

Risk adjustment of the discount rate in cost-benefit analyses¹

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ABSTRACT

Previously, governmental guidelines for choice of discount rate allowed for differentiation of the rate based on the project's systematic risk. [This article was written in Norway in 2018.] After 2014, this was no longer allowed. This was in part because the risk adjustment proved to have low transparency and consistency across sectors. The guidelines now demand that the risk adjustment follows a return requirement that suits a large group of public-sector projects. We show that practitioners in the energy and environmental field deviate from the guidelines by making additional risk adjustments. In light of this, we point out weaknesses in the arguments for the revision in 2014. We also suggest how one can make consistent and transparent project specific risk adjustments.

¹ This article arose as part of a dialogue seminar on the discount rate by the Oslo Centre for Research on Environmentally Friendly Energy (CREE). Both [authors] presented at the seminar, and Nesje was one of the organizers. We are grateful for discussions with the participants. Special thanks to Kenneth Birkeli, Brita Bye, Rolf Golombek, Rolf Korneliussen, Espen Langtvet, Lars Peter Myklebust, Karine Nyborg, and Guro Børnes Ringlund for suggestions for the article. Thanks also to the editor, Ragnhild Balsvik, and to an anonymous referee for useful comments. The article is part of the research activity of CREE, which is supported by the Research Council of Norway (RCN). Nesje is grateful for the hospitality of Northwestern University where parts of the research were done. The visit was supported by the RCN. Contact information: frikk.nesje@econ.uio.no and diderik.lund@econ.uio.no.

INTRODUCTION

The discount rate in benefit-cost analyses is a return requirement. Choice of the right discount rate is thus important to ensure a socially desirable portfolio of public-sector investments. As part of this, it is beneficial to consider project specific risk. Theoretically, the discount rate used for evaluating a project can typically be expressed as a risk free interest rate and an adjustment thereof based on the project's systematic risk. Systematic risk is a risk concept based on covariance, i.e., to which extent future net project revenues covary with other revenue (or possibly with wealth, or with returns).

The government's guidelines for choice of discount rate has changed over time. In the period 1999-2014 the guidelines allowed for differentiation of the discount rate based on the project's systematic risk. After 2014, this was no longer allowed. This was in part because the risk adjustment proved to have low transparency and consistency across sectors. The guidelines now require the risk adjustment to follow a normal return requirement that suits a large group of public-sector projects (the normal project).

In this article we point out weaknesses in the arguments for the revision in 2014, and we suggest how to make consistent and transparent project specific risk adjustments. The inspiration for the article comes from the dialogue seminar on the discount rate by the Oslo Centre for Research on Environmentally Friendly Energy (CREE) in November 2017.² During the seminar it appeared that practitioners in the energy and environmental field deviate from the governmental guidelines. In some cases this is due to unclear guidance from the government on how to understand the guidelines. This leads to confusion among practitioners when the discount rate is chosen. In other cases a practice that deviates from the guidelines seems reasonable. That many cases showed substantial difference between the guidelines and practice, prompted us to study more closely the background for today's guidelines.

Before we present the suggestion on how to make consistent and transparent project specific risk adjustments, we discuss why the government's guidelines were revised in 2014, and how practice deviates from these. We present a simple two-period model for valuation of uncertain project revenues (and costs) to show which uncertainty should be considered relevant, and to illustrate how to estimate the willingness to pay for various risky projects.³ Furthermore, we discuss overviews of quantifications for projects within oil and climate. We also briefly mention uncertainty through many periods.

² The programme for the dialogue seminar is available online [in Norwegian]: http://www.cree.uio.no/outreach/events/user-meetings/dialogseminar_171116.html.

³ To quantify willingness to pay entails the same as quantifying the required expected return. When an agent knows the exogenous simultaneous probability distribution for a cash flow (from a project) and other future revenues, the agent is able to decide how much he is willing to pay for this, at a maximum. Thus he also determines how large expected return he requires, at a minimum. If the cash flows occur in many periods, this return will be an internal rate of return.

