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Risk-adjusted long-term social rates of discount for transportation infrastructure investment

Lars Hultkrantz*, Niclas A. Krüger [1], Panagiotis Mantalos [1]

Örebro University, School of Business, 701 82 Örebro, Sweden

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ABSTRACT

We modify a method recently suggested by Weitzman (2012, 2013) for determining a risk-adjusted social discount rate (SDR) term structure consistent with both the (augmented) Ramsey rule and the consumption-based CAPM. Using this approach we estimate SDR for transportation infrastructure investments based on an analysis of correlations between transportation, split between road and rail, and between passenger travel and freight transport, and GDP in Sweden 1950–2011. We show that this can be estimated from two time-series following a random walk with drift, even if the variables are not co-integrated. Based on current estimates of the risk-free rate and the equity risk premium, we estimate the relevant SDR to be 5–6 per cent, possibly somewhat lower for investment in railroads for passenger travel, and only slowly declining within the investment horizon. This is higher than the current rates used in, for instance, Sweden, Germany and the UK.

1. Introduction

The single most important economic parameter in economic appraisal of transportation infrastructure investments is the rate of discount. However, while most countries derive this rate within a common theoretical framework, national recommendations vary astonishingly much, from 1 to 15 per cent (Harrison, 2010). Also, these rates seldom take account of neither the risk within a project, nor the uncertainty of future economic growth. In this paper, based on an idea suggested by Martin Weitzman (2012, 2013), we estimate empirically risk-adjusted social discount rate (SDR) term structures for transportation infrastructure in Sweden.

The two most used theoretical constructs for analysing the SDR are the Ramsey equation and the consumption Capital Asset Pricing Model (CAPM). The Ramsey rule sets the SDR to the sum of a utility discounting term and a consumption smoothing term while the CAPM gives the equilibrium rate of return requirement for a risky asset as the sum of the rate of return on a riskless asset and a term compensating for systematic risk, i.e., the risk that cannot be diversified away.[2] While the Ramsey equation is often seen as the natural candidate for analysis of public investments, it is derived within a deterministic framework without consideration of project or macroeconomic risk. Recently it has been shown how this equation can be augmented to account for the uncertainty of overall consumption growth. This uncertainty gives rise to a third term that reflects a precautionary or insurance-like aspect of investments as a means for hedging against macroeconomic risk. This research also shows that, under a variety of assumptions, the SDR term structure is falling, at least in the very long run. Still, the augmented Ramsey equation does not, as the CAPM does, account for the systematic project risk. Even more recently however, in response to a challenge from a committee under the Norwegian Ministry of Finance, Weitzman has suggested a way to close the gap between the consumption-based CAPM and the Ramsey rule

* Corresponding author. Tel.: +46 19 301416.
E-mail addresses: lars.hultkrantz@oru.se (L. Hultkrantz), niclas.kruger@oru.se (N. A. Krüger), panagiotis.mantalos@oru.se (P. Mantalos).
[1] Tel.: +46 19 303030.

[2] A common distinction, disregarding the risk compensation issue, made in the literature is between a prescriptive approach (based on the Ramsey equation) and a descriptive approach (based on actual market rates, as in the CAPM). However, as argued by Goulder and Williams III (2012), this is misleading. Both approaches are «prescriptive», but the first is suitable for determining whether a given policy would increase social welfare (as defined in a social welfare function), and the second for determining whether the policy would be a potential Pareto improvement (i.e., fulfil the Kaldor-Hicks criterion). These two purposes may or may not coincide.

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(Hagen et al. 2012, Weitzman, 2012, 2013).[3] Using this approach we here derive a risk-adjusted SDR for evaluation of investments in transportation infrastructure, based on Swedish data. Our contribution here is two-fold. First, we make the first empirical application of this method, and also provide some input into discussions on the choice of SDR for transportation-infrastructure investments. Second, we demonstrate how the Weitzman approach can be implemented using data with various time-series properties.

The benefits of transport infrastructure investments depend to a large extent on traffic volumes, which are likely to be correlated with GDP. Using annual data for GDP and traffic volumes, split between road and railroad, and between freight transport and personal travel, respectively, for the period from 1950 - 2011 we estimate what Weitzman (2013) calls "real project gamma" (henceforth gamma), showing expected-value normalized correlations between traffic volumes and GDP. We show that this parameter can be estimated when the traffic volume and GDP both follow a random walk with drift, even when the variables are not co-integrated. However, over a long time-span the relation between these two variables is not necessarily linear, which poses an additional problem in the estimation of gamma. We find, using linear models, that, for all four measures of traffic volume, the value of the parameter is close to one, and that estimates based on non-linear relationships are very similar. Therefore, variation in benefits from transportation infrastructure replicates the variation in GDP to a large extent. In addition to traffic volumes, the willingness to pay for travel time reductions is also correlated with GDP. Due to the positive correlation, we find that the SDR remains close to the rate of return required on non-diversifiable wealth, over the typical time horizon of a transportation infrastructure investment, although Weitzman's approach generally yields a declining term structure that approaches the risk-free rate at long time horizons. We, therefore, do not find support for the recent reduction of SDR rates in for instance the UK, Sweden and Norway.

