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THE DISCOUNTING PREMIUM PUZZLE:

Survey evidence from professional economists*

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Abstract

We survey the attitude towards the risk-adjustment of efficient discount rates among the economics profession. Three-fourth of our respondents recommend adjusting discount rates to the risk profile of the project under scrutiny, in clear opposition to the standard practice of using a single discount rate in most public administrations around the world. For example, on average, respondents recommend using a larger discount rate for railway infrastructures than for hospitals and climate mitigation. We also observe that the degree of discounting discrimination between obviously different risk profiles remains rather limited in our sample. This generates a "discounting premium puzzle": economic experts want to penalize risky public projects much less than financial markets do for private investments. Finally, among experts supporting a single discount rate, there is no consensus about whether it should be based on the average cost of capital in the economy, the sovereign borrowing cost, or the Ramsey rule, yielding disagreement on its level.

Keywords: Risk premium, project-specific discount rate, survey evidence.

JEL codes: D81, G11

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1 Introduction

More than fifty years ago, William Baumol (Baumol, 1968) commented that few topics in our discipline rival the social rate of discount as a subject exhibiting simultaneously a very considerable degree of knowledge and a very substantial level of ignorance. How much progress did our profession achieve in building a science-based consensus on this key societal issue? In this paper, we re-explore this issue by reporting the results of a survey on the opinions of a broad sample of professional economists. We go beyond the standard approaches of either calibrating the Ramsey rule or estimating the average cost of productive capital to examine broader questions related to the potential desirability of having different discount rates for projects with different risk profiles. Our main finding is that a large majority of professional economists recognizes the necessity to adjust discount rates to the risk profile of the projects under scrutiny, in the spirit of the modern asset pricing literature. But another finding of our survey is that, when comparing projects with very different risk profiles, experts discriminate the discount rates much less than what markets have done during the last century or so.

We are not the first to survey discounting attitudes in our profession. Weitzman (2001) has pioneered the field by surveying the rate at which expected net benefits of climate mitigation should be discounted. He obtained a mean annual discount rate of 3.96%, with a standard deviation of 2.94%.[1] More recently, Drupp, Freeman, Groom, and Nesje (2018) have produced a survey about opinions on the long-term risk-free discount rate, in order to test the link between this rate and its predicted value from the Ramsey rule. They obtained a mean annual discount rate of 2.25% and a standard deviation of 1.63%. It is difficult to compare the two surveys because the study by Drupp et al. took place at a time of much lower interest rates and growth expectations, and because their later survey explicitly considered a risk-free cash flow. An important observation is that both studies exhibit a large degree of disagreement among experts about which discount rates should be used, both for risk-free projects and for projects that reduce greenhouse gas emissions. However, these surveys do not address the key question of how to deal with the wide heterogeneity of the contribution of public projects to the aggregate risk borne by their stakeholders, citizens and taxpayers.

It is noteworthy that Weitzman's earlier survey documents a much larger degree of disagreement on the discount rate to be used for calculating the social cost of carbon than the more recent survey by Drupp et al. on the risk-free rate. There are two possible interpretations of this observation. The first interpretation is that economists worked hard during the last two decades to build a scientific consensus on the efficient discount system. The second interpretation however is that nothing like that happened, but economists disagree on how to adjust the discount rate to the riskiness of the social benefit of climate mitigation that is implicitly contained in Weitzman's survey question.

As a preview of our own survey results relating to climate change mitigation, we find that the mean annual rate recommended by our respondents to discount climate damages is 2.28%, with a

[1] Since damages in most integrated assessment models following on from Nordhaus are assumed to grow in line with economic activity, the growth corrected discount rate may lower, say about 2% per year.

standard deviation of 2.22%. Let's first observe that this degree of disagreement about the climate discount rate is smaller than the one observed by Weitzman two decades ago, thereby suggesting a convergence. Second, observe that this mean climate discount rate is not statistically different from the mean risk-free discount rate in our sample, which is 2.30% for a 10-year maturity. Would that mean that economic experts believe that green investments are mostly risk free? This is surprising because most integrated assessment models assume that global warming damages are proportional to economic activity. In our integrated assessment models, damages are thus high in future states of nature where economic activity is high and marginal utility of consumption is low. One would expect policy makers to take account of risky damages which frustrate consumption smoothing by including a risk premium in the rate for discounting global warming damages (and thus leading to a lower social cost of carbon and less ambitious climate policy). But, this is not what we find in our survey results.

This echoes a remarkable characteristic of public discounting systems in most Western countries, namely the existence of a single rate to discount the flow of expected net benefits of a variety of different public investment projects. This implies that public administrations ignore risk, risk aversion, and hedging possibilities in their evaluations of public policy with medium-term and long-term consequences. To illustrate, compare two public investment projects with different risk profiles. The first project is to expand the capacity of intensive care units (ICUs), which will be most useful for the next pandemic, when, again, the economy will be badly hit. ICUs thus offer insurance value as they are most valuable at times of lower economic activity and high marginal utility of consumption. The second project is to expand the capacity of a railway line, which will be most useful for the next economic boom, when the economy will prosper. The railway line has lowest (greatest) benefits when the economy is in a recession (boom) and thus exacerbates macroeconomic volatility. Now let us calibrate the two investments so that they generate the same flow of *expected* social benefits.

Should we really consider these two projects as generating the same social value ex ante? The reality is that the ICU project hedges macroeconomic risk, whereas the railway project increases it. The standard textbook valuation (or asset pricing) methodology consists in recognizing the insurance benefit of the ICU project by discounting its flow of expected net benefits at a lower discount rate than for the railway project. Not adjusting discount rates for projects with different risk profiles leads to misallocation of public funds, with many socially undesirable risk-increasing projects (e.g., investment in railroads, sea ports, airports or highways) undeservedly passing the test of a positive NPV, and many socially desirable risk-reducing projects (e.g., investment in ICU projects) failing it.

Storing oil in the Strategic Petroleum Reserve for the next oil shock, or masks for the next pandemic are other examples of public investments which (like ICU projects) reduce risk and should therefore be discounted at a rate smaller than the interest rate. Gollier (2021) estimates the welfare cost of the misallocation resulting from using a single discount rate to evaluate investment projects with different risk profiles. It could entail a permanent loss exceeding 20% of the share of GDP affected by this practice of using an uniform discount rate. Another example is what discount rate to use when discounting future primary surpluses to evaluate the sustainability of the outstanding value of public debt? Future primary surpluses, especially future tax revenues, are pro-cyclical and therefore risky. They should therefore be discounted not at a very low risk-free rate but at a much higher risk-adjusted discount rate (e.g., Bohn, 1995; Barro, 2020; Jiang et al., 2021). The market seems to adopt a lower discount rate despite the riskiness of future primary surpluses. This may be explained by a convenience yield on public debt (Jiang et al., 2021).

Although this message has not yet been heard by public decision-makers, our survey provides strong support for them to change their discounting guidelines. It shows that a vast majority of the surveyed professional economists believes that governments should stop using a single discount rate for public evaluations. The standard theoretical pseudo-justifications for using a single discount rate have been debunked for a long time now. The Arrow-Lind theorem (Arrow and Lind, 1970) holds only for projects that have no effect on aggregate risk. The Ramsey rule (Ramsey, 1928) only provides an estimate of the efficient rate at which riskless benefits should be discounted. It is a mistake to use the average cost of capital as an all-purpose discount rate of the funding institution (Merton and Bodie, 2000). Finally, five decades of modern asset pricing theory has clearly demonstrated the normative necessity of adjusting discount rates for project-specific risk when valuing investment projects and assets.

Our survey shows that economists have learned from the theories that they have developed over the years to remove the ambiguities raised by Baumol (1968) surrounding the discounting system. However, our survey generates a new "equity premium puzzle". Indeed, our respondents seem to be reluctant to widely discriminate discount rates on the basis of risk, i.e., to the same extent that financial markets have been doing over the last century. They recommend a larger discount rate for railway projects than for health projects, but the difference remains modest, and they do not seem to allow for risk in the recommended rate for discounting marginal global warming damages. This may be due to a lack of knowledge about how large the impact of these projects is on aggregate risk, thereby generating a form of status quo bias. Alternatively, this may stem from green and social biases towards climate and health policies among our respondents.