GUIDELINES AND PRACTICE

The recommended practice for choice of discount rates in government has changed through time:

- *NOU 1983: 25.*⁴ Benefit-cost analyses rely only on expected values and application of the Ramsey rule (see [below]). Here, there is no risk adjustment of the discount rate. The background for this is Arrow and Lind (1970) who assume that the project's cash flow is independent of macroeconomic variables.
- *NOU 1997: 27, Circular R-14/ 1999 and Circular R-109/ 2005.* The Ramsey rule is seen as problematic. Benefit-cost analyses consider systematic risk. The project's risk premium in the discount rate is based on the Capital Asset Pricing Model [CAPM], a framework for estimating required expected returns. The background for this is, inter alia, Lind (1982), one of the authors of Arrow and Lind (1970), who has realized that risk should be considered (see also Lund (1993a), who also discusses Arrow and Lind (1970) for the case of a small, open economy).
- *NOU 2012: 16 and Circular R-109/ 14.* The CAPM is seen as problematic. The guidelines no longer recommend to differentiate the discount rate based on the project's systematic risk. Benefit cost analyses adjust for risk based on the normal project's systematic risk, which is defined as a normal required return that suits a large group of public-sector projects.

This normal required return is set to 4 percent. The only exception is for public-sector projects in direct competition with private-sector agents. The government does not want to outprice private-sector agents by applying a lower discount rate. In such cases one will thus apply the same discount rate as the private-sector agents.

In our view, the revision in R-109/ 14 is problematic. The circular goes further than NOU 2012: 16 by no longer differentiating return requirements according to systematic risk. The NOU also removes this differentiation in the recommendation for basic analysis. Only in cases where this risk is unusually low or high, there is a recommendation to reduce or increase the required expected return in supplementary analyses (section 5.7).

We understand the argument as twofold. In part, there is a lack of trust in the CAPM, and likely less trust than in 1997. In part, practice has revealed that it is close to impossible to quantify differentiated risk premia in a way that can be implemented in government. The latter point is related to the emergence of a room for discretion in adjustment for the project's systematic risk. This gave strategic incentives to adapt the discount rate, and thus a lack of consistency between sectors.

We believe it necessary to distinguish between the model and its quantification. There can be good reasons to maintain the model even when quantification is found difficult. As we shall show below, the covariance measure of relevant risk does not rely on

⁴ NOU refers to Official Norwegian Reports [Noregs offentlege utgreiingar]. The NOUs we consider give recommendations for choice of discount rates. R refers to circulars [rundskriv] from the Ministry of Finance [of Norway]. These give the guidelines. Observe that NOUs and circulars are referred to differently in the main text and the reference list. This is to ease the presentation.

strict, very unrealistic assumptions. The most important assumption is that utility can be measured as expected utility. Section 5.2.3 in NOU 2012: 16 points to a number of assumptions for the CAPM, and claims that these are so unrealistic that one should disregard the model. There is no explanation of what one is left with, in that case.

In the presentation [below], we arrive at a covariance measure in expression (4) without the following assumptions. All four are mentioned in section 5.2.3 in the NOU, as if they were necessary, but they are not.

- *The agents maximize utility.* At the outset, our interest is whether a project will increase or decrease utility, but we do not need the assumption that agents are capable of any overall maximization of utility.
- *The agents have uncertain future income only from an optimally chosen portfolio.* We can allow them to have other uncertain sources of income, e.g., work or non-tradeable assets. (Norway as a nation has chosen to view petroleum in the ground as such an asset, until extraction.) The agents do not need any optimally chosen portfolio at all.
- *The market portfolio contains all future uncertain sources of income.* We do not need such a portfolio.
- *The agents have quadratic utility functions, or the uncertain returns are normally distributed.* This is also unnecessary to arrive at a covariance-based measure of risk.

We admit that the covariance in (4) cannot be directly measured in data. However, the problem in measuring the covariance cannot be a sufficient reason to claim that one should not try. There seems to be agreement on some risk premium. The disagreement is whether this premium can be differentiated. NOU 2012: 16 states that this can happen in unusual cases, while R-109/ 14 stipulates that it cannot happen at all.

