to the meaning thereof will be required.

International allowance price as calculation price

In a situation where Norway is subject to an international emission commitment, Norway (i.e. the Government of Norway) will have the option of purchasing allowances from abroad. If the binding emission targets of the authorities only quantify Norway's contribution to global emission reductions, without any additional requirements as to where and how this is to be achieved, the international allowance price represents the marginal opportunity cost of emission reductions applicable to Norway as a country. As long as the Government of Norway is in a position to purchase EU allowances (or similar), the abatement cost of any project implemented in Norway may be measured by using the international allowance price as a yardstick.

If Norway would like to reduce emissions where the cost of doing so is the lowest, irrespective of location, it would imply that all measures with a cost below the allowance price are implemented in Norway, and that any abatement measures on top of that are effected via the purchase of allowances in the international market. Such a policy means that the international allowance price will reflect the price necessary to realise existing emission targets.

However, one important objection may be raised in this regard. If the systems for the measurement and control of emission reductions abroad are inadequate, it may mean that the purchase of international allowances does not represent actual emission reductions. In such case the international allowance price will not represent the appropriate opportunity cost of national emission reductions either. Economic literature has observed that this may be a problem as far as CDM allowances are concerned. Hagem and Holtsmark (2008) have, for example, discussed problems relating to leakage and compliance with the *additionality condition* (the requirement that the project triggering the emission reductions would not have been implemented had it not been for the income from the sale of allowances) when using the CDM mechanism. However, the Committee is not aware of any criticism to the effect that the purchase of EU allowances does not represent actual emission reductions.

If an international allowance price is used as the calculation price, one will also have to examine how such price will change over time in real terms. The EU allowance price changes on a daily basis, and the uncertainty associated with international negotiations and European climate policy is significant enough to make it challenging to project allowance price information from the market 20–30 years into the future, cf. the discussion in Chapter 9.4.2. There is also considerable uncertainty with regard to the period up to 2020; the market for trading in allowances for delivery in the years close to 2020 is fairly thin, and the Committee is not aware of whether any market for the delivery of allowances after 2020 does exist.

Necessary cost of domestic emission reduction targets

It was assumed above that the binding emission targets of the authorities only concern the quantity of Norway's contribution to global emission reductions. If the authorities pursue a climate policy that involves additional real restrictions, such additional restrictions will influence the cost of offsetting the greenhouse gas emissions of a project through reductions elsewhere in the economy.

The Climate Settlement (see Chapter 9.3.1) contains wording to the effect that two thirds of the emission reductions in 2020 shall take place domestically. If this is implemented, it will increase the marginal cost of compensating for the greenhouse gas emissions of projects. In such case the international allowance price cannot, as a matter of course, be taken to represent the marginal abatement cost. If the domestic abatement requirement is just met to begin with, the domestic emissions of the project will have to be compensated by domestic emission reductions, irrespective of whether these are more expensive than paying the international allowance price. If a "binding emission target" defines requirements with regard to both the contribution to global emission reductions and the domestic portion thereof, the domestic marginal cost, and thus the calculation price, will probably exceed the international allowance price.

One challenge in basing calculation prices on politically defined targets is precisely the fact that it requires the authorities to formulate credible emission targets for a sufficiently long time horizon. An issue arising in this context is what weight to attribute to a domestic emission target if one observes that current climate policy is not in conformity with such target. It may in Norway be argued that the Government currently has a domestic emission target for 2020 (cf. Chapter 9.3.1), but no such target for subsequent years. When the central government working group Climate Cure 2020 examined policies and measures for realising such target, it indicated that the domestic marginal cost was NOK 1,100 – 1,500 per tonne of CO_2e (Climate Cure, 2010). If it is assumed that no additional measures will be implemented within the allowance requirement sector, the calculations from Climate Cure 2020 showed that the necessary marginal cost will be significantly higher. As long as actual taxes are not adjusted in line with the domestic emission reduction target, it is not obvious that such target can be considered, for the time being, to constitute a real, binding restriction on Norwegian greenhouse gas emissions.

9.6 Current use of carbon prices in cost-benefit analysis in Norway and abroad

9.6.1 Use of carbon prices in Norway

The *Cost-Benefit Analysis Guide* of the Ministry of Finance (2005) includes a brief discussion of dealing with greenhouse gas emissions in a cost-benefit analysis context. The following is stated on page 24:

Global environmental problems are linked, *inter alia*, to greenhouse gas emissions. In such cases national targets will often be related to international commitments. A national commitment can be handled through a tax system that reflects the economic costs of compliance therewith. The environmental taxes should in such case be considered an established fact for cost-benefit analysis purposes. If the commitment can alternatively be met through the purchase and sale of allowances internationally, the analysis can instead be based on the international allowance price. Alternatively, one may use model computations, etc., to estimate the value of an allowance. It is, as a general observation, important to take into account the possibility that calculation prices may change over time as the result of changes in international environmental targets.

The practical use of carbon prices and carbon price paths in the analysis of public investments in Norway is more clearly outlined in the various sectoral cost-benefit analysis handbooks. *The Norwegian National Rail Administration* has recently revised its guide from 2006. It follows from *Method Handbook JD 205 Cost-Benefit Analysis for the Railways* (Norwegian National Rail Administration (2011), pages 81-82) that no greenhouse gas emission estimates are included in the analysis of new railway investments in Norway, whether in direct operations or in the production of the propulsion energy. The reason given for this by the Norwegian National Rail Administration is that it purchases certificates of origin for electricity and that payment for these "is used to develop additional production capacity at a named hydroelectric power plant, thus implying that the indirect contribution to increased demand for polluting power is eliminated" (page 82).

The Norwegian National Rail Administration has informed the Committee that it assumes, for purposes of most analyses, that emissions in the construction phase and in the production of rolling stock have in the long run been captured by taxes and regulations. In other words, that the environmental costs are implicit in the estimated construction costs and capital costs of rolling stock, respectively. Moreover, the Norwegian National Rail Administration states that it will, during the course of 2012, be revisiting the assumption that the purchase of certificates of origin makes no contribution to increased demand for polluting power.

For other means of transport (and diesel-powered trains), the Norwegian National Rail Administration uses estimates from the Climate Cure 2020 medium scenario for the EU ETS allowance price; see Table 9.1. Global air pollution rates *per vehicle kilometre* are based on the said prices per tonne, as well as on emission factors for different means of transport based on calculations from the former National Pollution Control Authority.

The Norwegian Public Roads Administration conducts climate analyses using the EFFECT estimation software. In the most recent version (as per the date of the present Report); EFFECT 6.4, the Climate Cure 2020 medium scenario has also been used: For the years until and including 2015, a fixed unit price of NOK 210 per tonne is used. For the years between 2015 and 2030, a unit price is estimated by interpolation between the specified years and their appurtenant values. For years from 2030 inclusive, a fixed unit price of NOK 800 per tonne is used. The Norwegian Public Roads Administration also notes that it estimates emission costs associated with construction, emission costs associated with maintenance changes (primarily altered quantities of bitumen and electricity), as well as emission costs associated with changes in traffic emissions.

The use of carbon prices is also of relevance outside the transportation sector. The sectoral guide for cost-benefit analysis in the defence sector (Ministry of Defence, 2010) does, for example, encourage the use of market data for carbon prices for purposes of valuing greenhouse gas emissions.

9.6.2 Recommendations on the use of carbon prices in other countries

The recommendations on the pricing of greenhouse gas emissions abroad vary from country to country:

- Sweden adheres to the transportation sector guidelines in ASEK 5 (2012). These recommend using a calculation price of SEK 1,080 per tonne for short-term investments (the current petrol tax) and SEK 1,450 per tonne for long-term investments (the net present value of the petrol tax, real price adjusted on the basis of GDP per capita). One is also recommended to prepare sensitivity estimates based of SEK 3,500 per tonne.
- The United Kingdom has changed its method for the valuation of greenhouse gas emissions. Prior to 2009, the estimated global social cost of carbon was used, but one has now switched over to pricing in line with the necessary marginal cost of meeting long-term domestic emission reduction targets in conformity with the EU Climate and Energy Package. Until 2030, different prices are used for different sectors, depending on whether these are within or outside the EU ETS. The calculation prices for sectors encompassed by the EU ETS shall reflect the expected market price of allowances, whilst prices for other sectors are in line with national emission targets. The UK authorities have specified which prices to use until and including 2100. However, preparation and presentation of sensitivity analyses is also encouraged; see Table 9.3.
- HEATCO, an EU project for harmonising the valuation of transportation projects (HEATCO, 2006), recommends using identical prices for all analyses in Europe. The guidelines are based on the social cost of carbon, as well as on abatement costs. It is emphasised, in particular, that future emissions will involve a higher social cost of carbon than current emissions, which indicates, all else being equal, an upwards sloping price path (reference is made to Watkiss et al. (2005a)). HEATCO presents, on the basis of computations made by Watkiss et al. (2005b) for the Department for Environment, Food and Rural Affairs in the United Kingdom, a table recommended for use in cost-benefit analyses in Europe (see Table 9.4).

Table 9.3 Carbon prices recommended by the HEATCO report. Euros per tonne of CO_2e. 2002 prices

Year of emission	Recommendation
2000–2009	22
2010–2019	26
2020–2029	32
2030–2039	40
2040–2049	55
2050	83

Source: HEATCO, Delivery 5 (2006).

Table 9.4 Calculation prices used in the United Kingdom (excerpts). Pounds sterling (£) per CO_2e. 2011 prices

	Within the allowance requirement sector			Outside the allowance requirement sector		
Year	Low	Medium	High	Low	Medium	High
2008	19	19	19	27	53	80
2015	12	19	24	30	59	89
2020	19	29	35	32	64	95
2030	37	74	111	37	74	111
2040	72	143	215	72	143	215
2050	106	212	318	106	212	318
2080	113	324	535	113	324	535
2100	71	284	497	71	284	497

Source: Department of Energy & Climate Change (2011).

9.7 The assessments of the Committee

In order to ensure efficiency in production, the same prices must be applied to private and public decisions. Hence, the same applies to calculation prices for cost-benefit analysis purposes. If the taxes on greenhouse gas emissions had been such as to adequately adjust for the externalities associated with greenhouse gas emissions, subject to any domestic targets and carbon leakage considerations, these producer prices should also have been used for cost-benefit analysis purposes.

At present, carbon prices in Norway differ so much between sectors and between different types of fossil fuels that it is difficult to justify such differences by carbon leakage considerations. Consequently, the current differentiated taxes are not well suited as a basis for establishing calculation prices for greenhouse gas emissions for cost-benefit analysis purposes. Instead, the Committee recommends that one joint carbon price path be used in the cost-benefit analysis of public decisions across all sectors.

What is the correct calculation price for greenhouse gas emissions depends on what question one would like the analysis to answer. It will in many cases be appropriate to perform calculations using different calculation prices, which calculations will in such case address different issues. This applies, in particular, to analyses of projects and measures which are motivated by climate considerations or which have major emission implications. However, since the climate issue will often be only one of the many considerations reflected in a cost-benefit analysis, it is necessary to choose one price path to represent the main alternative.

A decisive question when choosing a calculation price for cost-benefit analysis purposes is whether emissions from a project will result in higher global emissions, or whether the greenhouse gas emissions increase will be roughly offset by emission reductions elsewhere. If the emissions from a project result in a corresponding global emissions increase, the relevant calculation price is the global marginal social cost of carbon. If the emissions increase is offset by reductions elsewhere in the economy, the marginal abatement cost is the relevant basis for determining the calculation price. Which abatement cost paths should be applied in such cases depends on the context:

Two-degree global warming target: If an international agreement in conformity with the two-degree target exists, or if Norwegian authorities have expressly stated that they will act as if such an agreement exists, this may be held to define a limitation on Norwegian emissions. The marginal abatement cost inferred from such target should therefore be used as the calculation price of greenhouse gas emissions for cost-benefit analysis purposes.

Domestic targets: If the authorities have adopted, and comply with, national emission reduction targets, calculation prices may in principle be based thereon, as these would represent a limitation on domestic emissions. At present, the Norwegian authorities have outlined objectives with regard to domestic emissions in 2020; see Chapter 9.3.

International allowance prices: If Norway is subject to an international commitment, like the Kyoto Protocol, or if Norway has of its own accord defined targets that are met through the purchase of allowances, increased greenhouse gas emissions in Norway will be offset by reduced emissions elsewhere under the cap-and-trade system. At present, Norway is subject to the Kyoto Protocol, which specifies an emissions cap for its member states. Access to an international cap-and-trade system may also be interpreted to mean that the Norwegian authorities have the option of realising emission reductions at a fixed international price.

An international agreement in line with the two-degree target is not a realistic short-term prospect. The Committee is therefore of the view that it would not be appropriate to use price paths inferred from the two-degree target as a main alternative in the present situation. Elements like the highlighting of efforts to combat climate change and other non-priced effects must be assumed to be of importance to decision makers' assessment of projects. However, these and similar considerations should be discussed separately.