2 Theory and practice

Risk aversion is the cornerstone of our decision theories under uncertainty since Bernoulli (1738, 1954).[2] Under its most general definition, risk aversion is characterized by the property that any mean-preserving spread in consumption deteriorates welfare ex ante. Independently of the way in how this individual preference is translated into a decision theory, it implies by definition that the value of an uncertain benefit must be negatively related to the intensity of its contribution to the risk borne by the beneficiary. The valuation method based on the discounted value of the flow of expected benefits using a unique discount rate violates this general easy-to-understand principle. It stems from a fallacious interpretation of the Arrow-Lind theorem (Arrow and Lind, 1970; Bazelon

[2] Of course, prudence and ambiguity aversion matter too but we will focus on risk aversion for the purpose of this paper.

and Smetters, 1999; Lucas, 2014; Baumstark and Gollier, 2014; Boyer, 2018) stating that a single discount rate should be used for public policy evaluation. Indeed, the Arrow-Lind theorem is valid only for benefits that are statistically independent of aggregate consumption. At the margin, such benefits uncorrelated to the aggregate risk do not affect it and should therefore not be valued.[3]

There are two approaches to characterize the social discount rate under uncertainty. Under the approach of pricing by arbitrage, a future uncertain benefit B should have the same value as a traded asset generating exactly the same contingent benefit, state by state. In other words, the rate at which $E[B]$ should be discounted must be equal to the expected rate of return of that asset.[4] As demonstrated by the existence of a large positive premium on stocks and corporate debts, these market discount rates are strongly influenced by the asset's risk profile and liabilities concerned. For example, according to Jordà et al. (2019), the average real return of sovereign bills in 16 countries between 1870 and 2015 has been 0.98% per year, whereas the average annual real return of equity has been 6.89% during the same period. Conversely, assets that hedge macroeconomic risk, such as some insurance contracts or gold, generate expected returns smaller than the (safe) interest rate.

The larger expected rates of return of riskier assets translate into a larger Weighted Average Cost of Capital (WACC) to fund the underlying investments. The WACC is therefore the discount rate that mono-investment firms will often use to evaluate the profitability of their project. However, for corporations with multiple activities, it is a "WACC fallacy" (Krueger et al., 2015) to use the corporation's WACC as the single discount rate to value all its investment projects. A corporation investing in a high-risk project should realize that by doing so, it raises its cost of capital to fund its entire portfolio of investments. An extreme version of this fallacy is obtained when applying it to sovereign debt, as documented for example by Boyer (2022) in the case of Canada. The rate of return of sovereign bonds is not a relevant measure of the discount rate to value public investment projects, for two reasons. First, there is the same spillover effect of risky projects on the cost of capital of the state. Second, a large fraction of the risk of public projects is not borne by sovereign bondholders, but by taxpayers and citizens, which implies that the rate of return of sovereign bonds represents a very partial measure of the public WACC.

The normative approach offers an ethical reinterpretation of the modern theory of asset pricing. Under the veil of ignorance, intergenerational and intertemporal welfare should be represented by discounted expected utility. In this framework, transferring consumption to the future should be valued using the intertemporal marginal rate of substitution. More specifically, at date 0, one unit of consumption at date t in state s should have a present value

$$m_{ts} = p_{ts} e^{-\delta t} u'(c_{ts})/u'(c_0), \tag{1}$$

where p_{ts} is the date-0 probability of state s at date t, c_{ts} is the consumption level in that state and

[3] This result requires that risk aversion have only second-order effects, as is the case under Expected Utility (Segal and Spivak, 1990). This is illustrated by the Arrow-Pratt approximation for the risk premium, which is proportional to the variance (i.e., the square of the size of the risk) of final consumption.

[4] In continuous-time finance, the exact rule is that the expected benefit should be discounted at rate $R = \log(E\exp(r))$, where r is the rate of return of the duplicating asset. If r is $N(\mu, \sigma^2)$, R equals $\mu + 0.5\sigma^2$.

date, u is the increasing and concave utility function of the representative agent, and δ is the rate of pure preference for the present. The random variable m_t is often referred to as the stochastic discount factor. A benefit B_t at date t is a bundle of Arrow-Debreu securities $B_{ts} \mid_s$ whose value V today should be equal to

$$V = E[m_t B_t]. \tag{2}$$

Expressing V as the present value of the expected benefit, i.e., $V = \exp(-rt)E[B_t]$, yields the following expression for the discount rate r:

$$r = \delta - \frac{1}{t} \ln \frac{E[B_t u'(c_t)]}{u'(c_0)E[B_t]}. \tag{3}$$

In general, the discount rate r depends upon the risk profile of the future benefit B_t, because $E[B_t u'(c_t) \mid B_t]$ is not proportional to B_t. One exception is when B_t and c_t are statistically independent. The Consumption-based Capital Asset Pricing Model (C-CAPM) of Lucas (1978), Rubinstein (1976) and Breeden (1979) provides a simple solution to (3) in the special case in which c_t follows a geometric brownian process of trend μ and volatility σ, $u'(c) = c^{-\gamma}$ with $\gamma \geq 0$, and $B_t = \xi_t C_t^\beta$ with $\beta \in \mathbb{R}$, (ξ_t, C_t) being statistically independent with $E[\xi_t] = 1$. Observe that β is the income-elasticity of the benefit. Positive-β projects raise the risk borne by the representative agent as their benefits are smaller in the lower-income states. On the contrary, negative-β projects hedge the aggregate risk. In this C-CAPM framework, the social discount rate r is linear in the risk profile β of the benefit B and is independent of the maturity of the benefit:

$$r = r_f + \beta\pi. \tag{4}$$

Equation (4) illustrates that it is socially desirable to adjust the discount rate to the risk profile of the project. It confirms that the Arrow-Lind theorem is valid only for zero-β projects.

Aggregate productive capital (including human capital) generates a net output equaling the aggregate consumption, so that it has a β equaling unity. The average cost of capital of the economy must then be equal to $r_f + \pi$. Using this rate as an all-purpose discount rate is wrong as it would overvalue high-β projects and it would undervalue low-β projects.

The Ramsey rule (Ramsey, 1928) has played a key role in the recent debate on the social discount rate (Drupp et al., 2018). It is a special case of the C-CAPM described above. Indeed, under the C-CAPM calibration of equation (4), we can rewrite the risk-free rate as[5]

$$r_f = \delta + \gamma\mu - \frac{1}{2}\gamma^2\sigma^2 \text{ and } \pi = \gamma\sigma^2. \tag{5}$$

The first equation is often referred to as the ”extended Ramsey rule”, the pure Ramsey rule being limited to the case of a sure growth ($\sigma = 0$). Observe that the (extended) Ramsey rule is useful to measure the social discount rate only for risk-free projects ($\beta = 0$).

We will not cover extensively the abundant literature related to the failure of the C-CAPM to

[5] Martin (2013) generalizes the C-CAPM rule to the non-Gaussian case and Kreps-Porteus preferences.

explain observed market prices, because we focus on how investments and assets should be valued, not on how they are priced in existing (potentially inefficient) markets. Let us just mention two puzzles. They are based on the observation that the Lucas model tends, on the one hand, to predict a much too large risk-free rate, and, on the other hand, a much too small aggregate risk premium compared to observed market returns. The volatility of annual growth rates of consumption has been around 2% in the western world over the last century. Hammitt and Gollier (2014) surveyed various expert statements that suggest that a coefficient of relative risk aversion γ between 1 and 3 represents a realistic calibration of risk preferences. Considering $\gamma = 2$ as a benchmark, the C-CAPM formula (5) implies that macroeconomic uncertainty reduces the risk-free rate by a mere 0.1%, and that the risk-adjustment of discount rates should be parametrized by an aggregate risk premium of $\pi \sim 0.1\%$. Consider for example the case of a portfolio of diversified equities. Following Bansal and Yaron (2004) for example, such a portfolio is a highly leveraged version of the aggregate risk, typically represented by a beta of 3. Thus, the C-CAPM predicts an equity return of 0.3%, which is one degree of magnitude smaller than what has been observed on financial markets over the last century.