Even if the CAPM has weaknesses, one should consider whether it can be used for quantifying covariance. This could be a pragmatic first point of departure. It is also possible that the model gives (approximately) correct numbers for expected return in firms in the private sector. The model can be self-fulfilling because it is widely used (see, e.g., Graham and Harvey (2001)), independently of theoretical objections. This is relevant for two reasons. Partly because it may be the relevant alternative return for a public-sector project. Partly because the government does not want to give own activities an advantage in competition.

The wish for consistency in benefit-cost analyses between sectors was a goal for the revision to R-109/ 14. This relates to what we perceive to be the technical reasons for the revision. However, it appears that governmental practice has not changed accordingly. Two cases in the energy and environment field exemplify that practice has not become more similar across sectors after the new circular:

- At CREE's dialogue seminar on the discount rate in November 2017, it emerged that a different practice from that stipulated by R-109/ 14 characterizes benefit-cost analyses. Statnett [the system operator for electricity in Norway] uses a higher

discount rate than the circular's 4 percent when they consider network investments that are directly related with, inter alia, petroleum extraction and connection of hydro and wind power. This is with regard to assumed higher systematic risk in these sectors. The motivation of Statnett resembled what appears in NOU 2012: 16, as discussed above. The Norwegian Water Resources and Energy Directorate does the same for licenses for hydro and wind power, based on high systematic risk for the power sector. The Norwegian Environment Agency has used a discount rate of 8 percent for calculations of discharge allowances for mining. If practice were to follow R-109/ 14, a discount rate of 4 percent should be applied.

- For the petroleum activity, a 7 percent discount rate is still being used, even if R-109/ 14 stipulates 4 percent. This is, e.g., stated in the Guide for Plan for Development and Operation as “the authorities’ required return” [our translation] (Olje- og energidepartementet, 2017a), and 7 percent is used by the Ministry of Petroleum and Energy in calculations of profitability in the state budget for 2018 (cf. written answer to Stortinget [the parliament of Norway] (Dokument 15: 418, (2017–2018)). It is reasonable to expect a closer discussion of the justification for this when the circular which covers all governmental activity categorically stipulates 4 percent. The ministry is open for discussion. In OED (2017b), they state: “It is debatable what is the right discount rate for the various calculations.” [our translation] In this letter, the ministry uses 4 and 7 percent as alternatives. Moreover, it is interesting to notice that the [then] minister has hinted that the actual required return is lower than 7 percent. In connection with calculations of profitability of the Goliat field, showing an internal rate of return between 0.9 and 5.9, [then] Minister Søviknes stated [our translation], “If I had received 5.9 percent return on my savings account, I would have been very satisfied” (Lorentzen, 2017). Thus it is in this case unclear how the discount rate relates to the required expected return, as defined for the normal project in the circular. Based on the statements above, the discount rate is different from this.

The cases above show how inconsistent governmental practice is in the field of energy and environment. With these observations there is little reason to believe that consistency has been reached across sectors after introduction of the new circular. Furthermore, the evaluations of the profitability of the Goliat field illustrate a large problem. Practitioners deviate from the circular for projects that are being evaluated separately at the political level.

It is natural to discuss the status of the circular for various parts of governmental activity. This holds in particular for cases where practitioners deviate from the circular. But there is also a need for better guidance from the The Norwegian Government Agency for Financial Management on how to interpret the circular.⁵ Some of the inconsistent practice that was highlighted during CREE's dialogue seminar is related to uncertainty among

⁵ The current Guide (Direktoratet for økonomistyring, 2014) is unclear on the choice of discount rate. The text in section 3.5.3 is closer to NOU 2012: 16 than R-109/ 14, and can thus contribute to confusion.

practitioners over what discount rate to apply. There is also uncertainty over when governmental business competes directly with private-sector agents.⁶

However, some practice that deviates from R-109/ 14 can be reasonable. Some attempts by practitioners to consider project specific risk, as it emerged under CREE's dialogue seminar, is closer to the intention of the NOU. In any case it is problematic when adjustment for systematic risk is made in non-transparent ways. In this area, the CAPM may be helpful.