The Committee finds, against this background, that if the authorities have binding domestic emission targets, then both producer prices (taxes) and calculation prices for public cost-benefit analysis purposes should be inferred from such targets. Climate Cure 2020 (2010) has computed different paths based on various assumptions towards 2020.

If Norwegian targets are instead related to overall global emissions caused by Norway, and Norwegian emissions are subject to an international cap-and-trade system, the calculation price for greenhouse gas emissions should be based on expectations with regard to the international allowance price.

The recommendation not to use prices inferred from the social cost of carbon or the two-degree target is based on the assumption that increased emissions from individual projects will not result in increased global emissions – only in changes to *where* those emissions are taking place. It is important to bear this in mind both when planning analyses and when interpreting the (analyses) findings. In particular, calculation prices determined in this manner are not suited for evaluating how ambitious a global climate policy should be, since the abatement cost appears to be considerably lower than the social cost of carbon (or the necessary marginal cost of realising the two-degree target) over the next few years.

By international allowance prices are primarily meant the prices faced by the Norwegian authorities when purchasing allowances. During the first commitment period under the Kyoto Protocol, this has predominantly been the price of CDM allowances. This price has been closely correlated with the price of EU allowances. The latter has a stronger institutional foundation than the market for CDM allowances, whilst the market for CDM allowances, or allowances from other/new mechanisms, including the second commitment period under the Kyoto Protocol, faces a more uncertain future. Doubt has also been expressed with regard to the actual magnitude of the emission reduction effect from CDM allowances. The Committee recommends, against this background, that market expectations concerning the price of EU allowances be used as the basis for formulating a carbon price path that reflects the international allowance price.

The uncertainty associated with future international climate agreements is so high that the Committee is of the view that it is challenging to arrive at a definite position with regard to allowance prices beyond 2020 on the basis of information from the current cap-and-trade system. International allowance prices will also be uncertain, and highly susceptible to political decisions and signals, between now and 2020. The two-degree target has a very strong position in the international climate negotiations and is expressly incorporated into Norwegian policy. Although internationally binding agreements in relation to this target have yet to be concluded, the Committee takes the view that a realistic scenario is for the price of EU allowances to approach the two-degree path over time. If an international allowance price path is used, the Committee recommends that such path be based on the EU ETS allowance price as far as concerns those years for which futures prices are quoted, before gradually approaching a path reflecting the two-degree target, cf. Table 9.2.

The Committee also recommends, against the background of a number of conflicting considerations in the determination of calculation prices for greenhouse gas emissions, that sensitivity analyses be carried out, using different principles in establishing calculation prices for emissions, especially in those cases where the cost-benefit analysis is particularly sensitive to different carbon price paths. Such computations may be of considerable benefit to decision makers (the authorities).

9.8 Summary recommendations

Based on the discussion in the present Chapter, the Committee makes the following recommendations:

- The current differentiated tax and quota structure for the private sector is not suitable for use in cost-benefit analysis. A joint carbon price path should be applied for purposes of cost-benefit analysis.
- The appropriate calculation price for greenhouse gas emissions depends on what question one would like the analysis to answer. The Committee adopts the assumption that the authorities are subject to binding emission limitation targets, thus implying that increased emissions in one location necessarily have to be compensated by reductions elsewhere. The Committee recommends, on this basis, that the calculation price for greenhouse gas emissions be based on the marginal cost of emission reductions (the marginal abatement cost). If there are no binding emission limitation targets, the carbon price path should, in principle, be based on the marginal social cost of carbon instead.
- If the authorities are subject to binding domestic emission reduction targets, the calculation prices should be derived from the constraints resulting from such targets. Climate Cure 2020 (2010) has calculated a number of such paths towards 2020.
- If binding Norwegian targets are related to the contribution to total global emissions caused by Norway, and Norwegian emissions are subject to an international cap-and-trade system, the calculation price for greenhouse gas emissions should be based on expectations as to the international allowance price. From the various allowance prices in current international trading systems, the Committee recommends the use of the EU ETS allowance price. The path should be based on market expectations of future allowance prices. For years in respect of which no prices are quoted, the price path should over time approach an assumed two-degree path based on internationally recognised model computations.
- For projects where the cost-benefit analysis is particularly sensitive to different carbon price paths, it will be useful to prepare sensitivity estimates assuming a two-degree path for all years.

If the national or international political situation changes, such as to make new climate targets binding on the Norwegian economy, it is the marginal abatement cost given these new targets that should form the basis for the main joint calculation price alternative for greenhouse gas emissions.

If Norway finds itself, in future, in a situation where the authorities are not subject to binding emission reduction targets, thus implying that emissions increases in one location cannot be assumed to imply emission reductions elsewhere, the carbon price path in cost-benefit analysis should, in principle, be based on the marginal social cost of carbon.

The specific paths should be prepared by the Ministry of Finance in consultation with other affected ministries.

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Chapter 10
Valuation of life and health

10.1 Introduction

From the terms of reference of the Committee:

> The cost-benefit analysis guide offers general recommendations as to how one may seek to quantify the value of accident-reducing measures. This may, for example, be of relevance to cost-benefit calculations concerning safety measures within the transportation sector. The estimated value of a statistical life lost is presented in such a context. The Directorate for Health and Social Affairs recommended, in a report from 2007, the broad use of such a concept in intersectoral health impact assessments. The Committee shall examine what weight intersectoral cost-benefit assessment standards should carry in the evaluation of the impact on life and health, including within the health sector, and any ethical issues that may be raised thereby.

The terms of reference refer to the recommendations in the Ministry of Finance cost-benefit analysis guide (Ministry of Finance, 2005) as to how life and health may be valued and incorporated into the cost-benefit analysis of accident-reducing measures. The Ministry of Finance guide from 2005 is based on the recommendations made in the NOU 1997: 27 Green Paper, but the guide also includes updated recommendations on the economic valuation of statistical lives and life years. The present Green Paper is, as noted in Chapter 2, a supplement to the NOU 1997: 27 and NOU 1998: 16 Green Papers. The present Chapter therefore briefly outlines the assessments and recommendations made in the NOU 1997: 27 Green Paper in this area.

Life and health impacts may be included in the cost-benefit analysis of both preventive measures and treatment measures. However, it should be noted, to begin with, that any cost-benefit analysis of treatment measures will form part of the basis for making general capacity decisions, and not decisions at the level of individual patients. General capacity assessments are concerned with, for example, how much overall capacity one should have for a specific type of cardiac surgery. Such general assessments are referred to as first-order decisions at group level by the Lønning 2 Committee (NOU 1997: 18 Green Paper). Assessments as to what treatment shall be administered to each individual patient, in view of the available capacity, is referred to as second-order decisions in the NOU 1997: 18 Green Paper. Available capacity at group level shall thus, ideally speaking, be determined through well-founded first-order decisions, which define the framework for making second-order decisions for individual patients at the clinical level.

In Chapter 10.2, we briefly explain some key concepts used in the recommendations in the NOU 1997: 27 Green Paper, and frequently used when discussing life and health in a cost-benefit analysis context, whilst conclusions and recommendations from the NOU 1997: 27 Green Paper are discussed in Chapter 10.3. In Chapter 10.4, we outline the Committee's interpretation of the terms of reference. In Chapter 10.5, we embark on a more detailed discussion of the meaning and applicability of the terms discussed in Chapter 10.2, based on recent research. Chapter 10.6 discusses practices and applications for the valuation of life and health in various countries, including Norway. The assessments and recommendations of the Committee are set out in Chapter 10.7 and Chapter 10.8, respectively.

10.2 Some key concepts

Ex-ante versus ex-post events – relevance to identifiability and willingness to pay studies

Ex ante means, in the context used in the NOU 1997: 27 Green Paper, that the accident or disease has not occurred, and hence that affected individuals cannot be identified with any certainty. Correspondingly, ex post means that the event has occurred and that the affected individuals can be identified. The reason why the NOU 1997: 27 Green Paper also highlights "a large number of individuals" and "small risks" as prerequisites for using economic valuations of life and health in cost-benefit analysis (cf. Chapter 2) is that this is the setting frequently used in studies of the willingness to pay (cf. Chapter 2) for reduced risk. Whether a large number of individuals and small risk for each individual are also necessary criteria for the ex-ante *transfer* of valuations and uses related to cost-effectiveness analysis (cf. below) is discussed in Chapter 10.5.

Cost-effectiveness analysis in health economics

The term cost-effectiveness analysis is used in the NOU 1997: 27 Green Paper and Ministry of Finance (2005) to designate an analysis of various measures that all offer the same benefits. Hence, the ranking of the measures will depend exclusively on the costs of such measures (cf. Chapter 2). In health economics analysis, this type of comparison of measures is often termed cost-minimisation analysis, whilst the term cost-effectiveness analysis is used to designate the analysis of measures offering different benefits that are measured on a common, comparable scale; for example quality-adjusted life years (cf. e.g. the discussion of "cost-effectiveness analysis" in Drummond et al., 2005, and Boardman et al., 2011). If such measures can be scaled up or down, measures that offer different benefits to begin with can be made identical as far as the magnitude of the benefits is concerned, and be ranked on the basis of costs only. Such scaling may be difficult in practice, but it follows from the above that it would not make much of a difference in theory whether one assumes that cost-effectiveness analysis means that the measures being compared offer identical or non-identical benefits – as long as these benefits are measured on a common, comparable scale.

If quality-adjusted life years ("QALY"; see below for a definition) is used as the health indicator, cost-effectiveness analysis is often termed cost-per-QALY analysis (Norwegian Directorate of Health, 2011). Unlike cost-benefit analysis (as a specific method of analysis), cost-effectiveness analysis does not include the economic valuation of health indicators. However, it is fairly common for health economics analysis to subsequently compare the estimated cost-effectiveness of a measure, e.g. in terms of NOK per QALY gained, with an estimated monetary value per QALY. Such values may be based on different premises (cf. Chapter 10.5, Box 10.1).

The value of a statistical life

The value of a statistical life ("VSL") is defined in the NOU 1997: 27 Green Paper as the value of a one-unit reduction in the expected number of fatalities over a given period. VSL is often estimated as the sum of money each individual in the population is willing to pay for a given reduction in the risk of (premature) death, e.g. due to accident or air pollution (OECD, 2012). An estimated VSL represents the overall willingness to pay of a given population (here Norway's population) for a risk reduction of the exact magnitude that can be expected to save one life. Reference is made to the NOU 1997: 27 Green Paper for a more comprehensive theoretical explanation of VSL.

The value of a statistical life year

The value of a statistical life year ("VOLY") is discussed in the NOU 1997: 27 Green Paper as an alternative to using VSL for cost-benefit analysis purposes. The argument in favour of using VOLY is that life years can be a more precise unit of measurement in cases where the measure under evaluation applies to young or old individuals, where a large or small number of life years can be gained. Ministry of Finance (2005) recommends using VOLY for sensitivity analysis when measures affect the old and infirm, and a higher VSL value when measures affect children.

Measurement of health-related quality of life - Quality-adjusted life years

Quality-adjusted life years ("QALY") are discussed in the NOU 1997: 27 Green Paper as a possible decision-making criterion for prioritisation between different patient groups and cases.

Statistical lives and statistical life years are concepts that lend themselves to measurement by counting. It is not equally straightforward either to observe or to count the health-related quality of life. A number of disease-specific measurement instruments are in existence, which are predominantly used in clinical contexts, but can also be used for economic analysis. Quality-adjusted life years ("QALY") has been developed as a generic (joint) measurement instrument that can be used to compare measures to counter different diseases or injuries. Quality-adjusted life years are represented by an indicator ranging from zero to one, which indicator is based on various dimensions of the health-related quality of life. The quality indicator is multiplied by the duration of the benefit to become quality-adjusted life years. A quality-adjusted life year equal to 1 reflects a "full score" on all dimensions included in the measurement instrument used.

Reference is made to the NOU 1997: 27 Green Paper for an overview of quality of life measurement methods and various indices/instruments for the use of QALY in analysis. It is not necessary to calculate any monetary value of QALY when using QALY as a benefit indicator in cost-effectiveness analysis.

10.3 Conclusions and recommendations from the NOU 1997: 27 Green Paper

Chapter 12 of the NOU 1997: 27 Green Paper provides a thorough discussion of dealing with health risk changes in a cost-benefit analysis context. We reiterate the conclusions and recommendations from the NOU 1997: 27 Green Paper in Chapter 10.3, as many of these are deemed to remain intact. The recommendations in the NOU 1997: 27 Green Paper are divided into recommendations on accident risk analysis and recommendations on health sector analysis. Said division is premised on differences in the identifiability of individuals, differences in health risk and health-related quality of life, as well as differences in expected lifespan. Presentation of recommendations from the NOU 1997: 27 Green Paper is supplemented by comments and pointers to where the topics are discussed in the present Green Paper. Reference is made to the NOU 1997: 27 Green Paper for a more thorough presentation, and to Institute of Transport Economics ("TØI") (2010) for an updated overview of the theoretical and empirical basis for the valuation of reduced accident risk.