Various explanations have been given, some arguments relying on preferences (Bansal and Yaron, 2004), and others relying on beliefs (Barro, 2006). The general idea of this asset pricing literature is that markets are efficient and that the Lucas model is misspecified. For example, Barro (2006) claims that the existence of low-probability macroeconomic catastrophes not recognized in the Brownian calibration of the pricing equation (3) can solve the two puzzles. More generally, Cochrane (2017) discusses various other possibilities for explaining these two puzzles varying from habits in consumption, idiosyncratic risks, heterogeneous preferences and probability of mistakes to attitudes to averting risk being different from those to averting intertemporal fluctuations and to long-run risks.

Weitzman (1998) calibrates the pricing rule (2) in a rather different way than Lucas (1978). Rather than assuming a geometric Brownian process for the dynamics of consumption, Weitzman implicitly supposes that the growth rate g of consumption will be constant in the future, but that it is unknown today. Once g is revealed, a constant interest rate $\rho = \delta + \gamma g$ will prevail. Given that g and ρ are uncertain today, equation (2) tells us that a unit sure benefit materializing in t years should be valued today as $V = E[e^{-\rho t}]$. This is equivalent to using the following maturity-specific discount rate

$$r_t = -\frac{1}{t} \ln E[e^{-\rho t}]. \tag{6}$$

It is noteworthy that r_t can be interpreted as the "certainty equivalent" of ρ using an exponential utility function with absolute risk aversion t. It is easy to check that under this representation of stochastic growth, the social discount rate r_t decreases with maturity t. It tends asymptotically to the lower bound of the support of the distribution of ρ for large maturities. This approach is often referred as "gamma discounting" because Weitzman (2001) calibrated equation (6) with a gamma distribution for the discount rate ρ. A declining term structure can also be obtained with other probability distributions. Observe that this gamma discounting model is limited to the analysis of the risk-free discount rate.

It happens that the C-CAPM and gamma discounting differ fundamentally on the degree of serial correlation in annual growth rates. In the Lucas C-CAPM, annual growth rates are serially independent and the term structure of discount rates is therefore flat. In the Weitzman model of gamma discounting, annual growth rates are perfectly correlated, and the term structure declines with maturity. More generally, Gollier (2009, 2016) shows that the term structure of risk-free discount rates should decline if shocks to the rate of economic growth are persistent. Persistence magnifies long-term risk and the precautionary investment motive. It is noteworthy that this argument is limited to the risk-free discount rate. Because the persistence of macro shocks magnifies long-term uncertainty, it also increases the long-term aggregate risk premium. Thus, its net effect on the long risk-adjusted discount rate is ambiguous for investment projects with a positive beta (Gollier, 2016).

To sum up this short discussion of the theory of discounting, both the approach of pricing by arbitrage and the normative approach support the necessity to adjust discount rates to the risk profile of the project under scrutiny. The parameter characterizing the risk profile of a project is the income-elasticity β of its net benefit.

France is the only country to use a system in which discount rates are adjusted to the estimated beta of its net benefits. Currently, the French risk-free rate for evaluating public investment projects is $r_f = 1.2\%$, whereas the risk premium is $\pi = 2\%$. Norway has used a similar discounting system earlier this century, but it has decided to revert back to a single discount rate more recently (Hagen et al., 2012). The United Kingdom uses a benchmark discount rate with the exception of a smaller discount rate for evaluating investments in the health sector (Treasury, 2018). The Netherlands uses a benchmark discount rate of 2.25% with two exceptions: a lower discount rate of 1.6% is used for "costs that are largely or wholly independent of usage (i.e. fixed costs)", and a larger discount rate of 2.9% is used for "benefits that are highly non-linear relative to usage, where usage, moreover, depends on the state of the economy" (Rijksoverheid, 2020). In the United States, a single rate of 7% is commonly used, but a rate of 3% may be used under some conditions that are not clearly defined (but definitely not related to risk profiles) (OMB, 2003).

3 Survey

In this section, we discuss our survey design, sample selection and survey dissemination.

3.1 Survey design

Our survey has been designed to answer three main research questions. First, we want to understand if there is a consensus among economists over using risk-adjusted discount rates when conducting a cost-benefit analysis of public investment projects. Second, we want to better understand what rules and scientific framework people apply when choosing discount rates. We conjecture that one expert's attitude towards discounting is highly dependent upon whether that expert is willing to adjust the discount rate to risk or not. Third, among people who agree on the use of risk-adjusted discount rates, how much do they discriminate between low-beta and high-beta investment projects in their choice of discount rates?

The actual survey that we have used is given in Appendix A. The first question respondents have to answer when they entered the survey is about their willingness to adjust discount rates to the risk profile of specific investment projects. Depending on their answer, either yes or no, we classify the respondents into two categories, "risk-adjusting" economists and "non-risk-adjusting" ones. The two categories of respondents are then directed to different follow-up questions.

For non-risk-adjusting economists, questions 2 and 3 ask respondents what real discount rate should be used to discount the expected benefits of public investment materializing in 10 years and 100 years. Throughout the survey, quantitative questions are always open-ended, and respondents only need to provide point estimates in percentages and are free to skip these questions whenever they want. Comparing these two rates, we are able to see whether people adopt a flat term structure of discount rates in the given time horizon or not. Questions 4 asks respondents what kind of arguments they had used to answer questions 2 and 3 (see below).

The follow-up questions that risk-adjusting economists encounter have been designed to assess the extent to which they adjust the discount rate to what we consider to be very different project-specific risk profiles. To this end, we consider three types of public projects: railway infrastructure, a hospital, and a project that curbs CO_2 emissions. As explained earlier, it is easy to imagine that having a new hospital will be most useful for the next pandemic, when the economy will again be badly hit. Because the time window of the survey was in the middle of the COVID crisis, it is likely that most respondents had in mind this potentially negative correlation between aggregate consumption and the value creation of an hospital. On the contrary, expanding the capacity of a railway line will be most useful for the next economic boom, when the economy will prosper. This suggests that the beta of the hospital project may be negative and is in any case smaller than the beta of the railway project, which should imply that decision-makers should use a smaller rate to discount the benefits of hospitals than the rate used to discount he benefits of railways.

To provide more flesh to this hypothesis, we used data from the US Bureau of Economic Analysis which has quantified added value creation by sectors on an annual basis since 1997 (see https://apps.bea.gov). The beta for a sector corresponds to the estimate of the slope coefficient of an OLS regression with the change in the logarithm of sectoral added value creation as the dependent variable and the change in the logarithm of GDP as the independent variable. We report in Table C.1 the estimated beta of a few sectors relevant for this survey. The "rail transportation" sector has a positive beta of 2.27, which means that this sector is much riskier than a portfolio of diversified assets in the economy. On the other hand, the sector named "hospitals" by the BEA has a beta of -0.32. Other health sectors also have a negative beta, which means that investing in health infrastructures reduces the aggregate risk and has a negative beta.

The sign of the climate beta depends crucially on whether future economic growth is to some degree carbon-intensive or not. Dietz, Gollier, and Kessler (2018) argue that the climate beta can in principle be either positive or negative. In the positive-climate-beta story, the main source of uncertainty is the evolution of Total Factor Productivity (TFP). If the TFP is larger than expected, emissions and consumption will also be larger than expected, everything else unchanged. Because the climate damage function is convex with respect to concentration, the marginal benefit of mitigation will also be larger. This implies a positive climate beta. In the negative-climate-beta story, the main source of uncertainty is about the climate sensitivity (i.e., the response of global mean temperature with respect to the stock of atmospheric carbon). If the climate sensitivity is larger than expected, climate damages will be larger, and aggregate consumption net of these damages will be smaller. At the same time, abatement efforts will have a larger marginal benefit, thus yielding a negative climate beta. Dietz, Gollier, and Kessler (2018) calibrate the DICE model and show that one should expect a positive climate beta smaller than unity. But clearly, few people have examined this issue, and there is no consensus on it (yet).

To sum up, our hypothesis is that railway assets are riskier than assets related to climate mitigation and health infrastructures. The jury is still out to determine which of these latter two assets is riskier than the other. This suggests a larger discount rate for railway assets. Moreover, because of the potential negative beta of health assets, it could be efficient to discount them at a rate smaller than the risk-free rate.