In the next section, we give a theoretical background. We set up a simple model of the social value of a transportation infrastructure investment and point out the essential role of the rate of discount, GDP growth and the relation between these two variables, which includes the issue on how covariance risk should be considered in the rate of discount. We describe the two "workhorse" models for determining the rate of discount, i.e., the Ramsey equation, with recent extensions, and the CAPM; and then the synthesis approach suggested by Weitzman. In an Appendix we extend his analysis by showing how the gamma can be estimated from two variables that both follow a random walk with drift even if they are not co-integrated. In Section 3 we describe and analyse data, and estimate this parameter for four types of infrastructure investments. In Section 4, we use these results to compute the SDR for Sweden. These results are discussed in Section 5 and Section 6 concludes.

2. Theory

2.1. Discounting of a transport infrastructure project

Public investments in major infrastructure projects are dynamic in nature, and decision-making must account for the uncertainty. There are multiple sources of uncertainty, such as uncertainty with regard to traffic demand, deterioration and costs.

The use of the infrastructure, thus future traffic demand, is obviously a main source of uncertainty. Another important source of uncertainty is the future relative prices used to value project benefits. The lion's share of benefits of a road or rail project normally emerge from improvements in travel time durations, travel time reliability, and traffic safety compared to a reference alternative (for instance a "do nothing" alternative). Recent research on the value of travel time savings (Abrantes and Wardman 2011; Börjesson, Fosgerau, & Algers, 2012; Ramjerdi, Östli, & Flügel, 2012) suggests that the willingness to pay for travel time reductions is closely related to income, with an elasticity close to one. Moreover, the value of traffic safety and, in particular, the value of a statistical life also strongly depends on income, and the income elasticity may exceed unity (Hammit & Robinson, 2011). Based on such results, Norway, Sweden and the UK have recently revised CBA guidelines, recommending that these economic parameters are assumed to increase over time with the growth of GDP per capita.

Flyvbjerg, Skamris Holm, and Buhl (2003) find that there is a systematic underestimation of costs (and overestimation of benefits) for so-called mega-projects, which is attributed to psychological delusion and/or political deception. Another and perhaps more simple explanation, provided by Eliasson and Fosgerau (2013), can be that these projects have been up for a competitive tender, or have been selected in competition with other projects, which gives rise to a "winners curse" selection bias (i.e., the probability of being selected is higher if cost by mistake is underestimated than if it is overestimated). However, for relatively standardized projects, this might be less of a problem. Even if construction cost overruns are common, costs are relatively close in time compared to future traffic demand. Some countries have, partly in response to Flybjerg's finding, introduced new procedures where construction costs are recalculated at a late stage of the investment planning process when more of the real constraints to the project are known. Another approach is taken in the UK where an "optimism bias" component is sometimes added to the calculated construction cost, using the "outside view" or "reference class forecasting" approach developed by Flyvbjerg and colleagues (Ansar, Flyvbjerg, Budzier, & Lunn, 2014).

Deterioration of roads and railroads, finally, depend on age and (heavy) traffic (Lindberg, 2002). Thus, road and rail deterioration inherits the stochastic properties from traffic flow and is not an independent stochastic process.

To focus on these sources of uncertainty, consider an infrastructure project i with a known upfront cost I and a stream of uncertain net benefits B_t,$(t = 1,2\ldots,T)$ held from the value of the travel-time savings achieved (i.e., the difference between the "do something" and "do nothing" alternatives) and discounted with year-specific discount rates r_t. The expected net present value of this project is:

$$\begin{aligned} E(\pi_i) &= \sum_{t=1}^{T} e^{-r_t t} E(B_t) - I \\ &= \sum_{t=1}^{T} e^{-r_t t} \left\{ A + \left[k_i m E\left(\frac{y_t}{pop_t}\right) \right] \cdot E(z_i) E[x_t(y_t)] \right\} - I, \qquad (1) \end{aligned}$$

where A is a constant, representing a constant stream of "other" project benefits not related to time savings. $k_i m \frac{E(y_t)}{pop_t} = k_i E(v_t)$ is the travel-time saved by the project per traveller (k_i) times $E(v_t)$, the expected value of saving an hour of travel time, assumed to be proportional (with the proportion factor m) to $E(y_t/pop_t)$, the expected GDP per capita. Further, $E[x_t(y_t)]$ is the expected national traffic volume, assumed to be a function of GDP and $E(z_i)$ is the expected portion of national traffic that will use the specific infrastructure.

[3] Until 2012, Norway was one of the few OECD countries that used risk-adjusted social discount rates motivated by the CAPM. The new recommendation in 2012 is inspired by Weitzman's suggested approach.