10.3.1 Accident risk – recommendations from the NOU 1997: 27 Green Paper

From the NOU 1997: 27 Green Paper, p. 111:

> It is not unproblematic to make recommendations on how the valuation of changes to the risks associated with life and health should be incorporated into cost-benefit analysis. One reason for this is that the technical basis for doing so remains unsettled in many respects, especially as far as empirical applications are concerned. However, an even more important consideration is that decisions relating to life and health will in most cases involve ethical trade-offs that are not necessarily meaningfully illuminated by economic theory. Nevertheless, the Committee deems it appropriate to make some recommendations on the valuation of changes to the risks associated with life and health.

Comments:

Unresolved aspects of the technical basis and empirical applications identified in the NOU 1997: 27 Green Paper are widely dispersed valuations of statistical lives due to data availability, choice of method, different types of risk, as well as the problems individuals experience in making rational choices and understanding complex problems that involve low probabilities. Such insensitivity to the magnitude of the risk reduction ("scope bias") and validity problems in hypothetical valuation studies ("hypothetical bias") remains unresolved (Andersson and Treich, 2012, Hultkrantz and Svensson, 2008, 2012), and hence the uncertainty associated with the valuation estimates is considerable (Institute of Transport Economics ("TØI"), 2010).

The ethical trade-offs discussed in the NOU 1997: 27 Green Paper have to do with the observation that valuation of life and health can hardly be related to one specific life, and should preferably be made in a context where the willingness to pay concerns a reduced probability of death and health impairment, without knowing the identity of the afflicted persons. Hence, the requirement is that life and health be valued in situations where a large number of individuals are facing small risks.

In 1997, the Committee took the view that the risks associated with life and health can on certain conditions (cf. the clarification outlined by the Committee in the next paragraph) be subjected to an economic valuation and incorporated into cost-benefit analysis, despite such valuation involving difficult ethical issues.

From the NOU 1997: 27 Green Paper, p. 111:

> The Committee is of the view that cost-effectiveness analyses can often be appropriate for the assessment of changes in accident risk. If one chooses, in addition thereto, to perform a complete cost-benefit analysis, as a specific method of analysis, the Committee believes that the willingness to pay for risk changes should be included on the benefit side of the

analysis. The Committee will nevertheless recommend that such valuation be limited to situations in which a large number of individuals are facing small risks of an undesirable outcome, cf. the discussion in Chapter 12.1.

In those cases where separate willingness to pay analysis is not performed, the Committee will recommend starting out from the estimate of NOK 10 million (at 1991 prices) per statistical life, cf. the discussion in Chapter 12.3.2. However, the Committee will not recommend any separate supplements being added with regard to altruism or gross (alternatively net) production value. This is because the theoretical basis for such supplements seems unclear, cf. the discussion in Chapter 12.5.2, and the general perspective that the Committee will in cases involving such doubt tend to err on the side of caution in choosing estimates. This implies that the Committee recommends an amount that is about NOK 4 million lower than that recommended by Elvik (1993) as the value of avoiding one traffic fatality.

Comments:

The estimate of NOK 10 million at 1991 prices per statistical life was updated to NOK 15 million at 2005 prices in Ministry of Finance (2005) and updated to NOK 17.4 million at 2010 prices in Norwegian Government Agency for Financial Management ("DFØ") (2010).

Altruism is here taken to mean a willingness to pay for a risk reduction that increases the welfare of others. The NOU 1997: 27 Green Paper assumes that production value as the result of changes in the production capacity of individuals is included in the measured willingness to pay for a risk reduction.

From the NOU 1997: 27 Green Paper, p. 112:

It may in some cases be argued that a statistical life should be accorded a value different from NOK 10 million, although no specific willingness to pay analysis has been carried out. The background to this is often an assessment as to the number of remaining life years or whether those affected seek the risk of their own volition, and not necessarily that the actual willingness to pay is higher than in the average case. One example may be traffic safety measures targeting children going to or from school. There may be reason to believe that many people will, with varying degrees of explicitness, wish to attribute a value in excess of NOK 10 million to each statistical life in such cases, because, *inter alia*, each life saved represents many remaining life years. It is likely, on the other hand, that the average willingness to pay may be fairly low for accident reduction relating to involvement in hobby activities like e.g. skydiving. The Committee will nevertheless recommend that the valuation of NOK 10 million per statistical life be applied in all cost-benefit analysis in such cases. However, cost-benefit analysis of changes to accident risk should include a description outlining what group of individuals would be encompassed by the measure. Such a description enables the decision maker to choose, if desirable, a different ranking of measures than would be implied by the value of a statistical life, when taken in isolation. This corresponds to the approach recommended by the Committee with regard to the presentation of distribution policy issues in Chapter 4.

Comments:

The question of whether one should use statistical life years in analysis instead of, or in addition to, statistical lives is discussed in Chapters 10.5 and 10.7.

Despite the assumption of a relatively low willingness to pay in cases where individuals seek a risk of their own volition, the NOU 1997: 27 Green Paper recommends the same valuation as for other types of risk. It is worth noting, in this context, that the Lønning 2 Committee (NOU 1997: 18 Green Paper) identified a lifestyle that impairs the effect of a measure as one of several "criteria that may be included when making discretionary prioritisations" in the health sector.

10.3.2 Cost-benefit analysis in the health sector – recommendations from the NOU 1997: 27 Green Paper

Willingness to pay studies are commonly used in the valuation of changes in risks associated with life and health caused by measures in other social sectors than the health sector. In the context of preventive measures, e.g. relating to accidents, one may ask individuals about their willingness to pay for reduced accident risk before the health impairment has materialised. However, the measures under assessment in the health sector are often related to diagnosis, treatment and rehabilitation. At those stages it will often be the case that the disease has already been contracted or the injury has already been sustained, or that groups with high risk exposure (for example associated with the inheritability of rare diseases) may be known, and hence those individuals who will benefit from the measure will be more readily identifiable.

From the NOU 1997: 27 Green Paper, p. 113:

> The Committee is of the view that using willingness to pay within the health sector is in most cases considerably more problematic than with regard to accident risk. The most important reason for this is than one will rarely be in a position to fully base decisions on an ex ante perspective where a large number of individuals are facing small risks. It will typically be the case that some individuals have already contracted a disease, and using willingness to pay may seem unreasonable in such an ex-post situation. One example may be determining cardiac surgery capacity, which will affect both individuals who are completely healthy at the moment, individuals with a high probability of contracting cardiovascular disease and individuals who are already ill. It is difficult to see how willingness to pay studies can do much to solve the prioritisation problem in such a situation. In addition, it can be difficult to obtain useful findings from a willingness to pay survey because most people will have little experience with valuing health goods in monetary terms.

Comments:

Whether it is theoretically justifiable and ethically appropriate to use valuation of life and health in the analysis of treatments when such valuation is *not* based on studies of willingness to pay in an ex-post situation, but is instead based on the *transfer* of valuations estimated in an ex-ante situation, is discussed in Chapters 10.5 and 10.7.

From the NOU 1997: 27 Green Paper, p. 113:

> The problems associated with using willingness to pay make it appropriate to use cost-effectiveness analysis within the health sector. However, it can often be difficult, as discussed in Chapter 12.6.1, to find cases where the benefits from various measures are the same, thus enabling the use of cost-effectiveness analyses. This means that quality-adjusted life years should be considered as a potential decision-making criterion.
>
> In principle, the use of quality-adjusted life years offers a systematic method for prioritisation between different patient groups and cases. The method implies that everyone with the same disease is treated the same irrespective of income and wealth. However, this does not mean that the method solves the difficult distribution problems that will be encountered whenever scarce resources are to be allocated within the public health service. As far as the Committee is concerned, it seems both unrealistic and undesirable for various groups to be subjected to strict prioritisation on the basis of one single indicator like quality-adjusted life years. This is in line with views expressed by the Lønning Committee (NOU 1997:18), which notes that quality of life is a very difficult phenomenon to measure, and that quality-adjusted life years therefore cannot be the sole criterion when assessing the desirability of a health investment. Reporting of quality-adjusted life years may nevertheless provide information of interest to decision making, e.g. in the context of the evaluation of alternative medicine types. In addition, the use of quality-adjusted life years means that the effects of different treatment methods are described in a systematic and precise manner. The Committee therefore recommends a continued effort to make more systematic use of quality-adjusted life years or other disaggregated health indicators when performing health economics assessments.

Comments:

The recommendation in the NOU 1997: 27 Green Paper for a continued effort to make more systematic use of quality-adjusted life years (see above for an explanation of the concept) has largely been adhered to (cf. Chapter 10.6).

The NOU 1997: 27 Green Paper notes that the use of cost-effectiveness analysis can contribute to efficient resource use within a fixed budget limit, with no need for explicit economic valuation of life and health. This applies irrespective of whether one uses statistical lives, statistical life years or quality-adjusted life years as health indicator. Various aspects of the economic valuation of quality-adjusted life years are discussed in Chapter 10.6.

10.4 The Committee's interpretation of the terms of reference

The duties stipulated in the terms of reference are to "examine what weight intersectoral cost-benefit assessment standards should carry in the evaluation of the impact on life and health, including within the health sector, and any ethical issues that may be raised thereby". The Committee has deemed it necessary to clarify its interpretation of its duties as thus stipulated in the terms of reference, before presenting its assessments and recommendations.

10.4.1 Interpretation and delimitation of the terms of reference

Different meanings may be attributed to some of the concepts mentioned in the terms of reference. The Committee has therefore specified its interpretation of the concepts "intersectoral standards", "cost-benefit assessment", "life and health" and "what weight", and the consequences thereof for the delimitation of the terms of reference.

10.4.1.1 Intersectoral standards

Intersectoral standards are here interpreted as uniform practices (standards) for using cost-benefit analysis in various sectors where life and health feature as major or minor effects. These may amount to recommendations on more homogeneous method use, more homogeneous health indicators and/or more uniform economic valuation of health indicators. Since the terms of reference mention the value of a statistical life, the terms of reference are interpreted as requesting an examination of the standardisation of the economic value used for analysis purposes.

10.4.1.2 Cost-benefit assessments

The Committee has applied a broad interpretation of the term "cost-benefit assessments". This means that such term is used in the broader sense of economic analysis (i.e. not only as a specific method of analysis, cf. Chapter 2). Said interpretation is supported by the fact that little use is made of cost-benefit analysis, as a specific method, in the health sector, together with the fact that the health sector is expressly mentioned in the terms of reference.

Valuation of the benefit side is not necessary for cost-effectiveness analysis purposes, and hence standardisation of valuation estimates is, generally speaking, not required for such purposes. Nevertheless, the issue arises because it is, as mentioned above, not uncommon to combine cost-effectiveness analysis where the benefit side is measured in quality-adjusted life years, or in other standardised, comparable units, with threshold values intended to define acceptable limits for cost per benefit unit (e.g. per quality-adjusted life year). It should be noted that such practice makes cost-effectiveness analysis very similar to cost-benefit analysis (as a specific method of analysis).

10.4.1.3 Life and health

Life and health may be included in cost-benefit analysis in the form of various units of measurement. The value of a statistical life is expressly mentioned in the terms of reference. Statistical lives are the most commonly used economic valuation units in studies of the willingness to pay for reduced accident risk. In the health sector, the degree to which measures affect expected lifespans or not varies, and their objectives are often concerned both with extending lifespans and improving health, whilst some measures only influence health, and not lifespans. Statistical lives or life years are not suited for capturing the benefits of improved health. Since quality-adjusted life years are commonly used units of measurement in economic analysis within the health sector, and the health sector is expressly mentioned in the terms of reference, the Committee assumes that life and health in this context includes the units of measurement statistical lives, statistical life years and quality-adjusted life years. The Committee focuses on these aggregate units of measurements because intersectoral standards may be of relevance in relation thereto, but there is nothing to prevent more specific health indicators from being used for cost-benefit analysis purposes.

10.4.1.4 Weight in evaluations

The Committee has been requested to examine "what weight" intersectoral cost-benefit assessment standards should carry "in the evaluation of the impact" on life and health.

One possible interpretation of this is that one shall examine whether economic valuations could and should be used in the prioritisation of resources for measures with an impact on life and health. This includes whether economic theory justifies a recommendation to the effect that the authorities should establish threshold values for the maximum acceptable cost per QALY (or other health indicators) and, if applicable, what should be the level of these threshold values.