As a warm-up, we first ask risk-adjusting economists to compare the discount rates they would use for different types of investment projects, i.e., railway infrastructure versus climate mitigation policies, and railway infrastructure versus a hospital. These qualitative questions could also be used as a consistency check after we have asked respondents a point estimate of the discount rates in percentage needed to value the expected present discount benefit of different projects materializing in 10 years. We also ask the respondents their view on the risk-free rate and stock return over the next 10 years. Assuming equation (4) holds, we are able to estimate the beta of different projects. The validity of this assumption is further verified in a question where we ask respondents whether they would recommend adjusting the project-specific discount rate linearly with a measure of the project's impact on the aggregate risk such as its consumption beta as recommended by standard asset pricing theories. We also ask risk-adjusting economists whether diversifiable risks should be priced.

Our survey also contains two further questions on what discount rate respondents would use to discount future government primary surpluses in ten years in order to assess the solvency of public debt and what rate they would use to discount future climate damages when calculating the social cost of carbon.

After answering these quantitative and qualitative questions on discount rates, all respondents are asked about what rules they apply when choosing discount rates. In this question, we provide them a list of seven decision rules that are popular in the economics profession. Besides Arrow-Lind theorem, Ramsey rule, C-CAPM and gamma discounting we discussed in section 2 , the arbitrage argument, the average cost of capital in the economy and the sovereign borrowing cost are also included as possible theoretical frameworks. Of course, our list of decision rules may not be exhaustive. So respondents are also given the freedom to express other alternatives. To our best knowledge, this is the first time this kind of question has been asked. In the previous related studies such as Weitzman (2001) and Drupp et al. (2018), researchers directly assume a decision rule for people without asking if this is indeed the case.

We also ask respondents how familiar they are with the topic on social discounting on an eleven Likert scale with zero indicating "not familiar at all" and 10 indicating "very familiar". Different from Drupp et al. (2018) who only considered experts in social discounting, namely, individuals have authored or coauthored at least one pertinent publication in the field of social discounting in a leading economics journal, our survey target economists with very diverse research fields. This self-reported familiarity will allow us to make a distinction between economists who consider themselves an expert in social discounting and those who do not. Also, we believe self-reported familiarity could be sometimes more informative about individuals' expertise than authorship, especially when a publication is not single-authored. At the end of the survey, we collect respondents' social demographic information including gender, age, country of work, profession, and research fields.

3.2 Sample selection and survey dissemination

We target economists with a good record of publications but they may not necessarily be an expert on social discounting. This will allow us to assess the extent to which experts and non-experts disagree or agree with each other. Ideally, we also want respondents to be sufficiently diverse in socio-demographic background such as age, gender, country of work, research fields, etc. These types of variations could help us identify which factors may actually influence people's view on social discounting. As we shall see in Section 4 , even within our economics profession, depending on their research field, people may have very different views on the choice of discount rates.

For the purposes described above, we use IDEAS/RePEc (https://ideas.repec.org/) to select economists into our sample. We only considered top 10% economists as of January 2021, who were still alive at the time when our survey was carried out.[6] The main drawbacks we can see with the use of IDEAS/RePEc are that only authors registered with the RePEc Author Service are considered and only works listed on RePEc and claimed as theirs by registered authors are counted. So we may lose some economists of our interest and an economist's rank score may not be based on his or her total research output. Since we decided to conduct the survey online by sending respondents an email with personalized survey links, respondents' email address were manually collected either directly from IDEAS/RePEc or their personal webpage. We obtained a sample of 5,392 economists after excluding those for whom we could not find valid email addresses.

Starting from 8th, February 2021, we have sent out a link to the online survey (implemented by O-tree, Chen et al., 2016) via e-mail to all potential respondents, and used three general rounds of reminders, each time slightly varying the subject line and motivation for answering the survey. The online survey remained accessible until 14th, March 2021. The initial e-mail text is provided in Appendix B. In our last invitation email, we told our respondents that they can also write us back.

[6] A series of rankings by different criteria are aggregated. The average rank score is determined by taking a harmonic mean of the ranks in each criterion. For a list of criteria, see the general ranking page on IDEAS/RePEc. There are 64332 registered authors evaluated for all the rankings.

4 Results

4.1 On the use of risk-adjusted discount rates

In total, 948 economists (so the response rate was 17.6%) answered at least our first question in the survey and 719 (75.8%) of them agreed to use risk-adjusted discount rates.[7] Among 663 respondents who completed our survey,[8] 481 (72.5%) agreed to use risk-adjusted discount rates and 182 did not. For the following analysis, we will focus on the sample with respondents who completed our survey.[9] We can further split this sample into two sub-samples according to the respondent's answer to our first question on the use of risk-adjusted discount rates, i.e., the sub-sample of risk-adjusting respondents and the sub-sample of non-risk-adjusting respondents.

In Table C.2, we report summary statistics on the respondents' country of work (US, EU and UK, other countries), their research fields (MMF indicating "macroeconomics or monetary economics or finance", PEER indicating "public economics or environmental resource and energy economics", other fields), their gender (male, female, other), their profession (academic, non-academic) and their age group (under 54, between 55 and 64, above 65). More than 90% of our respondents are male and an academic economist. However, there are large variations in terms of respondents' country of work, research fields and age in both subsamples. The average score of familiarity on an eleven-Likert scale for the sub-samples of risk-adjusting and non-risk-adjusting economists are 3.90 ($s.d.$ = 2.68) and 3.91 ($s.d.$ = 2.80), respectively, indicating that most respondents indicate that they are not very familiar with the topic "social discounting".

Interestingly, the composition of respondents is fairly comparable across these social-demographic dimensions between the two sub-samples, except for their research fields (Chi-squared test with p-value< 0.001). Our regression analysis reported in Table C.3 confirms this. We find that MMF economists are significantly more likely to use risk-adjusted discount rates but PEER economists are less likely (but statistically not significantly) to use risk-adjusted discount rates compared to economists from other fields. This result reflects the fact that there is considerable heterogeneity in how economists approach risk, and that it seems to depend on their field of study. Our two qualitative questions asking respondents in the sub-sample of risk-adjusting economists if they would recommend using C-CAPM for selecting discount rates and if diversifiable risks should be priced further confirms this. We observe that MMF economists are much more prone to not pricing risks that can be diversified (60.5% versus 48.2% on average), and are more likely to use C-CAPM for selecting discount rates (47.1% versus 33.1% on average) (see Table C.4 and C.5). Over the last few decades, classical MMF textbooks have promoted the idea that, at equilibrium, discount rates and the WACC will be differentiated by their factors of risk, among which the consumption beta. Among the 253 MMF economists, 53 of them, or 21%, opted for a non-risk-adjusted discount rate.

[7] 2,077 economists have clicked on the survey link and have seen the introduction page of the survey. However, more than half of them did not proceed further.

[8] Namely, those people arrived at the last page of the survey but they were allowed to leave certain questions unanswered.

[9] Including those people who dropped out in the middle of the survey will not change qualitatively the results presented here.

It is true that the finance literature has long shown that the C-CAPM theory has limited empirical success (Campbell, 2003). This may explain the reluctance of some experts in the field to support adjusting discount rates for risk. But this limited consensus is a surprise for the authors of this paper, as the C-CAPM provides a strong well-established *normative* support to adjusting discount rates for risk.

Nationality does not explain support for recommending to adjust for risk. In particular, its support in France (the only country with a risk-adjusted public discounting system) is not statistically different from other countries, as 9 French experts in 39 dissent with this recommendation. We could also have expected that older experts would be less favorable to the consensus, as the Arrow-Lind theorem has long been a prominent argument for not adjusting for risk until, say, the turn of this century. This is not the case, because age has no statistically significant impact on the recommendation. Finally, it is also somewhat surprising to see that self-reported familiarity with the topic of "social discounting" does not explain at all the choice of recommending risk-adjusted discount rates. This may be explained by the existence of different schools of thought on the issue, as described in Section 2. People familiar with the Ramsey rule for example could support a single rate, whereas people familiar with the C-CAPM could support the adjustment to risk.

We have also asked our respondents what decision rules they would use when choosing discount rates. Table C.6 summarizes the results on this question. In either of the sub-samples, about 35%-37% of the respondents use only one of the seven provided approaches when they choose discount rates, sometimes joint with their own approaches. That is, a large majority of the respondents do not simply apply one unique approach to the choice of discount rates. Interestingly but maybe not surprisingly, respondents in the sub-sample of risk-adjusting economists are clearly more likely to use both arbitrage arguments and the C-CAPM that are sensitive to risk but they are less likely to use the Arrow-Lind theorem which only applies to diversifiable risks, compared to respondents in the sub-sample of non-risk-adjusting economists.