THE INVESTMENT CRITERIUM

Consider an individual agent through two periods (periods 0 and 1). Let this agent have a time additive utility function within the time-discounted utilitarian tradition with risk aversion in period 1:

$$V = U(C_0) + \theta E[U(\tilde{C}_1)], \text{ where } 0 < \theta < 1.$$

Here, C_0, \tilde{C}_1 are consumption of the agent, and U is a per-period utility function. \sim designates uncertainty, E is expectation, and θ gives utility discounting, i.e., to which extent the agent discounts future utility from today's point of view.

Consider a possibility for increased future consumption combined with a reduction of today's consumption by investment in period 0, where the increase is uncertain:

$$C_0 = Y_0 - I, \tilde{C}_1 = \tilde{Y}_1 + I(1 + \tilde{r}_I) \equiv \tilde{Y}_1 + I\tilde{R}_I.$$

Y_0, \tilde{Y}_1 are income for the agent, I is investment, and \tilde{R}_I [gross] return [one plus rate of return]. The investment is desirable if

$$dV/dI = -U'(C_0) + \theta E[U'(\tilde{C}_1) \cdot \tilde{R}_I] > 0.$$

Use the rule, $\text{cov}(\tilde{x}, \tilde{y}) = E(\tilde{x} \cdot \tilde{y}) - E(\tilde{x})E(\tilde{y})$, and rewrite as

$$E(\tilde{R}_I) > \frac{U'(C_0)}{\theta E[U'(\tilde{C}_1)]} - \text{cov} \left[\frac{U'(\tilde{C}_1)}{E[U'(\tilde{C}_1)]}, \tilde{R}_I \right]. \quad (1)$$

The first fraction on the right-hand side is well known from the discussion of the discount rate under full certainty, since⁷

$$\frac{U'(C_0)}{\theta U'(C_1)} \approx 1 + \delta + \eta g, \quad (2)$$

⁶ It also seems to be somewhat challenging for some practitioners to distinguish between the descriptive and normative parts of a benefit-cost analysis, where the descriptive part is quantification of alternative cash flows, while the normative part is the discounting of these.

⁷ Take logs, and make an approximation for small δ and $g := \frac{C_1 - C_0}{C_0}$ (cf., e.g., Dasgupta (2008) or Gollier (2012, p. 36)).

where $1 + \delta = 1/\theta$, $-\eta$ is the elasticity of the U' function, which under full certainty gives us the aversion of the agent to inequality in consumption over time, and g is the growth rate of consumption.⁸

Consider now optimal choice of a risk free investment. Assume, as a simplification, that the agent is free to save and borrow at a risk free rate. Let this rate be r_f , which defines the gross interest rate, $R_f = 1 + r_f$. This implies that (1) is satisfied with equality for R_f (replacing \tilde{R}_I). If not, the agent would save more, or borrow less, as long as (1) is satisfied with inequality, and vice versa if the opposite inequality holds. This implies that the two consumption magnitudes, C_0 and \tilde{C}_1 , are adjusted until equality holds. Because R_f is non-stochastic, the covariance is 0, and we find,

$$R_f = \frac{U'(C_0)}{\theta E[U'(\tilde{C}_1)]}, \quad (3)$$

which simplifies the investment criterion. If the right-hand side of (2) is set equal to the risk free gross interest rate from (3), we get the Ramsey rule. The rule gives equality between return on investment in risk free capital on the production side, r_f , and the welfare maintaining intertemporal trade-off on the consumption side, $\delta + \eta g$.⁹ In the sections to follow, we discuss the occurrence of risky investments as a reason to deviate from the Ramsey rule when quantifying the discount rate.¹⁰

Maintain that risk free investment is chosen optimally, but allow risky investment, and other investments that are not chosen optimally. Then the investment is desirable if

$$E(\tilde{R}_I) > R_f - \text{cov} \left[\frac{U'(\tilde{C}_1)}{E[U'(\tilde{C}_1)]}, \tilde{R}_I \right]. \quad (4)$$

For most projects the covariance in (4) is negative, so that the required return, which is given from the right-hand side, is greater than R_f . This is because most projects give higher income in economic upturns, i.e., when consumption is high. Under risk aversion, a high \tilde{C}_1 gives a low $U'(\tilde{C}_1)$, so that $\text{cov}[U'(\tilde{C}_1), \tilde{R}_I] < 0$.