In Chapter 3, the Committee has specified that it considers the outcome of economic profitability assessments to be part of the basis for making decisions, and not a decision-making rule. In Chapter 3, the Committee has also emphasised that the economic profitability of a measure (as calculated through cost-benefit analysis) cannot be interpreted normatively as a matter of course, but should primarily be considered a descriptive calculation of the net willingness of the population to pay. The extent to which actual decisions should and shall be based on the net willingness of the population to pay is a matter that falls outside the scope of cost-benefit analysis. The question of what weight should be attributed to life and health when the authorities are to make actual decisions must be considered a political and ethical question that falls outside the scope of the terms of reference of the Committee. On the other hand, the Committee takes the view that it falls within the scope of the terms of reference to comment on the theoretical and empirical basis for calculating, introducing and using, if applicable, threshold values as mentioned above.

The NOU 1997: 27 Green Paper recommended a value of a statistical life for use in the analysis of measures that reduce accident risk. These are primarily measures that result in small changes in risk for a large number of persons. In the health sector, there is often a need for evaluating measures that will result in a major change in risk for a fairly small number of persons, and where the persons concerned may also to some extent be identified. One possible interpretation of the terms of reference is therefore that these call for an examination of the extent to which economic valuations can be used in the analysis of health sector measures like diagnosis, treatment, rehabilitation, alleviation, etc., which involve major changes in risks associated with life and health, where the target group in many cases can be identified.

10.4.1.5 The Committee's delimitation of the terms of reference

The terms of reference are interpreted to mean that an examination of the following issues is requested: 1) To what extent could and should economic valuations be used as a basis for decision making in the analysis of measures that may entail major changes to risks associated with life and health, where it may, moreover, be known which individuals are affected by such changes in risk? 2) Should the economic values used in such analysis, if any, be the same for all sectors?

10.5 Interpretation and applicability of the terms VSL, VOLY and QALY

It is not necessarily unproblematic to use VSL to estimate the willingness to pay for lifesaving measures which involve non-marginal risk reductions, which pertain to groups with a different risk level than the general population to begin with and/or which can save lives that are identifiable in full or in part. Many measures in the health sector are characterised by exactly such circumstances. This will also have consequences for whether VOLY will be a good unit of measurement and for what use can be made of QALY. In the present Chapter we will examine the interpretation and applicability of VSL, VOLY and QALY in the cost-benefit analysis of life and health.

VSL

The value of a statistical life, VSL, is measured, as discussed above, by the willingness of individuals to pay for a *small risk reduction*. The VSL concept must be interpreted against that background. If a sufficiently large number of individuals experience a minor reduction in their risk of death (probability of premature death), these small risk reductions will in aggregate mean that society can expect fewer premature fatalities. However, the willingness of people to pay for small risk reductions will not necessarily be identical to their willingness to pay for lifesaving as such, and this imposes certain restrictions on the use of VSL to estimate the willingness of the population to pay for lifesaving measures in general.

A lifesaving measure may, for example, primarily relate to other people, whilst VSL is usually estimated on the basis of a marginal reduction in own risk. It may be known which persons' lives the measure is expected to save, or who has a particularly high probability of being affected. The risk reduction for those involved may be non-marginal (for example from highly probable death to highly probable recovery). Their risk level to begin with may be very different from the risk level of a representative selection of the population (for example because the target group is seriously ill to begin with). All these factors may affect the willingness to pay, at times considerably so (see Hammitt and Treich, 2007, and Hammitt, 2012).

Performing a cost-benefit analysis of lifesaving measures by using VSL may nonetheless be of interest in such cases as well, provided that one evaluates alternative measures by adopting a fairly peculiar and hypothetical approach, i.e. what is often termed «behind the veil of ignorance» (Harsanyi, 1955, and Rawls, 1971). This involves envisaging that one is not yet aware of one's own identity or how one will fare in life, and hence does not know whether one will become a cancer patient, have children, end up in a risk group for cardiovascular disease, etc. When considered from such a perspective, a new curative treatment for a specific group of cancer patients may, for example, be considered to involve a small risk reduction for each individual in the population, because nobody «yet knows» whether they will be afflicted themselves. This may conceivably be an interesting and relevant philosophical exercise for decision makers. Since neither the decision makers, nor the remainder of the population, are in actual fact behind any "veil of ignorance", it must nevertheless be emphasised that the findings from such a cost-benefit analysis cannot be considered a measure of the actual net willingness of the population to pay in the situation in which the decision is in fact made. It may still provide an interesting indicator for decision makers charged with prioritising the use of society's resources. It is under any circumstance important to note that VSL is a measure of the willingness to pay for a marginal risk reduction, and not for life and health as such.

A similar problem, although somewhat different in principle, arises when the change in risk applies to identified persons (Hammitt and Treich, 2007). A person who knows that her life will be saved by a measure will of course have an exceptionally high willingness to pay for such measure. Hence, a measure that is not economically profitable before the identities of those affected are known may nevertheless, as shown by Broome (1978), be profitable when measured after their identities have become known – because the change in risk has a very strong impact on their willingness to pay. Hammitt and Treich (2007) note that cost-effectiveness analyses can therefore, under certain assumptions, provide a more precise illustration of the welfare effects of such measures than can cost-benefit analysis. They also note that the findings from cost-benefit analysis for this type of measure can potentially be manipulated by tactical choice of the date of disclosing information in relation to the date of analysis.

VOLY

It is, as explained above, fairly straightforward to aggregate the willingness of individuals to pay for their own marginally reduced risk of death into a willingness to pay for a reduced number of expected premature fatalities in the population as a whole ("VSL"). It is, on the other hand, somewhat less clear how one might derive the value of a statistical life year ("VOLY") from the value of a statistical life. In estimating VSL, people are usually asked about their willingness to pay for a reduced risk of death, but not about how many years they expect to have left to live to begin with, or how much relative weight they attach to each of these years (their pure rates of time preference). Consequently, it is not obvious how best to convert VSL into VOLY. It is possible, under highly simplifying assumptions, to arrive at the relationship between VSL and VOLY presented in Box 10.1. The formula in Box 10.1 is based on, *inter alia*, the assumption that individuals' pure rate of time preference is constant over time, which assumption is questioned in recent literature (see for example Frederick, Loewenstein and O'Donoghue, 2002). Moreover, the formula makes implicit assumptions about the distribution of remaining life years and about time preferences amongst the respondents. The relationship between a marginally reduced risk of death and an expected life saved for society is more straightforward, and thus requires assumptions that are less strict, than the relationship between a marginally reduced risk of death and an expected life year saved for society.

VOLY can also be estimated directly via willingness to pay studies, cf. the discussion of applications in Norway in Chapter 10.6.1 and in the United Kingdom in Chapter 10.6.2.

QALY

As discussed in Chapter 10.2, it is not necessary to calculate any monetary value for QALY in order to use it as a benefit indicator in a cost-effectiveness analysis. There are various methods for calculating QALY, which often attach weight to different factors and which are often based on different principles (cf. e.g. the NOU 1997: 27 Green Paper and Olsen, 2009). Different measurement methods may reflect what are, in principle, different ways of posing questions. QALY as a unit of measurement in relation to changes in life and health has been criticised from many quarters. Arnesen and Norheim (2003), Augestad et al. (2012) and Hendriksen (2012) may, for example, be mentioned in a Norwegian context. Nor is there a full consensus amongst researchers within the field as to which method is preferable. Drummond et al. (2009) discuss how QALY may be developed and improved as a health indicator. Norwegian Directorate of Health (2011) and Norwegian Medicines Agency (2012) examine which measurement instruments are most appropriate to use for QALY in a Norwegian cost-benefit analysis context. However, no decision has thus far been made as to the standardisation of methods and the weighting of the health-related quality of life in QALY. Calculation of QALY involves, *inter alia*, having to assess how important different types of afflictions and disabilities are in relation to each other, and such choices may of course be controversial. QALY should therefore be considered an indicator, rather than an exact measurement method for health benefits.

Although the use of QALY methodology has tended to be considered an approach different from the use of the willingness to pay for health goods in health economics analysis (cf. also the fact that cost-effectiveness analyses is more frequently used than cost-benefit analysis, as a specific method of analysis, in analysing health measures), one has also sought to estimate the value of a QALY through willingness to pay studies (cf. e.g. Gyrd-Hansen, 2003, Dolan et al., 2003, Dolan et al., 2008, and Bobinac et al., 2010). Hammitt (2002) provides a thorough examination of the theoretical differences between willingness to pay ("WTP") and QALY. One may say, as a brief summary, that studies of the willingness to pay for a QALY suffer from the same methodological problems as studies of the willingness to pay for other non-market goods, and that issues relating to identifiability and non-marginal risk reductions are additional thereto. A person who knows that her life will be saved by a measure will obviously, according to Hammitt and Treich (2007), have an exceptionally high willingness to pay for such measure. This implies that the validity of such hypothetical valuations can often be questioned (cf. e.g. Smith and Richardson, 2005, Pinto-Prades et al., 2009, and Bobinac et al., 2012).

It is also established practice to convert VOLY to the value of a QALY (cf. e.g. Svensson and Hultkrantz, 2012, discussed in Chapter 10.6.2). Such practice is premised on a number of highly simplified assumptions; see Box 10.1. Firstly, it is assumed that VSL does in fact value life, and not risk reduction. Secondly, QALY is an indicator, and only measures aspects related to those dimensions that are included in the measurement instrument. When using the willingness to pay for statistical lives or life years, the valuation is not restricted to dimensions of any measurement instrument. Since the valuation of QALY is restricted by the dimensions of the measurement instrument, it is not possible to be entirely certain that 1 QALY corresponds to one year of "perfect" health, because it must be taken into consideration that the measurement instrument does not capture all aspects of health and life. Correspondingly, it is not possible to be certain that $QALY_t = w_t VOLY$ cf. Box 10.1, because it is not possible to be certain that QALY and VOLY measure the same dimensions of life. In addition, it is not obviously the case that the willingness to pay for health changes can be assumed to be related to the willingness to pay for life in a straightforward manner.

Box 10.1 Assumptions underpinning conversion from VSL to VOLY and QALY

Make the following simplifying assumptions: 1) All individuals are identical, thus implying, *inter alia*, that the mean VSL in the population equals the VSL of each individual; 2) VOLY is constant over the lifespan of the individual; 3) Expected remaining lifespan T for each of the (identical) individuals is known; and 4) The discount rate applied by each individual (see Chapter 5 on discount rates), δ, is known and constant over time. We will then have the following relationship between VSL and VOLY (Boardman et al., 2011, and OECD, 2012):

$$VSL = \sum_{t=0}^{T} \frac{VOLY}{(1+\delta)^t}$$

Assume, moreover, that it is possible to represent quality of life on a zero-to-one scale. Assume also that VSL can actually be interpreted as measuring the willingness of the population to pay for a life saved as such, and not only for marginal risk reductions (see Chapter 10.5). The willingness to pay for a QALY in a year *t* may then be calculated as w_tVOLY (Boardman et al., 2011), where w_t designates the quality of life in year *t* on the scale from zero to one. This implies that VOLY, which is an indicator that does not weigh life years by the health-related quality of life, is deemed to be equivalent to the value of a life year with perfect health (w_t=1).

QALY is often interpreted as expressing individual preferences. It may be appropriate to recall, in this context, that the aggregation of the preferences of various individuals is, generally speaking, theoretically problematic, cf. Chapter 3. Even if QALY had been sufficiently well measured to provide a precise description of the preferences of each individual, the questions of how best to aggregate QALY, and how to interpret such aggregated figure, would have remained.

Statistical lives, statistical life years and quality-adjusted life years are all aggregate health indicators. In principle, these can all be used for cost-benefit analysis purposes, irrespective of whether or not monetary values are attributed thereto. Quality-adjusted life years may be a more appropriate indicator for health gain than statistical life years when the quality of life during the life years gained is clearly inferior or varies considerably between alternative measures, in the same way that statistical life years may be a more precise indicator than statistical lives when the number of life years gained is small or varies considerably between measures. Although it may often be appropriate to use such aggregate health indicators, there is no reason to refrain from using more specific health indicators for cost-benefit analysis purposes (for example the expected change in the number of asthma cases amongst children).

Threshold values

A question that often arises when discussing health economics analysis is whether it is theoretically justifiable to recommend that the authorities establish threshold values for maximum acceptable costs per QALY or other health indicators. Such a threshold value would, if applied, be interpreted as a cap on how cost-intensive a measure can be per unit of health gain before its implementation is not recommended or permitted. Threshold values of this type may ensure that the same criterion is applied in different sectors and different contexts when determining which measures to implement. On the other hand, this also means a choice of decision-making criterion that is not necessarily in conformity with the views of the authorities.

If the threshold value is perceived as an estimate of the willingness of the population to pay, there is, in principle, little to distinguish such practice from attributing a monetary value to QALY and performing a cost-benefit analysis. If the threshold value is perceived as an actual cap on the willingness of the authorities to pay, the use of threshold values, or threshold value intervals, may turn such analysis into a decision-making tool, not only a component of a broader basis for making decisions. A practice in which a threshold value is linked to a form of automatic decision, with all measures calculated to have a cost-effectiveness in excess of the threshold value being implemented as a matter of course, has indeed met with some criticism. Such a practice may imply that less weight is accorded to other factors that the population and decision makers would like to emphasise, like e.g. the severity of a disease (NOU 1997:18 Green Paper and Weinstein, 2008). Grosse (2008) shows, in this context, that the willingness to pay for treatments that gain life years exceeds the willingness to pay for treatments for lesser afflictions. A number of authors also argue that the use of threshold values can give producers of pharmaceutical products and medical equipment an opportunity to adapt their prices and thus increase health sector costs (Drummond, 2003, and Grosse, 2008).