4.2 Analysis of the sub-sample of risk-adjusting respondents

Here we explore the attitude of the sub-sample of risk-adjusting economists towards the adjustment of discount rates to the risk profile of specific investment projects. Table C.7 and C.8 report our results on warm-up questions asking respondents to compare discount rates for different types of projects. Let us start with the comparison of climate and railways projects. From Table C.7, we see that one-third of the respondents who believe that discount rates should be adjusted to risk also believe that one should use the same discount rate for evaluating climate mitigation as for investments in railways. But 38.8% of the risk-adjusting respondents recommend a smaller discount rate for climate mitigation assets relative to railway assets, whereas only 16.2% recommend the opposite. This result is in line with our hypothesis that railway assets have a larger beta. It is noteworthy that there is one family of respondents with a much stronger preference for a smaller discount rate for climate mitigation. Indeed, 46.3% of the risk-adjusted PEER respondents express such a preference. One possibility is that environmental economists believe climate mitigation projects are less risky. But another possibility is that the environmental economists in this group have a "green bias" or they believe that ethical considerations require one not to discount future effects of climate mitigation very much.

In the next question, the respondents were requested to rank discount rates for hospitals and railways. Compared to the previous question, a larger fraction (58.4%) of risk-adjusting respondents recommended to use the same discount rate for the two family of assets. But 21.6% of the risk-adjusting respondents recommended a larger discount rate for railways than for hospitals, a much larger proportion compared to those who recommend the opposite (8.1%). MMF economists are more likely to apply a higher discount rate for railways (25%), compared to PEER economists (14.6%).

In Table C.9, we report the statistics of the point estimates of the sectoral discount rate in our sub-sample of risk-adjusting economists, for the 10-year time horizon. As expected from the previous results, the mean discount rate for railway assets is 3.38% (s.d. 2.06%), which is larger than the mean discount rate for health (mean 2.79%, s.d. 1.90%). On average, these respondents also recommended a climate discount rate of 2.28% (s.d. 2.22%), possibly suggesting that economists believe climate projects as less risky than health ones. This is a sizeable reduction compared to what Weitzman (2001) obtained two decades ago. Indeed, Weitzman's survey on which discount rate should be used for the social cost of carbon generated a mean of 3.96%, with a standard deviation of 2.94%. Our new estimate is not only smaller, but it is also more consensual as can be seen from the reduced standard deviation of the experts' point estimates.

Table C.9 also provides useful information about other discount rates. Let us start with the risk-free rate on which previous survey studies focused. In this survey, we obtain a mean interest rate of 2.30% (s.d. 1.72%). This is very close to the recent survey results from Drupp et al. (2018), who obtained a mean interest rate of 2.25% and a standard deviation of 1.63%. Interestingly, their survey focused only on the risk-free rate and it nudged respondents toward the use of the Ramsey rule, because questions were raised about the estimated growth rate of consumption, the rate of pure preference for the present and the elasticity of intertemporal substitution.

On average, risk-adjusting respondents recommend using a climate discount rate (2.28%) that is not statistically different than the risk-free rate (2.30%). This might suggest that experts do not believe that fighting climate change generates a benefit or cost in terms of hedging the aggregate risk. On the contrary, respondents recommend on average that health and railway infrastructures be discounted at a rate larger than the risk-free rate. This suggests that these investments raise the aggregate risk and should therefore be penalized by using a larger discount rate. Our earlier analysis summarized in Table C.1 is aligned on this recommendation for railways, but not for hospitals.

Table C.9 also indicates that the risk-adjusting respondents would use a mean discount rate of 2.52% per year to discount future primary surpluses to evaluate the solvency of the public debt. A primary surplus can be interpreted as collective savings, so it has a C-CAPM beta of 1 if the saving rate is constant. The difference of this discount rate with the risk-free rate gives us an aggregate risk premium of 0.22%, which is small. This suggests that either respondents do not use a risk premium as suggested by Blanchard (2019) or offset this risk premium by a convenience yield as suggested by Jiang et al. (2021).

We also questioned experts on the real expected rate of return of the stock market. In our sub-sample of risk-adjusting economists, the mean point estimate of the 10-year annualized expected return of stocks is 4.72% (s.d. 1.93%), which is much smaller than the 6.89% mean equity return estimated by Jordà et al. (2019) in 16 countries between 1870 and 2015. In our sample, the mean equity premium is only 2.43% (s.d. 2.13%), which is much smaller than the 6.4% equity premium observed in the U.S. between 1889 and 2010 (Mehra, 2012). More generally, although our sub-sample is composed of respondents who recommend to discriminate discount rates on the basis of the risk profile of the assets under scrutiny, we observe that the intensity of risk discrimination that they are ready to consider is quite limited. Among the six specific discount rates surveyed, the lowest and the largest mean discount rates are respectively 2.28% (climate mitigation) and 3.38% (railways). This suggests that risk-adjusting respondents use a relatively small aggregate risk premium to adjust sectoral rates.

When combining this observation with the one-fourth respondents in our sample who recommend using a single discount rate, this generates a "discounting premium puzzle": our economic experts want to penalize risky public projects much less than financial markets actually do for private investments. To illustrate this point, let us assume an aggregate risk premium of 2%. Following our earlier discussion on sectoral betas and using Table C.1, suppose that the betas for health, climate and railway sectors are respectively -0.3, 0.5 and 2. In this framework, climate mitigation and railway projects should be discounted at a rate, respectively, 1.6%- and 4.6%-points higher than the rate at which health projects should be discounted.[10] One possible interpretation of the discounting premium puzzle is that respondents believe that decision-makers do not derive their risk attitudes from saving and investment decisions in financial markets, but let these be governed by their own ethical and pragmatic attitudes.

In Table C.10, we examine the determinants of the point estimates of sectoral discount rates by regressing them on the respondents' characteristics. A few characteristics are statistically relevant. First, respondents from Europe and the UK recommend a smaller risk-free rate that is 0.51%-points and a sectoral discount rates for investments in railways, healthcare and climate mitigation, and for evaluation of the solvency of public debt that are, respectively, 0.92%-, 0.52%-, 0.71%, and 0.74%-points lower. MMF respondents recommend a risk-free rate that is 0.60%-points lower and an equity premium that is 0.83%-points higher. Their stronger willingness to adjust discount rates to risk may explain why they recommend on average a climate mitigation discount rate that is 0.67%-points lower, and similarly PEER respondents adopt a climate mitigation discount rate that is 0.55%-points lower. Our discounting premium puzzle is thus less apparent in the MMF and PEER sub-samples than in our general sample of economic experts. The respondents who justified their "willingness to adjust discount rates to risk on the basis of a modern asset pricing theory" tend to recommend a smaller risk-free rate that is 0.38%-points smaller and an equity premium that is 0.89%-points higher. They also tend to recommend larger sectoral discount rates.

[10] If the risk premium is much bigger, say 6.4% per year, climate mitigation and railway projects would have to be discounted at 5.12%- and 14.72%-points higher than the rate used to discount health projects. But the respondents seem to be working with a lower risk premium than financial markets.

For example, they recommend a climate discount rate that is 1.16%-points larger than the mean point estimate of the risk-adjusted sample. Finally, those who take sovereign borrowing cost as a premise for their social discount rate recommendations use a 0.68% lower discount rate to evaluate the solvency of the public debt than the risk-free rate.

4.3 Analysis of the sub-sample of non-risk-adjusting respondents

Going back to Table C.6, it is useful to examine the arguments used by the respondents of the non-risk-adjusting sub-sample to justify the use of a single discount rate. It is reassuring to observe that only 23.1% of these respondents rely on the Arrow-Lind Theorem to support their recommendation. This fallacious interpretation of this theorem is thus fading away of the apparatus of of cost-benefit analysis. More surprising is the limited role of the Ramsey rule, which is used as a basis for the choice of the discount rate by only 14.3% of this sample. In spite of the fact that the Ramsey rule continues to be the standard scientific base to determine the all-purpose public discount rate, it characterizes the rate at which risk-free projects should be discounted, as is the case for the sovereign borrowing cost which is used by 29.1% of the non-risk-adjusting respondents. But one third (34.1%) of them recognize alternatively the average cost of capital in the economy as a better choice for the discount rate. This WACC typically combines a risk-free rate and an aggregate risk premium. Finally, observe that only 8.8% of the non-risk-adjusting respondents mention ”asset pricing theory” as relevant to answer the question. From these observations, we see that the proponents of a single discount rate represent a rather heterogeneous population supporting their view from different theories and approaches.