⁸ Under full certainty this gives two reasons to discount. When $\delta > 0$, utility in period 1 has less weight than utility in period 0. Then the agent has a pure time preference, and discounts because he will experience utility earlier rather than later. When $g > 0$, the growth rate of consumption is positive. Since $\eta > 0$ leads to aversion against intertemporal consumption inequality arising from growth, this gives an additional reason to discount.

⁹ Cf., e.g., NOU 2012: 16, section 5.2.1. Within the literature there has been large disagreements on how to motivate and quantify the risk free discount rate. To our knowledge, Drupp et al. (2018), appearing after NOU 2012: 16, presents the most complete analysis of this topic so far. Out of about 200 experts in the literature, more than 75 percent are comfortable with a long-term risk free discount rate of 2 percent. The article also discusses the relevance of the right-hand side of (2), and quantifies δ , η , g , and r_f .

¹⁰ There may be other reasons to deviate from this deterministic version of the Ramsey rule. Drupp et al. (2018) discuss reasons to deviate from the right-hand side of (2) when the growth rate is uncertain.

Observe that total risk (measured by, e.g., variance) is irrelevant. The only relevant risk is the systematic risk, measured by covariance.¹¹ One can see this by considering an increase in the uncertainty of \tilde{R}_I . The new situation can be described as follows: Project revenue is now $I \cdot \tilde{R}_I \cdot \tilde{X}$, where \tilde{X} is multiplicative white noise, a variable which is independent of everything else in the model, with $E(\tilde{X}) = 1, \text{var}(\tilde{X}) > 0$. This yields unaltered covariance and required return, since¹²

$$\text{cov} \left[\frac{U'(\tilde{C}_1)}{E[U'(\tilde{C}_1)]}, \tilde{R}_I \cdot \tilde{X} \right] = \text{cov} \left[\frac{U'(\tilde{C}_1)}{E[U'(\tilde{C}_1)]}, \tilde{R}_I \right] E(\tilde{X}).$$

One implication is that if project revenue is a product of price and quantity, and quantity is independent of everything else in the economy, then quantity uncertainty is irrelevant.

Willingness to pay for the project for each agent is determined by covariance between project revenue and marginal utility. This is not directly observable. Under some assumptions (quadratic utility or normally distributed returns) one can instead use the covariance between project revenue and the agent's future consumption or wealth. If agents have (and use) the same opportunities to diversify future uncertain income in financial markets, their willingnesses to pay will be equal (see, e.g., Lund (1993c)).¹³

DIFFERENT QUANTIFICATIONS OF WILLINGNESS TO PAY FOR PROJECTS

Benefit-cost analyses use market prices when these exist. These give value for similar projects in the private sector. They also give willingness to pay for projects by consumers if these are buyers or sellers of the commodity. Corrections for taxes and external effects are well known (see, e.g., Drèze and Stern (1987)).

Uncertain projects are to some extent priced in financial markets. Here, stocks in listed firms with singular activity can give relevant prices for projects that correspond to this activity. Moreover, forward prices give present values for commodities. Nevertheless, this is incomplete and difficult to apply. Compared with the case of full certainty, many markets are missing. Furthermore, only a minor part of the population trade in financial assets, and it is not clear to what extent the willingness to pay of the majority is reflected in markets.