10.6 Practices and applications in various sectors and countries

Cost-benefit analysis of measures with an impact on life and health is carried out in many sectors of society. Such is the case both in Norway and in other countries (cf. Ministry of Finance, 2005, and OECD, 2012). However, the manner in which such analysis is performed varies, both in terms of the methods of analysis used and in terms of how the health effects are valued in monetary terms.

The health sector can, in the main, be said to use cost-effectiveness analysis[1] with quality-adjusted life years as health indicator or other health indicators that capture changes in the health-related quality of life, cf. e.g. Norwegian Directorate of Health, 2011, and Norwegian Medicines Agency, 2012, whilst the transportation sector principally uses cost-benefit analysis, as a specific method of analysis, with statistical lives as health indicator (cf. e.g. Norwegian Public Roads Administration, 2006). Chapter 10.5 addresses problems and limitations associated with the interpretation and valuation of the terms VSL, VOLY and QALY. However, the discussion in the present

[1] Using cost-benefit analysis, as a specific method of analysis, instead of cost-effectiveness analysis has also been discussed in the health sector (cf. e.g. Norwegian Directorate of Health, 2011, Johnson, 2012, and Sculpher and Claxton, 2012).

Chapter shows that these terms are extensively used, and that such use is not always in line with the theoretical/methodological recommendations.

We will here examine recommended valuations in Norway and other countries, and we have structured the subchapters into prevention and treatment.

10.6.1 Valuations recommended and applied in Norway

10.6.1.1 Prevention of injury or disease

The 2005 edition of the Ministry of Finance cost-benefit analysis guide recommends using NOK 15 million at 2005 prices as the value of a statistical life. It also allows for higher values to be used if each life saved represents many remaining life years. The estimate is based on the European Commission's VSL estimate of EUR 1.4 million at 2000 prices (approximately NOK 15 million at 2005 prices) for accidents (where the average age at death is about 40 years), and a somewhat lower value of EUR 1 million at 2000 prices (approximately NOK 11 million at 2005 prices) for a case of environmentally-related premature death (where the average age of fatalities is considerably higher), EC DG Environment, (2001). In the latter case, where the old and infirm die a few months, or possibly a few years, earlier than would otherwise have been the case, Ministry of Finance (2005) additionally recommends, as a sensitivity analysis, performing analysis using the value of a statistical life year (VOLY), which may be put at NOK 425,000 at 2005 prices. This figure is obtained from a study commissioned by the UK Department for Environment, Food and Rural Affairs (Chilton et al., 2004). Ministry of Finance (2005) also invites quality-adjustment of such value on the basis of QALY values for relevant diseases. The Norwegian Government Agency for Financial Management ("DFØ") cost-benefit analysis handbook (2010) uses the Ministry of Finance estimate for VSL (converted into NOK 17.4 million at 2010 prices). In addition, it refers to the Norwegian Directorate of Health's recommendation of NOK 500,000 at 2005 prices as the value of a statistical life year with perfect health (Norwegian Directorate of Health, 2007).

The transportation sector uses value estimates for risk reduction based on its own surveys. Norwegian Public Roads Administration Handbook 140 (Norwegian Public Roads Administration, 2006) stipulates, for example, a cost of NOK 26.5 million at 2005 prices for one traffic fatality. This cost estimate comprises both real economic costs (medical, equipment and administrative costs, as well as the loss of production imposed on society by accidents) and a welfare loss (the willingness to pay for reduced accident risk). The welfare loss represents 67 percent of the costs associated with fatalities. The loss of production is the value of the production lost as the result of fatalities and injuries, and is calculated on the basis of average labour income, specified by gender and age, less future consumption. The transportation bodies and Avinor have made, on the basis of a comprehensive Norwegian valuation study (Institute of Transport Economics ("TØI"), 2010), recommendations to the Ministry of Transport and Communications as to which unit prices should be used for cost-benefit analysis purposes in the transportation sector. These costs are approved by the Ministry of Transport and Communications. Institute of Transport Economics ("TØI") (2010) estimates the value of statistical lives at NOK 22 million at 2009 prices, based on a stated choice study, and at NOK 39 million at 2009 prices, based on a contingent valuation study. Institute of Transport Economics ("TØI") (2010) notes that this type of hypothetical valuation is subject to considerable uncertainty, and that the estimated VSL is approximately NOK 10 million at 2009 prices when the relative value of travel time and VSL are adjusted such as to make the value of travel time match the value of travel time from the value of time study conducted at the same time. Despite considerable variation in estimated VSL based on the various methods mentioned here, Institute of Transport Economics ("TØI") (2010) concludes that «the current level of the value of statistical lives in the official valuations for the transportation sector, which is approximately NOK 26 million at 2009 prices, can continue to be applied». In order to deal with the uncertainty associated with estimated VSL, Institute of Transport Economics ("TØI") (2010) indicates an uncertainty of (no less than) 20% in each direction. Approximately NOK 4 million at 2009 prices is added on top of the recommended VSL of approximately NOK 26 million at 2009 prices, to reflect the net loss of production, as well as medical, equipment and administrative costs, thus implying that the accident cost per traffic fatality is estimated at approximately NOK 30.2 million at 2009 prices by the Institute of Transport Economics ("TØI") (2010).

There are two main reasons why the estimate in Norwegian Public Roads Administration (2006), which was adjusted upwards and recom-

Table 10.1 Elements of Norwegian estimates for, and applications of, the value of a statistical life ("VSL") in the cost-benefit analysis of accident prevention measures

Elements of VSL	Ministry of Finance cost-benefit analysis guide (2005)	Norwegian Public Roads Administration Handbook 140 (2006)
Willingness to pay for averting a premature fatality	NOK 15 million at 2005 prices	NOK 18.3 million at 2005 prices
Net loss of production imposed on society in general by fatal accidents	Assumed to be included in the willingness to pay	Added on top
Medical costs not covered by individuals	Not discussed	Added on top
Equipment costs not covered by individuals	Not discussed	Added on top
Administrative costs	Not discussed	Added on top

mended for continued application in Institute of Transport Economics ("TØI") (2010), is about twice as high as the estimate recommended in the Ministry of Finance guide from 2005. These are summarised in Table 10.1. One reason is differences in what is included when estimating VSL. The Ministry of Finance assumes that the VSL from willingness to pay studies includes all benefits society derive from averting the loss of human lives. The Norwegian Public Roads Administration guide assumes that willingness to pay surveys provide data on the willingness of individuals to pay for intangible value and own consumption (referred to as welfare loss), and that tangible value like the net loss of production and medical, equipment and administrative costs (referred to as real economic costs) need to be added (Elvik, 1999). The Norwegian Public Roads Administration guide puts these costs at 33 percent of the cost of fatalities. The other reason is different estimates for the willingness to pay. The Norwegian Public Roads Administration estimates the willingness to pay at NOK 18.3 million at 2005 prices, whilst the Ministry of Finance estimate is NOK 15 million at 2005 prices.

In the report "Health Effects in Cost-Benefit Analysis" (Norwegian Directorate of Health, 2007), the Norwegian Directorate of Health recommends using NOK 500,000 at 2005 prices as the value of a statistical life year in perfect health for purposes of intersectoral cost-benefit analysis. The estimate is derived from the valuation of statistical lives lost in road traffic accidents and the assessment of various degrees of discounting (cf. Box 10.1). The estimate is rounded off to signal high uncertainty. The Norwegian Directorate of Health notes that the estimate does not include medical, equipment and administrative costs, the loss of production or the welfare loss of household members, unlike e.g. the method practised by the Norwegian Public Roads Administration. The Norwegian Directorate of Health estimate of NOK 500,000 at 2005 prices per QALY is used by the Norwegian Public Roads Administration to estimate positive health effects from increased physical activity associated with measures aimed at pedestrians and cyclists (Norwegian Public Roads Administration, 2011). The welfare loss from a *minor* injury in the transportation sector is estimated at NOK 467,000 at 2009 prices (Institute of Transport Economics ("TØI"), 2010), thus implying that this practice puts the said value at almost a par with the value of a quality-adjusted life year in the health sector.

10.6.1.2 Treatment and alleviation of injury or disease

The extent to which economic analysis is used as a basis for making decisions in the health sector in Norway is variable. To the extent that cost-benefit analysis is used, it is primarily in the form of cost-effectiveness analysis, and not in the form of cost-benefit analysis (as a specific method of analysis), and often with the benefit measured in terms of QALY.

Norway neither has any official QALY valuation, nor any so-called threshold value to determine what shall be classified as cost-efficient or not. However, in health economics analysis it is not uncommon for the analyst to define the cost-effectiveness of a project, measured in NOK per QALY gained, and comparing it to a QALY benchmark. Said benchmark then serves as a threshold defining how much a QALY can cost before the project is held not to be cost-efficient (cf. e.g. Norwegian Knowledge Centre for the Health Services, 2009). Such threshold values may be premised on various lines of reasoning, but can seem fairly random, and will at times lack both theoretical and empirical underpinnings (cf. e.g. Kristiansen, 2003, and Grosse, 2008).

The Norwegian Medicines Agency uses health economics analysis as a basis for deciding whether pharmaceutical products should qualify for pre-approved reimbursement under the government-funded prescription scheme. The pharmaceuticals industry seeks to include pharmaceutical products in the pre-approved reimbursement scheme, and a pharmacoeconomic analysis is required to be included in the applications. Such analyses shall be conducted pursuant to pharmacoeconomic analysis guidelines (Norwegian Medicines Agency, 2012). The guidelines stipulate no explicit economic valuation of life and health. The Norwegian Medicines Agency is authorised to grant pre-approved reimbursement status for pharmaceutical products that are considered cost effective and that fall below a defined expenditure limit. The expenditure limit, which is NOK 5 million in expected annual additional expenditure for the National Insurance System in the fifth reimbursement year, is a budgetary limit and is of no relevance to the cost-effectiveness assessment. Pharmaceutical products that are held to be cost effective and that involve expenditure in excess of the expenditure limit, are referred to the Ministry of Health and Care Services and included in the regular prioritisation decisions in the fiscal budget.

The Norwegian Directorate of Health has issued a consultative draft cost-benefit analysis guide for the health sector (Norwegian Directorate of Health, 2011). It addresses various methods of analysis and economic valuations of life and health for both preventive measures and treatments in the health sector. Norwegian Directorate of Health (2011) also illustrates how the cost-effectiveness of measures can be linked to the severity of the health condition. This was specified, in response to a commission from the National Council for Priority Setting in Health Care, in an evaluation of rare congenital diseases where many life years may be lost. The consultative draft suggested that both cost-benefit analysis, as a specific method of analysis, and cost-effectiveness analysis with QALY as health indicator can be used in the health sector. An economic valuation of NOK 500,000 per QALY was proposed for cost-benefit analysis, as a specific method of analysis, with NOK 100,000-1 million per QALY being proposed for sensitivity analysis purposes. The consultative comments submitted in respect of the guide are hardly indicative of a consensus, and a final version of the Norwegian Directorate of Health cost-benefit analysis guide has not yet been completed.

The Norwegian Knowledge Centre for the Health Services performs health economics analyses as a basis for decision making for the Ministry of Health and Care Services, the health trusts, the Norwegian Directorate of Health, the Norwegian Medicines Agency and the National Council for Priority Setting in Health Care. These analyses often use QALY as a health indicator, but other health indicators are also used if QALY is not available. When drawing conclusions, the Norwegian Knowledge Centre for the Health Services will often compare the estimated cost per QALY to a threshold value of NOK 500,000 per QALY, without this being related to the seriousness of the condition. A measure is often referred to as «cost-efficient» if its estimated cost-effectiveness is below the threshold value. An example is the analysis of the inclusion of vaccination against rotavirus (which causes gastroenteritis) in the Norwegian child immunisation programme (Norwegian Knowledge Centre for the Health Services, 2009). Said analysis concluded that such vaccination is cost-efficient if one includes the loss of production caused by parents being absent from work when their children get ill, and: "The conclusion with regard to the cost-effectiveness of introducing the vaccination is based on a threshold value for the willingness to pay per quality-adjusted life year gained of NOK 500 000." In addition to illustrating how threshold values are used for health economics analysis purposes, the analysis shows that whether and, if applicable, how loss of production is included in an analysis can have a major impact on findings.

