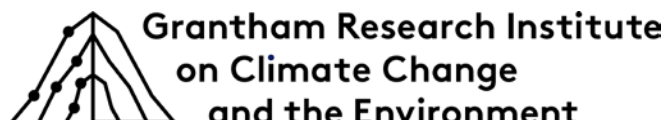


Social Discount Rates for Cost-Benefit Analysis: A Report for HM Treasury¹

By Mark Freeman², Ben Groom³ and Michael Spackman⁴

A summary report from two workshops on recent advances in social discounting practice and theory



¹ **Disclaimer:** The views displayed in this document are those of the authors and do not reflect those of HM Treasury.

² The York Management School, University of York (Email: Mark.Freeman@york.ac.uk)

³ Department of Geography and Environment, London School of Economics. (Email: b.groom@lse.ac.uk).

⁴ Centre of Climate Change Economics and Policy and Grantham Research Institute on Climate Change and Environment, London School of Economics (Email: m.i.spackman@lse.ac.uk).

Introduction

This paper was prepared as a summary of a workshop held in April 2016 on social discounting, which was a follow-up to a previous workshop held in June 2013. The document summarises the key theoretical and empirical evidence on social discounting that had emerged at the time since the Green Book of 2003. The authors would like to thank Loughborough University and the LSE Grantham Research Institute on Climate Change and the Environment for funding the first workshop in 2013. We would also like to thank the participants of the workshops and those who made comments on previous drafts of this document. In no particular order: Professor Simon Dietz (Department of Geography and Environment LSE and Grantham Research Institute on Climate Change and the Environment), Joseph Lowe (HM Treasury), Professor David Maddison (Department of Economics, Birmingham University), Professor Christian Gollier (Toulouse School of Economics), Professor Cameron Hepburn (University of Oxford, LSE), Dr. Antony Millner (Grantham Research Institute on Climate Change and the Environment, LSE), Frikk Nesje (Department of Geography and Environment LSE and Department of Economics, University of Oslo), Dr. Moritz Drupp (Department of Economics, Kiel University), as well as participants from government departments. This acknowledgement comes with the usual disclaimer that all the views contained in this report are the authors' own or those of the authors of the researcher papers discussed, and all remaining errors are our own.

Mark Freeman, Ben Groom, Michael Spackman

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Part 1: Social Discounting in the Green Book: an overview.

The Treasury Guidelines on Cost Benefit Analysis, henceforth the “Green Book”, takes as the Social Discount Rate (SDR) an estimate of how society values consumption at different points in time. This gives a Social Rate of Time Preference (STP) that is appropriate for discounting costs and benefits measured in consumption units.

The STP approach is distinct from the “Social Opportunity Cost of Capital” (SOC) approach to social discounting, derived mainly from private sector financial returns, which was used when HM Treasury first introduced social discounting in the 1970s. The STP approach is argued to be preferable partly because the SOC concept is not appropriate for comparisons over time of consumption with consumption, or of public spending with public spending (i.e. cost effectiveness analysis), and many applications are of this kind (Feldstein, 1970, 1973). The use of STP has typically led to a lower annual percentage rate of discount. In recent years, with real yields on Government bills and bonds being very close to zero or negative, the risk free rate of return is currently much lower than the STP.

The STP is also the appropriate time preference rate for comparing consumption with public spending (i.e. cost benefit analysis - CBA), as in the appraisal of publicly funded capital projects. However, in order to account for the fact that a pound of consumption is not the same as a pound of public spending (due to the inefficiencies introduced by increasing taxation for instance), adjustments are in principle required to the estimates of public spending. There are no procedures for this adjustment at present, so where STP is used, the decision criterion for CBA might be that projects are compared in terms of their benefit/cost ratios, to obtain the most consumption benefit per pound of public spending.⁵ While not a discounting issue per se, it is important to recognise this particular accounting issue when using STP.

The derivation of a Social Rate of Time Preference (STP)

Social time preference is conventionally derived from the following equation, often referred to as the Ramsey Rule:

$$SDR = \rho + \eta g = STP$$

where g is annual per capita growth of consumption, η is the elasticity of marginal utility of consumption and ρ is the utility discount rate, consisting of a component for pure time preference, δ , and, in HM Treasury practice, a component for certain types of risk, L , so that $\rho = \delta + L$.

Disagreement about whether the Ramsey Rule should be used for CBA stems from several issues: i) it does not reflect the opportunity cost of public funds; ii) it is derived from a purely consequentialist Utilitarian social welfare function that has a quite specific functional form; iii) the parameters of the Ramsey Rule are difficult to estimate and are the subject of some disagreement; iv) it does not account for project risk or uncertain growth in consumption; v) *intra*-generational distributional issues are not explicitly treated, since future well-being is captured by consumption growth of the average agent; and, vi) It is assumed that all costs and benefits can be placed in terms of consumption equivalents, which can ignore the complexities of relative price changes. Point i) and ii)

⁵ An SOC rate, in contrast, seeks to combine in one number both time preference and a social opportunity cost of public spending, but no single number can do this, as an adequate approximation, for more than a fairly narrow range of project lifetimes.

are discussed elsewhere in the Green Book, as is the issue of relative prices, point vi) (HMT, 2003, p 20-25). Further details of these points can be found in a recent report to the Office for National Statistics in relation to environmental assets (Freeman and Groom, 2016). We now turn to point iii), and in Part II we address point iv) and v).