Furthermore, several studies try to quantify covariances between future national income (or wealth) and various project revenues. Here one can also use historical data for, e.g., commodity prices to predict the covariance (Dixit and Williamson, 1989). In the literature, models are constructed where the covariance will be a result of various mechanisms in the model. Examples of this are simple theoretical models (see, e.g., Lund

¹¹ One can define "systematic risk" as the covariance expression in (4), including the sign. This implies that when the covariance in (4) is negative and has high absolute value, there is large systematic risk. Many models will simplify this by directly considering the covariance between consumption and project return. Then, systematic risk will have the same sign as (this latter) covariance.

¹² The equation only holds if \tilde{C}_1 is independent of \tilde{X} . But it holds as a good approximation if the project revenue is a small part of the budget for \tilde{C}_1 , and \tilde{X} is independent of all other elements of the budget.

¹³ Here, one can apply the CAPM to consider the covariance with the market portfolio.

(1993a)) which give a formula for the covariance, or more complicated numerical models, where simulation can give covariances as numbers (see, e.g., Minken (2005) and Vennemo et al. (2013)). We shall now in particular consider quantifications of willingness to pay for projects within oil and climate.

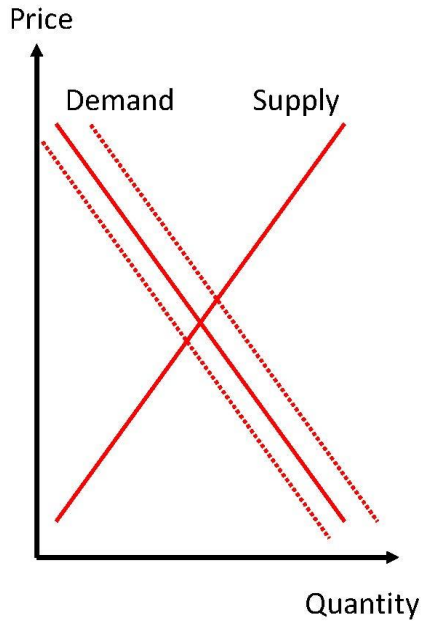


Figure 1: Positive systematic risk with uncertainty on the demand side.

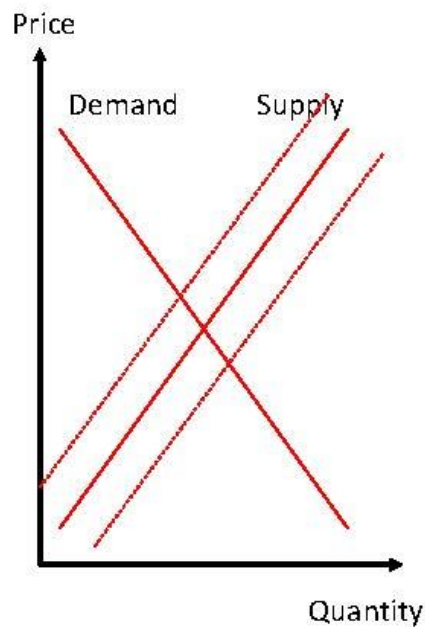


Figure 2: Negative systematic risk with uncertainty on the supply side.

Oil projects

A central question to quantify willingness to pay is whether oil price uncertainty, in the period when project revenues appear, primarily arises on the demand or the supply side.¹⁴ Consider the world market for oil. If the supply side is (approximately) stable, and the uncertainty primarily arises in demand, as in Figure 1, there will be positive systematic risk and a higher required expected return on oil projects. The reason is that changes will happen along the supply curve, which is fixed. High prices will coincide with high quantity, and likely with high return in stock markets. Such a case may be due to high uncertainty over whether a financial crisis will occur in the period when project revenues appear, or high uncertainty over whether the economy will recover after a financial crisis. If, instead, we have a fixed demand curve, and the uncertainty mainly arises from the supply side, as in Figure 2, there will be a negative systematic risk. High prices will then coincide with low quantity, and likely low return in stock markets. Such a case may be due to high uncertainty over whether there will be war in the Middle East, this uncertainty dominating over uncertainty on the demand side.