The National Council for Priority Setting in Health Care performs an advisory function on issues relating to quality and prioritisation in health and care services. The Council has advised on a large number of cases, and health economics analysis often forms part of the basis for making decisions. Its advice on the introduction of new health measures is premised on three prioritisation criteria: seriousness, benefits and cost-effectiveness (cf. NOU 1997: 18 Green Paper). In 2012, the Council has, for example, considered advising against the introduction of vaccination against rotavirus infection in the national child immunisation programme on the grounds that it is not a par-

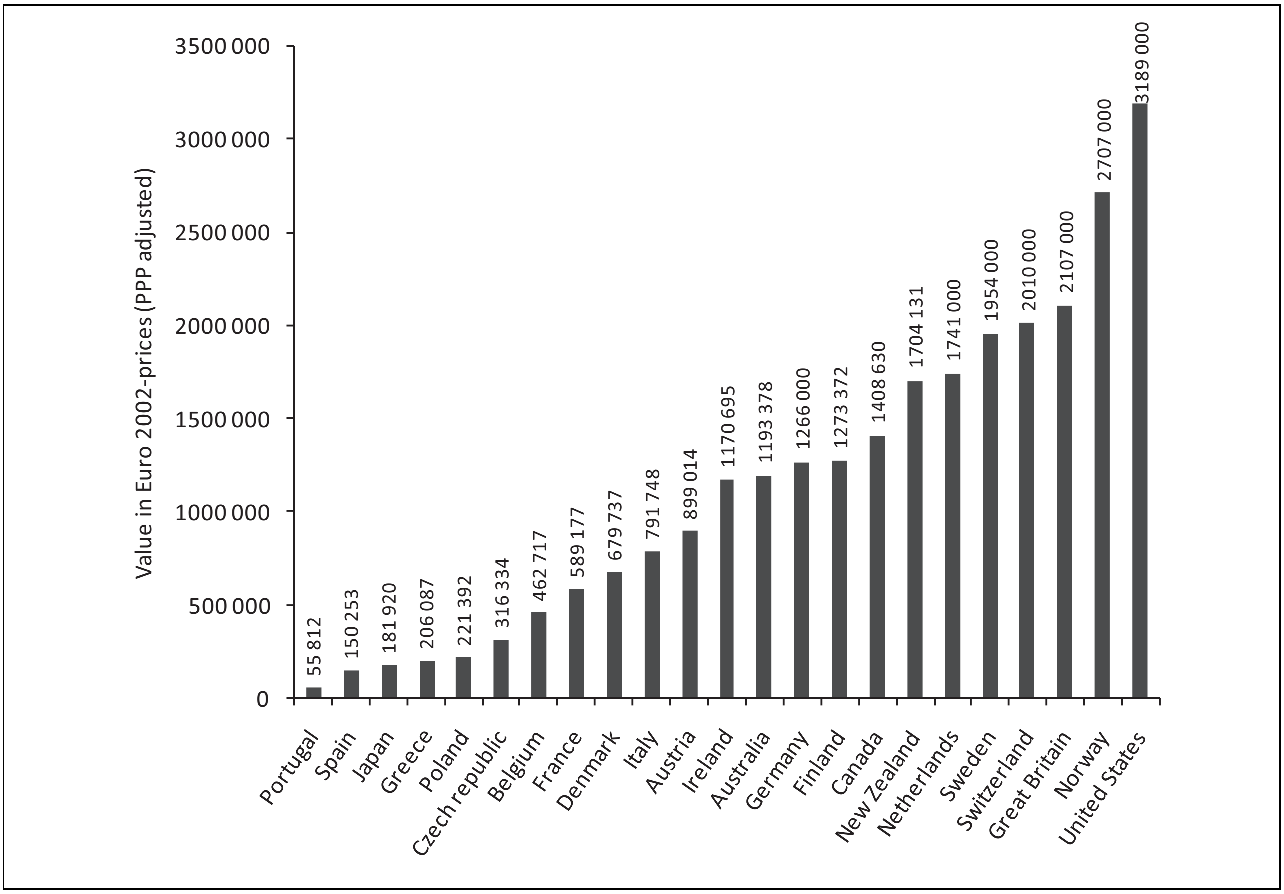

Figure 10.1 Official estimates for the value of a statistical life in the traffic sector in selected countries. Unit: Euros at 2002 prices (Purchasing Power Parity-adjusted).

Source: SafetyNet (2009).

ticularly serious disease for children. This was despite the vaccination having been found to be cost-efficient when including the loss of production (cf. the above discussion of threshold value).

10.6.1.3 Distributional considerations and other non-efficiency-related priorities

Cost-benefit analysis only forms part of the basis for making decisions about the prioritisation of resources. It is therefore important to note that the findings from a cost-benefit analysis are not tantamount to a decision/prioritisation. Weight will also be attached to other considerations than cost-effectiveness/economic profitability when making actual decisions.

The Lønning committees (NOU 1987: 23 and NOU 1997: 18 Green Papers) discuss prioritisation in the health sector. The NOU 1997: 18 Green Paper (the Lønning 2 Committee) concludes that three main priorities should apply in the health sector: 1) the severity of the condition, 2) the benefits from the measure, and 3) the cost-effectiveness of the measure. The principles outlined by the Lønning committees have been codified in the health legislation. The principles also mean that the Storting has concluded that cost-effectiveness is not the sole relevant prioritisation criterion within the health sector (cf. overview of the basic principles underpinning prioritisation, Norwegian Directorate of Health, 2012). An assessment exclusively focused on cost-effectiveness and linked to so-called cost-effectiveness "threshold values" through a form of "automatic decision-making", which thus fails to consider cost-effectiveness alongside the two other criteria, would mean that some relevant priorities are left out.

The weight attached to the severity of health implications is reflected in, for example, objectives like the zero vision in the road sector ("a vision for a transportation system that does not cause any loss of life or permanent injury"), in recommended valuations when a large versus a small number of life years are lost (Ministry of Finance, 2005), and in how seriousness is emphasised in the evaluation of resource use devoted to health measures (National Council for Priority Setting in Health Care).

10.6.2 Valuations recommended and applied in other countries

10.6.2.1 Prevention of injury or disease

A project funded by the European Commission, Directorate-General for Transport and Energy, reviews the use of cost-benefit analysis, as a specific method of analysis, in the evaluation of traffic safety measures (SafetyNet, 2009). The report compares the valuations of a statistical life in various countries (cf. Chart 10.1). Norway's value of a statistical life is obtained from the Norwegian Public Roads Administration's Handbook 140 (Norwegian Public Roads Administration, 2006).

All countries that make fairly extensive use of cost-benefit analysis are included in the comparison. The Norwegian Public Roads Administration's estimate for the value of a statistical life is the second highest in the world, according to this comparison.

The OECD has recently issued a meta analysis on the valuation of the risk of death in the environmental, health and transportation sectors (OECD, 2012). The report is based on data gathered and analysed over a four-year period. The database is, according to OECD (2012), the world's largest database of studies showing VSL based on stated preferences with regard to a small reduction in the risk of death. Based on the meta analysis, a VSL range of USD 1.8 million to 5.4 million at 2005 prices is recommended for an adult, with a point estimate of USD 3.6 million at 2005 prices (OECD, 2012), as far as the EU 27 member states are concerned. For transfers between countries, it is recommended that VSL be adjusted on the basis of differences in PPP-adjusted GDP, and that an income elasticity of the willingness to pay for VSL of 0.8 be used. Such a transfer to Norwegian conditions results in a range of NOK 20-60 million at 2012 prices, with a point estimate of approximately NOK 40 million at 2012 prices. For reasons of equality, OECD (2012) recommends no income adjustment for uses within a single country.

Willingness to pay for the life of a child is discussed in OECD (2004) in the context of the risk of environmentally-related death. Children do not have the cognitive or financial capacity to state such a value, and if one uses the willingness of parents to pay it is necessary to examine whether altruistic values are included in a consistent manner. OECD (2012) does not recommend general adjustment of VSL on the basis of age. OECD (2012) nonetheless recommends, based on existing empirical studies from Europe and the United States (US EPA, 2003, and OECD, 2010), using a VSL that is 1.5 – 2 times higher for children than for adults.

OECD (2012) provides a survey on how VSL is used in different countries and sectors. In the United States, for example, government bodies responsible for environment, transportation, food and medicines all make use of a different VSL (Hammitt and Robinson, 2011). The transportation sector in the United Kingdom makes use of a VSL corresponding to that used in the transportation sector in Norway (UK Department for Transport, 2009). Both countries add the loss of production, as well as medical and equipment costs (cf. 10.6.1.1).

According to OECD (2012), the focus in most countries that issue official recommendations on the valuation of life and health is on VSL, and not on VOLY. If VOLY is used in cost-benefit analysis, the findings from such analysis may differ from those obtained if using VSL, depending on, *inter alia*, the average age of the persons who benefit from the risk reduction; see also the discussion in Chapter 10.5 and Box 10.1. In other words, an analysis using VSL and an analysis using VOLY may differ in their findings, even if the number of lives saved is the same and VSL and VOLY have both been correctly measured. The countries using VOLY primarily derive such value from VSL, which involves, *inter alia*, making assumptions with regard to subjective discount rates, average individuals, etc. (cf. Box 10.1). Only a small number of studies estimate VOLY directly by using contingent valuation or choice experiments. EU countries predominantly use VOLY for sensitivity analysis. OECD (2012) identifies the United Kingdom as an example of a country using VOLY in its main analysis (i.e. not only in sensitivity analysis) of air pollution measures. Moreover, the United Kingdom uses a lower VOLY if the state of health of the target group is highly precarious and the lifespan lost is only a few months. Hence, the use of VOLY in the United Kingdom has a clear parallel in the use of QALY in the analysis of treatments in the health sector, where weight is also attached to the health-related quality of life of the target group. Svensson and Hultkrantz (2012) estimate an economic value of SEK 1.2 million per QALY (range SEK 750,000 – 3.2 million) based on Swedish VSL estimation studies.

10.6.2.2 Treatment and alleviation of injury or disease

Internationally, it is common practice to use cost-effectiveness analysis with quality-adjusted life years (QALY) as a health indicator to conduct economic analysis of health sector measures. International practice has, however, to some extent been more explicit than Norwegian practice when it comes to adopting threshold values defining what constitutes a cost-effective measure. NICE (National Institute for Health and Clinical Excellence) in England does, for example, use a range of GBP 20,000-30,000 per QALY when making its recommendations to the National Health Service in England (NICE, 2010). The NICE Citizens Council has concluded that treatments costing in excess of the upper limit of GBP 30,000 per QALY can be recommended in cases where the health condition is very severe and the treatment is of a lifesaving nature (NICE Citizens Council, 2010). The NICE lower limit is not interpreted in a corresponding manner. Nord (2009) notes that practice in countries like France and Germany is less uniformly focused on cost-effectiveness than the NICE model in England (Pouvourville, 2013, and Caro and Nord et al., 2010).

The World Health Organisation (WHO, 2012) proposes GDP per capita as a basis for grading the cost-effectiveness of health measures. Measures with a cost per QALY gained of less than GDP per capita are thus classified as "very cost effective". Measures with a cost per QALY gained of between one and three times GDP per capita are categorised as "cost effective", whilst measures with a cost per QALY gained of more than three times GDP per capita are categorised by the WHO (2012) as "not cost effective".

Both Grosse (2008) and Weinstein (2008) provide overviews and discuss how USD 50,000 per QALY has become established as a threshold value referred to in health economics analysis contexts in the United States. Both conclude that the provenance of the said figure is unclear. Grosse notes that the amount may have its origin in the actual cost of dialysis and a notion that such measure ought to be offered to Medicare patients with terminal renal failure. Grosse also proposes updating the interval from USD 20,000 – 100,000 per QALY at 1982 prices (Kaplan and Bush, 1982) to USD 40,000 – 100,000 per QALY at 2008 prices. Despite the existence of such threshold value estimates, the use of threshold values denominated in USD per QALY, to determine which health measures are cost effective is outlawed in the United States (US Public Law, 2010).

10.7 The assessments of the Committee

Above, the Committee has interpreted the terms of reference as follows: 1) To what extent could and should economic valuations be used as a basis for decision making in the analysis of measures that may entail major changes to risks associated with life and health, where it may, moreover, be known which individuals are affected by such change in risk? 2) Should the economic values used in such analysis, if any, be the same for all sectors? We will here discuss each of these two issues in turn.

10.7.1 Economic valuation as a basis for decision making

In Chapter 3, the Committee has emphasised that it considers the outcome of economic profitability assessments to form part of the basis for making decisions, and not as an outright decision-making rule. The Committee has also specified in Chapter 3 that the economic profitability of a measure (as calculated in a cost-benefit analysis) cannot necessarily be interpreted normatively, and must primarily be considered a descriptive estimate of the net willingness to pay of the population. The extent to which actual decisions should and shall be based on the net willingness to pay of the population is, on the other hand, a question that falls outside the scope of cost-benefit analysis. It is important to keep these underlying premises in mind when considering the discussion below.