The respondents who recommend to use a single discount rate could use two anchors to determine their preferred single rate, the risk-free rate in the spirit of the Arrow-Lind Theorem, or the (larger) average cost of capital in the economy. Table C.11 reports summary statistics on discount rates with a maturity of 10 years and 100 years reported by the sub-sample of non-risk-adjusting economists. Note that the average of 10-year discount rates reported by the non-risk-adjusting economists is not statistically different from that of the 10-year risk-free rate reported by the risk-adjusting economists in our sample (i.e., 2.53% versus 2.30% per year, p-value=0.21). More than 50% of the non-risk-adjusting respondents provided an estimate between 1% and 3% per year. Consistent with Drupp et al. (2018) who used a pool of experts in social discounting, the median estimate of the 10-year discount rate is also 2% per year. In the same spirit of our results for the sub-sample of risk-adjusting respondents, we are impressed by the low level of this mean discount rate. With such a low rate, do we have enough capital in the economy to finance all projects with a positive NPV? Don't we face the risk of starving the population by imposing a large saving rate to fund these projects, in the spirit of the industrialization phase in USSR of the thirties ?

This problem is even more prevalent for the 100-year discount rate which averaged 2.26% per year (s.d. 1.85%). This suggests that respondents support the now standard recommendation of using a decreasing term structure for risk-free discount rates. Indeed, the maturity spread of the 100-year rate over the 10-year rate is significantly lower than zero (p-value$<$ 0.01). This is somewhat in line with the view that governments should use a discount rate that declines over time when evaluating the future benefits and costs of public projects (Arrow et al., 2014). However, we also notice that about 42% (76 out of 182) of the respondents use the same discount rate for both maturities.

Table C.12 further examines the relationship between discount rates and respondents' socio-demographic characteristics. In column (1), we find that male economists use significantly larger rates to discount the expected benefit of public investment projects materializing in 10 years (1.98%-points higher), but use slightly lower rates for the 100-year period. However, this result should be interpreted with caution. For the restricted sub-sample we consider in column (1), there are only 7 female economists. A closer look at the reported values reveals that this significant gender difference was mainly driven by one female economist who has reported a discount rate of -7%. In columns (1) and (2), we find that economists in the EU and UK. have significant lower rates for both 10-year and 100-year maturities, i.e., 1.42%- and 0.97%-points lower, respectively. In columns (2) and (3), we find that economists who are more familiar with the topic of "social discounting" apply significantly lower discount rates over longer horizons albeit not very much lower (0.11%-points lower). Finally, similar to what we have observed with the risk-adjusting sub-sample (see Table C.10), those who take sovereign borrowing cost as a premise for their social discount rate recommendations use a lower discount rate for both 10-year and 100-year maturities, i.e., 0.96%- and 0.83%-points lower, respectively.

We believe that this finding is useful to understand why the disagreements about the level of the discount rate remain so pervasive even when taking the simplified approach of a single rate. Of course, it is difficult to rationalize the choice of a single discount rate when in reality the discount should be adjusted to risk.[11] The theoretical impossibility to rationalize the choice of a single discount rate may explain the absence of convergence about what this rate should be, as illustrated by the dual discount rates of 3% and 7% that prevailed in the United States over the last two decades.

5 Concluding remarks

The tradition in cost-benefit analysis and capital budgeting is to evaluate assets and investment projects by measuring the discounted value of the flow of future expected benefits. This means that the discount rate must take account of both dimensions of the valuation problem, i.e., time and risk. The double dimensionality of the problem is a source of complexity, misunderstandings and, eventually, large inefficiencies in the allocation of capital in the economy. A positive degree of risk aversion implies that any project that raises aggregate risk should be discounted at a rate larger than the risk-free rate. This simple fact poses a difficulty for economists who believe that a universal discount rate should be used, because it is not clear which rate should be used, the risk-free rate or an average risk-adjusted rate. The ambiguity of the OMB (2003) recommendation in the US proposing two potential universal rates, 3% and 7%, perfectly illustrates this problem.

[11] Gollier (2021) shows that using the WACC as the single discount rate minimizes the welfare cost of ignoring the risk adjustment.

In our non-risk-adjusting sub-sample, the mean discount rate recommended by our respondents is 2.53%, but those who rationalize their choice by the sovereign borrowing rate recommend a discount rate of 1.57% on average. But with such a low rate, do we have enough capital in the economy to finance all projects with a positive NPV? Don't we face the risk of starving the population by imposing a large saving rate to fund these projects?

This absence of consensus also raises a difficulty for experts who think that discount rates should be adjusted for risk, because it is unclear how and at which intensity this risk-adjustment should be performed.

We have attempted to describe the current experts' attitude toward these issues. Three-fourth of the respondents in our sample believe that discount rates should be adjusted for risk, as is recommended by any theory recognizing the fact that stakeholders are risk-averse. The respondents also seem to use a higher discount rate for projects whose benefits are pro-cyclical and a lower discount rate of projects that are counter-cyclical. Specific sectoral discount rates thus have strongly differentiated risk profiles. However, the degree of differentiation of their risk-adjusted discount rates is relatively small in our sample, and certainly much smaller than those derived from sectoral betas using the observed aggregate risk premium on risky financial assets. This survey therefore generates a new "public risk premium puzzle".

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Appendix A: The Survey

Introduction

This survey aims to better understand what discount rates economists think we should use for conducting benefit-cost analysis of public investment projects. Of course, many of you may not be experts on discounting. But, **even if you do not consider yourself to be an expert in this area, we would value your answers to this survey very much too**.

When you are ready, please click on the "Next" button to start.

Risk and discounting

Different projects have different risk profiles. For example, some investments generate larger benefits when economic growth is larger. Other investments generate larger benefits when the economy sinks. Finally, some projects have benefits that are essentially independent of economic growth.

Q1. To evaluate public investment projects, one should discount future expected benefits with a discount rate that is:

1. not adjusted to the risk of the project.
2. adjusted to the risk of the project.

If Answer to Q1 is "that is not adjusted to the risk of the project", then, respondents should answer the following questions:

In the questions below, we would like to know what real rate you would recommend for discounting the expected benefit of public investment projects with different maturities. **A rough point estimate is fine**. If you do not feel qualified to give answers or do not have enough information to answer the questions, please skip questions 2 and 3.

Q2. What real rate (annualized and in %) should be used to discount the expected benefit of public investment projects materializing in **10 years**?

(point estimate)

Q3. What real rate (annualized and in %) should be used to discount the expected benefit of public investment projects materializing in **100 years**?

(point estimate)

Q4. On which kinds of arguments have you based your answer to questions 2 and 3? (multiple choice list)

a. Arbitrage argument together with assets prices observed on markets.

b. Average cost of capital in the economy.

c. Sovereign borrowing cost

d. Arrow-Lind theorem (states are risk-neutral)

e. Ramsey rule or its extensions to risk.

f. Modern asset pricing theory (CAPM and extensions).

g. The certainty-equivalent value of the discount rate falling with time (e.g., Gamma discounting)

h. Other. Please specify _____

Here we repeat the question on familiarity and demographic questions that are shown below.

If Answer to Q1 is "that is adjusted to the risk of the project", then, respondents should answer the following questions:

In the questions below, we would like to know whether you would use different real rates to discount the benefits of different types of projects.

Q2. Would you recommend using a higher rate to discount the benefits of a railway infrastructure compared to the benefits of climate mitigation policies?

a. Yes, use a higher discount rate for the railway infrastructure.

b. No, use a higher discount rate for climate mitigation policies.

c. No, use the same discount rate for both the railway infrastructure and climate mitigation policies.

d. I do not know.