Historical estimates of covariance between oil price and return on various stock market indices show that it varies between positive and negative values:

- Lund and Nymoén (2018) use the stock market index S&P500 and find negative covariances in daily and weekly data for almost all the period 1993–2008. This indicates that the supply side seems to dominate, and that the required expected return on oil projects will be low.
- Meld. St. 19 (2013–2014) uses the stock market index FTSE and finds (Figure 2.6) negative covariances for the period 2003–2008, but positive both before and after, in monthly data. One interpretation of this is that the financial crisis gave large demand effects. If one foresees positive covariances in the future, the required expected return will be high.

Climate measures

The question here is what the value of climate measures is. That is, how much are we willing to pay today to reduce global warming in a later period. This value depends on whether future warming covaries positively or negatively with national income. This can be justified by a higher utility effect of climate measures in those future states in which

¹⁴ See further elaboration in Lund (1993a). Lund (1993a) gives a simple, formal account of the effects of demand and supply side uncertainty in the oil market. Suppose that Norway's national income increases in the demand for Norwegian products (apart from oil), which depends on the level of world income, and with the oil price. Internationally the oil price is determined in a market where supply is assumed to be an exogenous stochastic variable. Demand increases in world income and decreases in the oil price. World income depends on a stochastic variable, and also decreases in the oil price. If the stochastic part of world income and the supply, which is stochastic, are stochastically independent, one can arrive at a simple formula for the covariance between Norway's national income and the oil price. The analysis is based on this covariance formula.

warming is high. If there is negative covariance, that is, if there is a tendency to higher warming when national income is low, we will be more willing to pay for a given expected reduction in warming, than if there is positive covariance. This is due to lower utility in those states. We then see that negative covariance (between warming and national income) gives a lower required expected return on climate measures than positive covariance.

Similarly to the example with the oil market, different models will give different answers to what covariance to expect. If the model has only one source of uncertainty, it is crucial which variable this is. If there are several sources, the magnitudes of opposing effects will be decisive.

An additional problem is the difficulty in observing the value of the measures in the market. For this reason, model based studies are typically used. Different approaches have given different conclusions on the sign of the covariance:

- Sandsmark and Vennemo (2008) have a model in which uncertainty over climate development is exogenous. In the model, a worse climate leads to lower growth in national income. The value of climate measures is thus higher when national income is low. The required expected return is thus low.
- Nordhaus (2011) finds through model simulations results pointing to uncertain economic growth as driving climate uncertainty. This implies that the value of climate measures is higher when national income is high. Thus the return requirement is high.
- Dietz et al. (2018) consider both types of uncertainty, and conclude that uncertain economic growth is the more important driver. The required return is thus high. This model also includes other factors affecting climate uncertainty. It is thus difficult to ascertain how large the opposing effects actually are.

A preliminary conclusion for both oil projects and climate measures is that we need more research to find what kind of uncertainty that will dominate in the periods when project revenues will appear. We discuss this [below].

BRIEFLY ON UNCERTAINTY IN MANY PERIODS

We focus here on the premium added to reflect the project's systematic risk.¹⁵ Formula (4) holds also if the result of the investment is in a far future. We may let each "period" be, e.g., ten years. Normally a project will give results in many periods, but we disregard this for now. What is interesting to know, is whether the discount rate with a premium for systematic risk can be used for standard present value calculation over many periods, i.e., whether we can calculate present value with a factor

¹⁵ Gollier (2012) presents different approaches in the literature for how uncertainty in many periods affects the risk free interest rate. There seems to be some agreement in the literature that the risk free rate falls with the time horizon of the project.

$$1/(1 + r_I)^t,$$

where $(1 + r_I)$ is the right-hand side in (4), when the period length is one year, and t is the number of years. For the stock market, it is not altogether unreasonable, as a first approximation, to use the CAPM. This market repeats itself over time, and the risky returns are independent over time according to simple theories. Then the present value of receiving an income in t years will be discounted properly with a constant risk premium in the discount rate. This is a relevant economic criterion if a project gives revenues that are perfectly correlated with projects in the private sector, or possibly linear combinations of such projects.

More generally we can still not rely on this assumption to hold. There exist models showing how one should deviate.