If analysis is to serve as a decision-making tool in the sense that public sector measures are to be prioritised directly on the basis of their estimated economic profitability, it will be of essential importance to value as many effects as possible, also those for which economics does not appear to provide much valuation guidance – because the absence of an explicit valuation of an impact will be tantamount to applying a value of zero. However, the situation is different when analysis is only intended to provide decision makers with the best possible basis for making decisions. The primary function of analysis will then be, as stated in the NOU 1997: 27 Green Paper (p. 6), "*to clarify and elucidate the consequences of alternative measures*". The issue of how far one should go in attributing value to effects must therefore be considered in view of the extent to which economic valuation contributes to enhanced understanding of the consequences of the measure on the part of decision makers.

If one refrains from valuing life and health impacts in monetary terms, cost-benefit analysis can be carried out in the form of cost-effectiveness analysis or cost-effect analysis (see Chapter 2). If all consequences are valued and one conducts a full cost-benefit analysis, as a specific method of analysis, the findings will provide an indication as to the net willingness of the population to pay for the various measures, although this cannot readily be interpreted as a normative specification of the relevant measure's contribution to society's welfare.

A reasonable implication of these considerations is that monetary valuation of life and health impacts, for purposes of including these in cost-benefit analysis, as a specific method of analysis, should be limited to cases where theoretical and empirical evidence justifies an assumption to the effect that the chosen values reflect, directly or indirectly, the marginal willingness of the population to pay for the relevant impacts. Other valuation principles than aggregate individual willingness to pay, for example government-stipulated cost limits, will measure something else, and hence not be compatible with the interpretation of cost-benefit analysis, as a specific method of analysis, adopted in the present Report.

We will therefore, in the discussion below, attach weight to whether we find theoretical and empirical support for estimating the willingness of the population to pay for life and health impacts, also in the health sector. For those impacts where the Committee is of the view that such theoretical and empirical support does not exist or is, in our assessment, too weak, there will be a strong case for using cost-effectiveness analysis or cost-effect analysis, inasmuch as it will be very difficult to interpret the findings from a cost-benefit analysis (as a specific method of analysis).

If economic valuation is theoretically and empirically justified, it nevertheless remains to consider whether such valuation will provide decision makers with a better understanding of the impacts of alternative measures than can be achieved through forms of analysis that do not involve such valuation (cf. the fact that it is not necessary to value impacts in order to perform cost-benefit analysis, in the more general sense of the term used in the present Report). Whether economic valuation and cost-benefit analysis, as a specific method of analysis, offer a better basis for making decisions than does cost-effectiveness analysis, or cost-effect analysis, will need to be examined in each individual case.

VSL

The value of a statistical life, VSL, is measured, as noted above, by aggregation of the willingness of many individuals to pay for a *small risk reduction*. It is therefore (cf. Chapter 10.5) not necessarily unproblematic to use VSL to estimate the willingness to pay for lifesaving measures that involve non-marginal risk reductions. This is of particular concern for groups with a different risk level than the general population to begin with, and/or where the lives saved are identifiable, in full or in part. Many measures within the health sector will be characterised by exactly such circumstances.

If a sufficiently large number of individuals experience a minor reduction in their risk of death (probability of premature death), these small risk reductions will in aggregate mean that society can expect fewer premature fatalities. However, the willingness of people to pay for small risk reductions will not necessarily be in conformity with their willingness to pay for lifesaving as such (i.e. saving the lives of identified individuals), and this imposes certain restrictions on the use of VSL in the cost-benefit analysis of lifesaving measures in general.

A lifesaving measure may, for example, primarily relate to other people, whilst VSL is usually estimated on the basis of a marginal reduction in own risk. It may be known which persons' lives the measure is expected to be able to save, or who has a particularly high probability of being affected. The risk reduction for those involved may be non-marginal (for example from highly probable death to highly probable recovery). Their risk level to begin with may be very different from the risk level of a representative selection of the population. If one seeks to estimate the willingness to pay for reduced risk in groups that are already afflicted, or groups that have a higher risk than the "average individual" in the overall population, all these factors may affect their willingness to pay, at times considerably so. Using VSL to carry out cost-benefit analysis, as a specific method of analysis, of lifesaving measures may nevertheless be of interest in such cases as well. One may, in order to determine the willingness to pay to be used in such cost-benefit analysis, assume that alternative measures are examined by adopting a fairly peculiar and hypothetical approach, i.e. what is often termed «behind the veil of ignorance» (cf. Chapter 10.5.). This involves envisaging that one is not yet aware of one's own identity or how one will fare in life, and hence does not know whether one will become a cancer patient, have children, end up in a risk group for cardiovascular disease, etc. Since neither the decision makers, nor the remainder of the population, are in actual fact behind any "veil of ignorance", it must nevertheless be emphasised that the findings from such a willingness to pay assessment cannot be considered a measure of the actual net willingness of the affected population to pay in the situation in which the decision is in fact made.

VOLY

It is, as explained above, fairly straightforward to aggregate the willingness of individuals to pay for their own marginally reduced risk of death into a willingness to pay for a reduced number of expected premature fatalities in the population as a whole ("VSL"). It is, on the other hand, somewhat less clear how one might derive the value of a statistical life year ("VOLY") from the value of a statistical life. In estimating VSL, people are usually asked about their willingness to pay for a reduced risk of death, but not about how much relative weight they attach to each of the life years gained (their pure rates of time preference). Consequently, it is not obvious how best to convert VSL into VOLY.

The formula in Box 10.1 is based on a number of strict assumptions. Consequently, it is not obvious how best to convert VSL into VOLY. However, there is, generally speaking, no reason to expect the values of remaining life years for different age brackets to exhibit the structure indicated by the conversion from VSL to VOLY in Box 10.1. Consequently, there is no good theoretical or empirical justification for deriving VOLY estimates from a VSL estimated over all age brackets. The relationship between a marginally reduced risk of death and an expected life saved for society is more straightforward, and thus requires assumptions that are less strict, than the relationship between a marginally reduced risk of death and an expected life year saved for society.

VOLY estimates must instead be based on surveys of the willingness to pay for reduced risk within the same age bracket. However, general methodological problems associated with willingness to pay studies suggest that the validity of such valuations is open to doubt (cf. Chapter 10.5), and one may experience different valuations of identical health effects and identical valuations of different health effects if findings from such valuation studies are used for analysis purposes (cf. Chapter 10.6.1).

Identifying a VOLY estimate that may serve as an intersectoral standard for all age brackets is a task that involves as yet unresolved ethical, theoretical and empirical problems.

QALY

As discussed in Chapter 10.2, it is not necessary to calculate any monetary value for QALY in order to use it as a benefit indicator in a cost-effectiveness analysis. There are various methods for calculating QALY, which often attach weight to different factors and which are often based on different principles (cf. e.g. the NOU 1997: 27 Green Paper and Olsen, 2009). Different measurement methods may reflect what are, in principle, different ways of posing questions. QALY as a unit of measurement in relation to changes in life and health has been criticised from many quarters. Nor is there a full consensus amongst researchers within the field as to which method is preferable. Calculation of QALY involves, *inter alia*, having to assess how important different types of afflictions and disabilities are in relation to each other, and such choices may of course be controversial. QALY should therefore be considered an indicator, rather than an exact measurement method for health benefits.

In principle, it is possible to determine the willingness to pay for a reduction in the risk of a specific health impairment for a specific number of years (although it has turned out to be challenging in practice, and it also remains subject to the assumptions of small risks and large populations, cf. Chapter 10.5). If the willingness to pay for various states of health for a specific period of time is determined, it is also possible, in principle, to normalise such willingness by reference to a given state of health (for example the best one, with all states of health being represented by an index between zero and one). However, there is, generally speaking, no reason to expect the willingness to pay for a risk-reducing measure to have a linear form, thus enabling it to be inferred from a time-independent index and the duration of the state of health, as (implicitly) assumed in the economic valuation of quality-adjusted life years in Box 10.1.

The value of a QALY has been sought estimated through willingness to pay studies, but it may generally be noted that the validity of willingness to pay studies has been questioned and that the estimates are deemed to be highly uncertain (cf. Chapter 10.5). It is also established practice to convert VSL, typically via VOLY, into the value of a QALY. Such practice is premised on a number of highly simplified assumptions; see Box 10.1. Firstly, it is assumed that VSL does in fact value life, and not risk reduction. In addition, it is not obviously the case that the willingness to pay for health changes can be assumed to be related to the willingness to pay for life in a straightforward manner. Consequently, the conversion from VSL to valuation of QALY would appear to add further uncertainty.

Estimating the value of a QALY, either based on estimates from willingness to pay studies or converted from VSL estimates, is associated with both theoretical and empirical weaknesses. Consequently, there is no theoretical and empirical basis for stipulating any recommended economic value of a QALY.

10.7.2 Should the economic values used, if any, be the same for all sectors?

Cost-benefit analysis, as a specific method of analysis, is intended to provide a measure of the net willingness to pay. In order for this interpretation to be as correct and comparable as possible across analyses from different sectors, identical consequences should be evaluated identically in different sectors. The key consideration is for the findings to be understandable and fairly straightforward to interpret for decision makers, thus enabling the analysis to make a real contribution to improved decisions.

Methodological problems discussed above imply that theoretical and empirical evidence does not provide much support for establishing recommended VOLY and QALY figures. Attaching an economic value to a statistical life appears less challenging, from a theoretical perspective, than attaching an economic value to statistical life years or quality-adjusted life years. In addition, the availability of studies valuing statistical lives is better, as reflected in the existence of meta analyses (cf. e.g. OECD, 2012). Incidentally, OECD (2012) recommends carrying out national willingness to pay studies, rather than transferring values from other countries.

When it is unclear whether economic values incorporated in a cost-benefit analysis actually reflect the willingness of the population to pay, the findings from such analysis are difficult to interpret, and thus it also becomes unclear how said analysis can contribute to improved decisions. However, the Committee observes that valuations of life and health, in the form of VSL, VOLY and valuations of QALY, are in practice included in cost-benefit analysis in different ways in different sectors. This is, generally speaking, unfortunate.

If one wishes to make use of economic values for the willingness to pay for statistical life years and QALY, despite the difficulties of estimating these, both in practice and in principle, and wants such values to be reasonably consistent with the VSL estimate one uses, it is likely, in practice, that one will engage in some sort of calibration, with VOLY and the value of a QALY being derived on the basis of VSL (cf. Box 10.1), despite such calibration resting on a number of critical assumptions.

The Committee finds it theoretically and empirically justifiable to recommend an intersectoral VSL estimate (see below for further details). The Committee does not, on the other hand, find it theoretically and empirically justifiable to recommend an intersectoral standard estimate for VOLY or the value of QALY. This is partly because we find that the theoretical basis for such a valuation is weak, and partly because the empirical basis for estimating the willingness to pay appears to be considerably weaker for VOLY and QALY than for VSL.

We take the opportunity to reiterate, in this context, that there is no theoretical justification for interpreting VSL as a willingness to pay for lives as such. The latter implies that if such an interpretation is nevertheless applied, the informational value of the valuation will be limited, and thus generate findings that are difficult to interpret for decision makers. This is an argument in favour of attaching more weight to cost-effectiveness analyses and/or cost-effect analyses than to cost-benefit analysis, as a specific method of analysis, for projects where lives saved are an important consequence and the prerequisites for using VSL (small risk reductions and unidentified individuals) are not in place.

VSL

Institute of Transport Economics ("TØI") (2010) estimates the value of statistical lives in relation to reduced risk of road transport accidents in Norway under various hypothetical valuation methods. A stated choice study estimates VSL at NOK 22 million at 2009 prices and a contingent valuation study estimated VSL at NOK 39 million at 2009 prices. Institute of Transport Economics ("TØI") (2010) notes that there is considerable uncertainty associated with this type of hypothetical valuation, and observes that the estimated VSL is approximately NOK 10 million at 2009 prices when the relative value of travel time and VSL are adjusted to bring the value of travel time into conformity with the value of travel time from the value of time study carried out at the same time. Such calibration can be considered an attempt at estimating a VSL with a more «correct» relative value, and thus possibly less influenced by hypothetical bias (cf. e.g. Sælensminde, 2003). The VSL estimate from the stated choice study, at NOK 22 million at 2009 prices, which values reduced risk simultaneously with reduced travel time, does in itself represent a method that attempts to estimate relative valuations. This is in contrast to the VSL estimate from contingent valuation, at NOK 39 million at 2009 prices, which values reduced risk in isolation, without relating it to travel time. Institute of Transport Economics ("TØI") (2010) concludes, despite considerable variation in estimated VSL based on the three different methods mentioned here, that «the current level of the value of statistical lives in the official valuations for the transportation sector, which is approximately NOK 26 million at 2009 prices, can continue to be applied». In order to deal with the uncertainty associated with estimated VSL, Institute of Transport Economics ("TØI") (2010) indicates an uncertainty of (no less than) 20% in each direction. Approximately NOK 4 million at 2009 prices is added on top of the recommended VSL of approximately NOK 26 million at 2009 prices, to reflect the net loss of production, as well as medical, equipment and administrative costs, thus implying that the accident cost per traffic fatality is estimated at approximately NOK 30.2 million at 2009 prices.