Q3. Would you recommend using a higher rate to discount the benefits of a railway infrastructure compared to the benefits of a hospital?

a. Yes, use a higher discount rate for the railway infrastructure.

b. No, use a higher discount rate for the hospital.

c. No, use the same discount rate for both the railway infrastructure and the hospital.

d. I do not know

In the questions below, we would like to know what real rate you would recommend for discounting the expected benefit of different types of public investment projects. **A rough point estimate is fine**. If you do not feel qualified to give answers or do not have enough information to answer the question, please skip questions 4-9.

Q4. What real rate (annualized and in %) should be used to discount **a sure** benefit of a project materializing in **10 years**?

(point estimate)

Q5. What real rate (annualized and in %) do you expect **the stock market** to deliver in the next **10 years**?

(point estimate)

Q6. What real rate (annualized and in %) should be used to discount the expected benefit of a project in *railways* materializing in **10 years**?

(point estimate)

Q7. What real rate (annualized and in %) should be used to discount the expected benefit of public investment projects in *health care* materializing in **10 years**?

(point estimate)

Q8. What real rate (annualized and in %) should be used to discount future primary surpluses in **10 years** to evaluate the *solvency* of public debt?

(point estimate)

Q9. What real rate (annualized and in %) should be used to discount *future climate damages to estimate the social cost of carbon*?

(point estimate)

Q10. On which kinds of arguments have you based your answer to question 2-9? (allowing for multiple choices)

a. Arbitrage argument together with assets prices observed on markets.

b. Average cost of capital in the economy.

c. Sovereign borrowing cost

d. Arrow-Lind theorem (states are risk-neutral)

e. Ramsey rule or its extensions to risk.

f. Modern asset pricing theory (CAPM and extensions).

g. The certainty-equivalent value of the discount rate falling with time (e.g., Gamma discounting)

h. Other. Please specify _____

Q11. When evaluating public investment projects, should we also adjust the discount rate to project-specific risks that can be washed out by diversification?

a. Yes, diversifiable risks should be priced.

b. No, diversifiable risks should not be priced.

c. I do not know.

Q12. Would you recommend adjusting the project-specific discount rate linearly with a measure of the project's impact on the aggregate risk such as its consumption beta as recommended by standard asset pricing theories?

a. Yes, I would

b. No, I would not.

c. I do not know.

Q13. How familiar are you with the research topic on social discounting (0 means "not familiar at all": 10 means "very familiar"?

To complete the survey, we kindly ask you to answer a few questions about yourself. **Your survey responses will be anonymous and secure**. Since the quality of information collected through this survey is important for our scientific study, please read the questions carefully and answer them to the best of your ability.

Q14.What is your gender?

a. Male

b. Female

c. Other

Q15.What is your age?

a. Under 18

b. 18 – 24

c. 25 – 34

d. 35 – 44

e. 45 – 54

f. 55 – 64

g. 65+

Q16. Where is your country of work?

Q17. Are you:

a. An academic economist

b. A non-academic economist

Q18. What are your main fields in economics? (allowing for multiple choices)

a. Applied microeconomics

b. Behavioral and experimental economics

c. Decision theory

d. Development economics

e. Econometrics

f. Economic history

g. Economics of education

h. Economics of technology

i. Environmental, resource and energy economics

j. Financial economics

k. Game theory

l. Health economics

m. Labor economics

n. Industrial organization

o. International trade

p. Macroeconomics

q. Market design

r. Microeconomic theory

s. Monetary economics

t. Public economics

u. Political economy

v. Other. Please specify _____

Appendix B: Invitation email

Dear [Personal identifier],

We hope this email finds you well and healthy.

We want to carry out a survey to better understand what discount rates economists think we should use for conducting benefit-cost analysis of public investment projects. Of course, many of you may not be experts on discounting. But, even if you do not consider yourself to be an expert in this area, we would value your answers to this survey very much too.

This short survey is anonymous and should not take more than 5 minutes to complete. To start, you can click on the link below:

[Survey links]

All data will be kept confidential. The deadline for filling the survey is 28th, February.

Thank you for your help.

Best regards,

Christian Gollier, Professor of Economics at Toulouse School of Economics

Rick Van Der Ploeg, Professor of Economics at Oxford University

Jiakun Zheng, Assistant Professor of Economics at Renmin University of China.

Appendix C: Tables and figures

Table C.1 Estimated sectoral betas

Sector	Beta
Rail transportation	2.27
Ambulatory health care services	-0.06
Hospitals	-0.32
Nursing and residential care facilities	-0.09

Note: The beta of a sector is measured by the OLS-estimator of the coefficient of regression of the delta log added value of the sector over the delta log of GDP. Data are from the US BEA (https://apps.bea.gov) from 1997 to 2018 on an annual basis.

Table C.2 Summary statistics on survey respondents

(i) Sub-sample of risk-adjusting economists

Country of work	Research fields	Gender	Profession	Age
US (40.3%)	MMF (35.8%)	Male (92.5%)	Academic (90.0%)	under 54 (33.0%)
EU and UK (41.6%)	PEER (25.6%)	Female (6.0%)	Non-academic (10.0%)	55-64 (33.7%)
Other countries (18.1%)	Other fields (38.7%)	Other (1.5%)	-	Above 65 (33.3%)

(ii) Sub-sample of non-risk-adjusting economists

Country of work	Research fields	Gender	Profession	Age
US (40.1%)	MMF (22.5%)	Male (92.9%)	Academic (94.5%)	under 54 (39.0%)
EU and UK (43.4%)	PEER (33.6%)	Female (7.1%)	Non-academic (5.5%)	55-64 (31.3%)
Other countries (16.5%)	Other fields (44.0%)	Other (0.0%)	-	Above 65 (29.7%)

Note: MMF indicates "macroeconomics or monetary economics or finance", PEER indicates "public economics or environmental resource and energy economics".

Table C.3 Logistic regression predicting the choice of using risk-adjusted discount rates

Male	0.10
	(0.36)
Other sex	14.61
	(540.68)
Age 55-64	0.23
	(0.22)
Age above 65	0.36
	(0.22)
EU and UK	-0.09
	(0.26)
US	-0.07
	(0.26)
PEER	-0.13
	(0.22)
MMF	0.58**
	(0.23)
Familiarity	-0.01
	(0.04)
Academic	-0.49
	(0.37)
Constant	1.09
	(0.53)
Observations	663
Log Likelihood	−379.08
Akaike Inf. Crit.	780.16

Note: Numbers in parenthesis are standard errors. Statistical significance is indicated as follows: *p<0.1; **p<0.05; ***p<0.01.

Table C.4 On the pricing of diversified risks

	MMF	PEER	Other fields	Whole
Not price diversifiable risks	60.5%	48%	37.1%	48.2%
Price diversifiable risks	29.1%	32.5%	39.8%	34.1%
Do not know	10.5%	19.5%	23.1%	17.7%
Observations	172	123	186	481

Table C.5 On the use of C-CAPM

	MMF	PEER	Other fields	Whole
Not use C-CAPM	22.7%	17.1%	18.3%	19.5%
Use C-CAPM	47.1%	30.9%	21.5%	33.1%
Do not know	30.2%	52.0%	60.2%	47.4%
Observations	172	123	186	481

Table C.6 Distribution of respondents using different approaches

Approach	Risk-adjusting subsample	Non-risk-adjusting subsample
Sovereign borrowing cost	130 (27.0%)	53 (29.1%)
Arbitrage argument	161 (33.5%)	29 (15.9%)
Asset pricing theory	114 (23.7%)	16 (8.8%)
Ramsey rule or its extension to risk	80 (16.6%)	26 (14.3%)
Average cost of capital in the economy	173 (36.0%)	62 (34.1%)
Gamma discounting	85 (17.7%)	29 (15.9%)
Arrow-Lind theorem	41 (8.5%)	42 (23.1%)
Using only one of the listed approaches	169 (35.1%)	67 (36.8%)
Other approaches	116 (24.1%)	51 (28.0%)
Total size	481	182

Table C.7 Discount rate for railroads versus discount rate for climate mitigation

	MMF	PEER	Other fields	Whole
Higher for climate mitigation	19.8%	11.4%	16.1%	16.2%
Equal	29.1%	35.8%	34.4%	32.8%
Higher for railroads	38.9%	46.3%	33.9%	38.9%
Do not know	12.2%	6.5%	11.6%	12.1%
Observations	172	123	186	481

Table C.8 Discount rate for railroads versus discount rate for hospitals

	MMF	PEER	Other fields	Whole
Higher for hospitals	9.3%	7.3%	7.5%	8.1%
Equal	52.9%	68.3%	57.0%	58.4%
Higher for railroads	25.0%	14.6%	23.1%	21.6%
Do not know	12.8%	9.8%	12.4%	11.9%
Observations	172	123	186	481

Table C.9 Summary statistics on point estimates reported by the risk-adjusted subsample

	10-year risk-free rate	10-year stock real return	10-year risk premium	10-year DR railroads	10-year DR for healthcare	10-year DR for public debt	DR for climate mitigation
Mean	2.30%	4.72%	2.43%	3.38%	2.79%	2.52%	2.28%
Median	2.00%	5.00%	2.00%	3.00%	2.50%	2.00%	2.00%
StdD	1.72%	1.93%	2.13%	2.06%	1.90%	1.82%	2.22%
Observations	349	343	339	334	328	314	323

Note: For the analysis in each column, we exclude missing data and data points that are outside [-10%,10%]. Thus, numbers of observations vary across columns.