- If a project has uncertainty that is only revealed when the income is realized in t years, i.e., a situation similar to a lottery, then we can calculate a value just before the uncertainty is revealed. This value can be discounted by a risk free rate, $(1 + r_f)^{-t}$ (Lund, 1993a).
- If a project produces primary commodities, we can consider historical data for covariance between commodity price and national income (or possibly the market portfolio). Observe that commodity prices do not necessarily need to grow over time in the same way as stock prices (Lund, 1993b).

Bye and Hagen (2013) elaborate upon some of the arguments behind NOU 2012: 16. Regarding discount rate and risk, they emphasize a model by Weitzman (2012), presented in Box 5.4 in the NOU. The model extends the CAPM into many periods. It is assumed that the result of a public project in a future period can be written as a weighted average of a non-stochastic and a stochastic part. As mentioned by Bye and Hagen (2013), this leads to a weighted average of discount factors, not of risk adjusted discount rates. Over many periods, the conclusion is that the discount rate will decrease with the time horizon.

In principle, Weitzman's model justifies differentiation of discount rates, since different projects will have different weights in the weighted average of discount factors. But at the same time the assumptions are at least as unrealistic as those underlying the CAPM. Gollier (2013) and Gollier and Hammitt (2014) show that different assumptions can lead to very different results. We cannot see that the literature has concluded on how to extend the model for risk adjusted discount rates to many periods. This does not mean that the expression (4) is invalid, but many challenges remain when a quantification of discount rates is attempted.

CONCLUDING REMARKS

Based on the inconsistent practice in government, it is natural to discuss the status of R-109/ 14 for various parts of governmental activity. Still, some practice that deviates from the circular can be reasonable. Parts of what appeared during CREE's dialogue seminar

show that attempts by practitioners to consider project specific risk are close to the intention of the NOU.

As defined in R-109/ 14, only the normal project's systematic risk will be adjusted for in the basic analysis. There is also no room for supplemental analyses. In light of the deficiencies of the circular and unclear practice in government, supplemental analyses for project specific risk should in some cases be made, in our opinion.¹⁶

In NOU 2012: 16 room is allowed for making supplemental analyses for those cases in which systematic risk is unusually low or high, i.e., if the project's systematic risk deviates clearly from the normal project. This is disregarded in the circular from the Ministry of Finance. In our view, another dimension is equally important, if not more. The evaluation of profitability of the Goliat field shows that practice in choice of required return is inconsistent also for projects that are considered separately on the political level. This is problematic because it gives practitioners room to adjust the discount rate for decisions that are politically important. It also makes it unclear if the project will be profitable in expectation.

Because the sum of investments in such projects in a sector can be large, they contribute much to the portfolio of public investments. For this reason it is particularly beneficial to consider project specific risk. For projects that are considered separately on the political level, supplemental analyses with adjustment for project specific risk, if this is below or above that of the normal project, should be a minimum requirement, in our view.

Examples of projects that are considered separately on the political level are found within oil and climate change. For these projects more research is needed for quantification of systematic risk. One possible method for this, in line with the discussion [above], is that the authorities develop advice based on views of what uncertainty will be dominating in the period when project revenues will appear. As a first quantification of covariance the CAPM may be useful. But more research is needed in order to arrive at relevant estimates for benefit-cost analyses.

Furthermore, one should ensure that risk adjustments in supplemental analyses are formulated in such a way that it is clear for practitioners what adjustment is being recommended. Precise criteria ensure that it is a simple task for a practitioner to decide whether the supplemental analysis should be made. Moreover, it reduces the opportunity to misuse project specific knowledge. In light of inconsistent practice in government, the supplemental analyses we suggest can contribute to increased consistency in benefit-cost analyses across sectors.

¹⁶ Minken (2005) and Vennemo et al. (2013) give calculations for risk premia for Norway. Examples of countries that allow specific risk adjustments, even if these are not in line with our intention, are France and the Netherlands. See Centraal planbureau (2015) and Groom and Hepburn (2017) for simple overviews of various countries' guidelines for choice of discount rates, including risk adjustments.

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