OECD (2012) recommends, based on a meta analysis, a VSL range of USD 1.8 million to 5.4 million at 2005 prices for an adult, with a point estimate of USD 3.6 million at 2005 prices (OECD, 2012), as far as the EU 27 member states are concerned. For transfers between countries it is recommended that VSL be adjusted on the basis of differences in PPP-adjusted GDP, and that an income elasticity of demand of 0.8 be used. Such a transfer to Norway results in a range of NOK 20-60 million at 2012 prices, with a point estimate of approximately NOK 40 million at 2012 prices. OECD (2010) recommends using a VSL for children that is 1.5 – 2 times higher than the average VSL.

The NOU 1997: 27 Green Paper examined whether production gains should be added on top of the estimated willingness to pay for VSL (cf. the overview in Chapter 10.3). The NOU 1997: 27 Green Paper concluded that the theoretical basis for such a supplement was unclear. The Committee relies on the conclusions from the NOU 1997: 27 Green Paper in this respect, and assumes that any net production gains can be held to be included in the measured willingness to pay. This interpretation means that the Institute of Transport Economics ("TØI") (2010) willingness to pay estimate from a stated choice study, in the amount of NOK 22 million at 2009 prices, should be considered as an estimate of the willingness to pay inclusive of production gains. Adjusted for GDP per capita developments (cf. Chapter 4 on income adjustment of the willingness to pay over time) and measured at 2012 prices, such estimate becomes somewhat higher. Besides, the Institute of Transport Economics ("TØI") (2010) estimate is at the lower end of the VSL range estimated for Norway on the basis of the values from OECD (2012). An upwards adjustment of the estimate to NOK 30 million at 2012 prices will to some extent compensate for part of the uncertainty associated with the estimates.

OECD (2012) recommends using a higher value of statistical lives in the analysis of measures targeting children than in the analysis of measures targeting adults (cf. Chapter 10.6.2). Ministry of Finance (2005) also allows for this. This is based on the premise that the willingness to pay for risk-reducing measures targeting children exceeds the willingness to pay for such measures targeting adults.

VOLY

The discussion in the present Chapter shows that conversion of VSL into VOLY is based on unreasonably strict assumptions. In addition, the estimates of the willingness to pay for VSL are subject to considerable uncertainty. Moreover, the empirical foundation for basing value estimates directly on surveys of the willingness to pay for VOLY is weak. This means, all in all, that the Committee does not find theoretical and empirical support for recommending a standard VOLY estimate.

A weak theoretical and empirical basis for estimating the willingness to pay for statistical life years, implies that a monetary value that is nonetheless attributed to statistical life years will be of limited informational value and be difficult to interpret for decision makers. This is an argument in favour of attaching more weight to cost-effectiveness analyses and/or cost-effect analyses than to cost-benefit analysis, as a specific method of analysis, whenever the specific nature of the measure indicates that statistical life years is an appropriate unit of measurement.

QALY

The discussion in the present Chapter shows, as was the case with VOLY, that conversion of VSL into an economic value of a QALY is based on unreasonably strict assumptions. Furthermore, the estimates of the willingness to pay for VSL are subject to considerable uncertainty and the empirical foundation for basing estimates for the value of a QALY directly on surveys of the willingness to pay is weak.

Empirical evidence suggests that the willingness to pay depends on seriousness (cf. Chapter 10.6). If one arrives, despite a weak theoretical and empirical basis, at an economic value of a QALY (cf. Box 10.1) that may seem consistent with VSL in terms of magnitude, one cannot necessarily assume that such an imputed value of a QALY is applicable to a measure irrespective of factors like, for example, the number of life years gained. Moreover, one needs to be aware, as a general observation, that effect measurements like QALY are variables that only provide an indication as to the magnitude of the impacts, and not precise measurement instruments. This means, all in all, that the Committee does not find theoretical and empirical support for recommending a standard value for a QALY. As with VOLY, this is an argument in favour of attaching more weight to cost-effectiveness analyses and/or cost-effect analyses than to cost-benefit analysis, as a specific method of analysis, whenever the specific nature of the measure indicates that quality-adjusted life years are an appropriate unit of measurement.

Threshold values

The values discussed above are based on the willingness of the population to pay. Such values would have been a good basis for establishing threshold values if the authorities wanted to prioritise resource use based on precisely what the population is willing to pay for. However, this principle is unlikely to be in conformity with the principles laid down in the report of the Lønning 2 Committee. Besides, willingness to pay is not necessarily, as noted in Chapter 3, aligned with welfare, and it can be argued that willingness to pay attaches relatively minor weight to benefits accruing to low-income groups. Consequently, it is unlikely to be theoretically justifiable to recommend that the Norwegian authorities should apply the values discussed here as caps on the cost per unit of health gain.

It is likely that a VSL estimate can nonetheless serve as an interesting point of reference for the analysis of measures within the health sector and other sectors. If, for example, one is able to identify measures with a cost per expected life saved that is considerably less than what the population is assumed to be willing to pay, this will indicate that one may be able to reap major gains at a low cost. What information decision makers should attach weight to when making their final decisions must, however, be deemed to fall outside the scope of the work of this Committee.

10.8 Summary recommendations

- Health indicators will have to be chosen on the basis of the specific character of the public measures in question. It will, for example, be more appropriate to use statistical life years than statistical lives when expected remaining life years deviate sharply between alternative measures. Correspondingly, it will be more appropriate to use indicators for quality-adjusted life years when improved health-related quality of life is an important consequence. It may also be relevant to use specific health indicators.
- It is not necessary to attribute an economic value to the health indicators statistical lives, statistical life years or quality-adjusted life years in order to include these in cost-effectiveness analysis or cost-effect analysis.
- It is proposed an economic value of a statistical life (VSL) at NOK 30 million at 2012 prices. It is recommended that this be applied to all sectors (cf. intersectoral standard in the terms of reference).
- In the analyses of measures specifically targeting the safety of children one may apply, by way of supplementary analysis, a higher value of a statistical life than for the general population. An appropriate level is twice the VSL of the general population.
- In principle, the value of equivalent consequences should be the same irrespective of sector, also for other health-related benefit indicators, like value of a statistical life year (VOLY) and quality-adjusted life years (QALY). However, the Committee is of the view that the technical basis for estimating the willingness to

pay for these is currently not sufficiently established to merit the recommendation of intersectoral standard values for VOLY and QALY.
- It is proposed that the economic value of VSL be adjusted in line with the growth in GDP per capita (cf. Chapter 4 on real price adjustments).
- For measures where effects on life and health represent a main consequence, especially where the measures imply significant risk changes for individuals and/or where the identity of those especially affected is known, it will often be more appropriate to use cost-effectiveness analysis or cost-effect analysis than cost-benefit analysis (as a specific method of analysis).

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Chapter 11
Financial and administrative implications

11.1 Introduction

From the terms of reference of the Committee:

> Technical developments have taken place nationally and internationally within the area of cost-benefit analysis since the Ministry of Finance published its cost-benefit analysis guide in 2000, and subsequently revised it in 2005. The Stern Review placed a special focus on social effects in the distant future. Similar and other types of issues have been noted by Norwegian academics. An expert committee is appointed, against this background, to review the cost-benefit analysis framework, and to consider the potential expansion and detailing of the cost-benefit analysis guidelines.
>
> …
>
> The Committee shall assess financial/administrative implications of its proposed measures.

11.2 Scope and objective

The main purpose of a cost-benefit analysis is to clarify and elucidate the consequences of alternative measures prior to making a decision about the implementation of measures. Consequently, cost-benefit analysis is a way of organising information (NOU 1998: 16 Green Paper). The analysis shall form part of a basis for making decisions, without thereby amounting to a decision-making rule.

Cost-benefit analysis, as a specific method of analysis, and cost-effectiveness analysis enable a uniform ranking of measures on the basis of their economic profitability. A *cost-benefit analysis*, as a specific method of analysis, quantifies all positive and negative effects of a measure in monetary terms to the extent feasible, based on the main principle that an impact is worth what the population is willing to pay, in aggregate, to achieve it. If the willingness to pay for all benefits associated with the measure exceeds the sum total of its costs, such measure is defined to be economically profitable (NOU 2009: 16 Green Paper). In principle, the cost of a project shall reflect the value of what one *must* forgo to implement such project, whilst its benefits shall reflect how much one is *willing* to give up (NOU 1997: 27 Green Paper).

However, economic profitability is not necessarily the sole consideration of relevance to decision makers. In addition to focusing on the economic profitability of measures, the analysis should also aim to describe all consequences that must be assumed to be of importance to the assessment of decision makers, including non-priced effects and the distributional implications of measures. The final discretionary assessment should then be left to decision makers. The handling of distributional considerations in cost-benefit analysis is discussed in more detail in Chapter 4.5 of the NOU 1997: 27 Green Paper, and is also addressed in Chapter 3 of the present Green Paper.

11.3 The recommendations of the Committee

In the chapters listed below, the Committee has set out its recommendations with regard to changes that should be made to calculation prices and to what additional information should be accorded weight to improve the basis for making decisions for each individual decision maker:

Chapter 3 Distribution effects
Chapter 4 Real price adjustment
Chapter 5 The social discount rate
Chapter 6 Lifespan, analysis period and residual value
Chapter 7 Net wider impacts of transportation projects
Chapter 8 Disasters and irreversible effects
Chapter 9 Carbon price paths
Chapter 10 Valuation of life and health

As far as individual recommendations are concerned, reference is made to the chapters listed above, as well as to the summary of recommendations in Chapter 1; Appointment, terms of reference and recommendations.

The most recent major revision of the cost-benefit analysis framework took place in 1997, with an update in the Ministry of Finance guide from 2005. Several sectors have, against the background of the intersectoral recommendations, prepared sector-specific guides that form the basis for cost-benefit analysis in those sectors.

The efforts of the Committee have been focused on an examination of those elements of the cost-benefit analysis framework identified in the terms of reference. The objective has been to ensure that the framework is in conformity with theoretical and empirical developments within the field.

It would be appropriate, in the wake of such a review, for those sectors that have prepared their own sector-specific guides to examine their guides with a view to ensuring that these are in conformity with the national framework, thus ensuring a harmonised methodology in Norway.

11.4 Administrative and financial implications of the recommendations of the Committee

Administrative implications for the preparation of cost-benefit analysis

Although the Committee makes a number of recommendations with regard to changing assumptions relating to the computation of calculation prices and the weighting of individual elements in cost-benefit analysis calculations, one would not expect the cost of preparing such analyses to increase or decrease. Some recommendations may entail modifications to calculation methods and data gathering, whilst other recommendations may simplify and clarify what information should be gathered. The net overall administrative implications of changes to the recommendations on the preparation of cost-benefit analysis must be assumed to be minor in scale. It must be assumed that any costs associated therewith are non-recurring costs.

Implications for the outcome of cost-benefit analysis

There may be changes in rankings based on the net economic benefits of projects. What impact the new recommendations will have on any given analysis will depend on the cost and benefit profile of the relevant project over time. It must nonetheless be assumed that projects for which it is now being proposed that major parts of the benefits shall be subjected to real price or income adjustment (based on GDP per capita) will perform better for analysis purposes than was previously the case. This may e.g. apply to transportation projects whose main benefits are time savings or a reduced risk of serious accidents.

Implications of changes in project rankings for decision makers

Decision makers are typically found at the political level, or at the executive level if decision-making authority is delegated. Analysis only forms part of a basis for making decisions, and does not amount to a decision-making rule. Consequently, any change in the ranking of projects within a sector and between sectors does not result, in itself, in different decisions. It is up to each decision maker to determine what should be accorded weight in making a final decision, whether it is net economic benefits or other decision-making criteria. Moreover, it should be noted that public sector decisions are made within the budget limits defined by the appropriating authority in Norway.

11.5 Overall assessment of the administrative and financial implications of the recommendations of the Committee

The Committee is of the view that the impacts on the cost of preparing each analysis are minor and that any such implications will take the form of non-recurring costs. The cost associated with the revision of sectoral guides is also a non-recurring cost. The benefits from the recommendations of the Committee take the form of, *inter alia*, simplified computation methods and more specific recommendations as to parameter values than has previously been the case, in addition to a generally updated framework that reflects theoretical and empirical developments within the field.

The recommendations of the Committee may change the internal ranking between various projects, based on the net economic benefits of the measures. Whether this has an impact on what measures are adopted by decision makers depends on what decision makers attach weight to in making their decisions. If weight is attached to net economic benefits, the recommendations may have implications in terms of which measures are implemented.

The proposals will have no budgetary implications if the general budget limits remain unchanged, either nationally or within a sector.

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