Table C.10 Linear regressions with point estimates of sectoral discount rates reported by risk-adjusting economists as dependent variables

	10-year risk-free rate	10-year stock real return	10-year risk premium	10-year DR railroads	10-year DR for healthcare	10-year DR for public debt	DR for climate mitigation
Male	0.26	-0.11	-0.23	-0.27	-0.04	-0.49	-0.54
	(0.40)	(0.48)	(0.52)	(0.49)	(0.45)	(0.46)	(0.55)
US	-0.29	0.24	0.62*	-0.16	0.14	-0.23	-0.23
	(0.25)	(0.30)	(0.32)	(0.31)	(0.28)	(0.28)	(0.34)
EU and UK	-0.51**	-0.23	0.27	-0.92***	-0.52*	-0.74**	-0.71**
	(0.26)	(0.30)	(0.33)	(0.31)	(0.29)	(0.29)	(0.35)
Age 55-64	0.43*	0.24	-0.07	0.38	0.52**	0.40*	-0.06**
	(0.22)	(0.26)	(0.28)	(0.27)	(0.25)	(0.25)	(0.30)
Age 65+	0.10	-0.07	-0.24	-0.07	0.14	0.35	-0.43
	(0.24)	(0.28)	(0.30)	(0.29)	(0.27)	(0.27)	(0.32)
MMF	-0.60***	0.18	0.83***	0.18	-0.11	-0.45*	-0.67**
	(0.22)	(0.26)	(0.28)	(0.27)	(0.25)	(0.25)	(0.30)
PEER	-0.06	0.30	0.34	-0.05	0.09	-0.06	-0.55*
	(0.25)	(0.29)	(0.32)	(0.30)	(0.28)	(0.28)	(0.33)
Familiarity	-0.00	-0.03	-0.00	0.03	0.02	0.00	-0.09*
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)
Academic	0.07	0.33	0.25	0.02	-0.70**	-0.43	0.48
	(0.30)	(0.36)	(0.39)	(0.38)	(0.35)	(0.35)	(0.42)
Arrow-Lind theorem	-0.23	-0.09	0.13	-0.28	-0.30	-0.27	-0.48
	(0.31)	(0.36)	(0.39)	(0.38)	(0.35)	(0.35)	(0.42)
Average cost of capital	0.38**	0.43*	0.01	0.44*	0.61***	0.06	0.68***
	(0.19)	(0.22)	(0.24)	(0.23)	(0.21)	(0.21)	(0.25)
Arbitrage argument	0.02	-0.10	-0.12	0.02	-0.03	-0.13	0.16
	(0.19)	(0.22)	(0.24)	(0.24)	(0.22)	(0.21)	(0.26)
Sovereign borrowing cost	-0.25	-0.14	0.15	-0.39	-0.25	-0.68***	-0.12
	(0.19)	(0.23)	(0.25)	(0.24)	(0.22)	(0.21)	(0.26)
Ramsey rule	0.26	-0.16	-0.56*	-0.00	0.28	0.00	0.44
	(0.25)	(0.29)	(0.32)	(0.30)	(0.28)	(0.28)	(0.33)
CAPM	-0.38*	0.47*	0.89***	0.79***	0.72***	0.42*	1.16***
	(0.22)	(0.25)	(0.28)	(0.27)	(0.25)	(0.24)	(0.29)
Gamma discounting	0.37	0.36	0.01	0.48*	0.50*	0.38	0.13
	(0.23)	(0.27)	(0.29)	(0.29)	(0.26)	(0.25)	(0.31)
Other approaches	0.35	0.39	-0.02	0.68**	0.31	0.08	0.14
	(0.25)	(0.30)	(0.32)	(0.31)	(0.28)	(0.28)	(0.34)
Constant	2.25***	4.10***	1.59**	3.32***	2.96***	3.78***	2.99***
	(0.53)	(0.64)	(0.69)	(0.65)	(0.61)	(0.63)	(0.73)
Observation	349	343	339	334	328	314	323
R-squared	0.12	0.05	0.10	0.12	0.14	0.13	0.12

Note: For the analysis in each column, we exclude missing data and data points that are outside [-10%,10%]. Thus, numbers of observations vary across columns. Estimates are in percentages. Notations of significance: *** for p-value¡0.01, ** for p-value¡0.05, * for p-value¡0.1. Standard errors are in parenthesis.

Table C.11 Summary statistics on discount rates used by the non-risk-adjusting subsample

	10-year discount rate	100-year discount rate	100-year minus 10-year
Mean	2.53%	2.26%	-0.34%
Median	2.00%	2.00%	0.00%
StdD	1.94%	1.85%	1.37%
Observations	152	149	149

Note: For the analysis in each column, we exclude missing data and data points that are outside [-10%,10%]. Thus, numbers of observations vary across columns.

Table C.12 Relationship between discount rates and non-risk-adjusted respondents' socio-demographic characteristics

	10-year discount rate	100-year discount rate	100-year minus 10-year
Male	1.98**	-0.41	-1.02*
	(0.77)	(0.79)	(0.56)
US	-0.33	-0.28	-0.08
	(0.47)	(0.45)	(0.32)
EU and UK	-1.42***	-0.97**	0.35
	(0.47)	(0.46)	(0.32)
Age 55-64	0.14	0.39	0.44
	(0.39)	(0.37)	(0.26)
Age 65+	0.15	0.33	0.32
	(0.39)	(0.38)	(0.27)
MMF	-0.50	-0.27	0.24
	(0.44)	(0.42)	(0.30)
PEER	0.18	-0.06	-0.23
	(0.38)	(0.37)	(0.26)
Familiarity	0.03	-0.09	-0.11**
	(0.06)	(0.06)	(0.04)
Academic	0.37	0.01	-0.42
	(0.66)	(0.64)	(0.45)
Arrow-Lind theorem	0.06	0.03	-0.07
	(0.38)	(0.38)	(0.27)
Average cost of capital	0.08	-0.15	-0.29
	(0.35)	(0.34)	(0.24)
Arbitrage argument	-0.30	0.29	0.61
	(0.44)	(0.43)	(0.30)
Sovereign borrowing cost	-0.96**	-0.83**	0.18
	(0.36)	(0.36)	(0.25)
Ramsey rule	-0.55	-0.71	-0.08
	(0.46)	(0.45)	(0.32)
CAPM	-0.40	-0.64	-0.27
	(0.58)	(0.56)	(0.39)
Gamma discounting	-0.11	-0.64	-0.48
	(0.45)	(0.44)	(0.31)
Other approaches	-0.35	-1.12***	-0.74**
	(0.43)	(0.42)	(0.29)
Constant	1.37	4.20***	1.43*
	(1.12)	(1.11)	(0.78)
Observations	152	149	149
R-squared	0.20	0.19	0.26

Note: For the analysis in each column, we exclude missing data and data points that are outside [-10%,10%]. Thus, numbers of observations vary across columns. Estimates are in percentages. Notations of significance: *** for p-value< 0.01, ** for p-value< 0.05, * for p-value< 0.1. Standard errors are in parenthesis.