The elasticity of marginal utility (of consumption?), η ⁶

Various approaches have been taken to estimating η . The empirical methods used include the following, with additional references in Groom and Maddison (2018) which updates previous work on this issue for the UK.⁷

- i. **The Equal Absolute Sacrifice approach:** η can be estimated by looking at the extent to which the income tax system is progressive. This progressivity, so the argument goes, can be assumed to follow from a belief that the marginal utility burden of the tax should be the same for all taxpayers. This measure is assumed to reflect inequality aversion.
- ii. **Life-cycle behavioural models: The Euler Equation approach:** η is interpreted as the inverse of the elasticity of intertemporal substitution and treated as a parameter to be estimated directly from econometric estimation of the Ramsey Rule form. This assumes that the Ramsey Rule takes the form: the interest rate, r , is equal to the STP: $r = \alpha + \eta g$, where, to account for distortions in the level, α is not generally interpreted as being equal to ρ . Aggregate or individual level data can be used.
- iii. **Additive preferences and the Frisch formula:** This approach relies on the presumed existence of additive preferences. Additivity implies that the marginal utility obtained from consuming infra-marginal units of the additively separable commodity, usually taken as food, is independent of the quantity consumed of any other commodity. Given additivity, all the information necessary for estimating η can be obtained via the Frisch formula by analysing the demand for the additively separable commodity. Groom and Maddison (2018) provide details of this approach.
- iv. **Stated Preference and Expert elicitation:** approaches i)-iii) are revealed preference approaches to estimating η . Yet hypothetical elicitation among individual respondents, sometimes using incentivised experiments, or consultation of experts are also potentially valid approaches to estimation. Drupp et al. (2018) undertook expert elicitation. Atkinson et al. (2009) is a good example of the stated preference approach.

Estimates from approaches i)-iv) are discussed at length below.

The utility discount rate: $\rho = \delta + L$

The utility discount rate, in the Treasury derivation, contains two components, pure time preference, δ , and a component for certain types of risk, L . Supplementary Treasury guidance on this matter, Lowe (2008), harmonises this position with that taken by the Stern Review (2007), which proposed $\delta = 0$ and $L = 0.1\%$ in the context of evaluating climate change mitigation. Key differences between the Green Book and the Stern Review positions are: i) Stern considers long-run intergenerational impartiality in motivating $\delta = 0$, while the Green Book is more concerned with shorter, albeit sometimes inter-generational, time horizons; and, ii) The Stern Review interprets

⁶ HMT (2003) has different notation for the elasticity of marginal utility. Instead of η , μ is used.

⁷ HMT (2003) cites the review of methods by Pearce and Ulph (1995) on this issue.

catastrophic risk solely as the likelihood of societal collapse such that there is no society to enjoy future welfare, while the Green Book interpretation is broader.

The Green Book inclusion of different concepts of risk in the L component is a practical short-cut. It now includes a risk of some natural or man-made national catastrophe, essentially ending the current social structure, the risk that across almost all projects there will always be some underestimation of risks (for example few will have considered the risk of a Japanese tsunami leading to premature shut down of German nuclear power), and a small factor for the systematic risk associated with the covariance of social costs and benefits with national income. Some of these issues are, strictly, better dealt with outside of the discount rate by adjusting the measure of benefits appropriately, rather than adjusting the discount rate. Others might be treated through project-specific adjustments to the discount rate to reflect differences in risk.

Growth of per capita consumption: g

g is an estimate of the future growth rate of per capita consumption. The previous Green Book estimate of growth uses the post-war period between 1949 and 1998, during which time real consumption growth was approximately 2%. What the expected growth rate will be for the next several decades is not clear. Groom and Maddison (2018) show that over the past 150 years, growth is closer to 1%.

The Green Book Social Rate of Time Preference (STP)

Taken together, estimates of the factors under-pinning the Green Book STP are still broadly consistent with an STP rate of 3.5%, as was adopted in the 2003 Green Book. Part II of this report provides more details on the estimates. As a brief comparison to practices elsewhere, the 3.5% can be compared to the French guidelines, which also follow an STP approach and recommend a basic, risk-free STP rate of 2.5%. The French discount rate is compatible with growth of 1%, $\delta = 0.5$, $L = 0$ and $\eta = 2$, although the French guidelines do not take a position on the exact values of the individual components (Quinet, 2013). In addition though, the French guidelines propose systematic risk premiums to accommodate project risks. These risk premiums increase the discount rate for the average project, giving an overall STP rate of 4.5%. The French guidelines also recommend a declining term structure for the risk free rate, and an increasing one for the risk premium (Quinet, 2013). The rationale for the declining term structure and the incorporation of project risk in the discount rate is discussed further in Part II.

Differing views on the STP parameters

The precise estimates of the parameters, and hence the value of the STP, have long been, and continue to be, subject to debate. There have always been contrasting estimates of the parameters even within the same conceptual framework, but particularly across conceptual frameworks. For instance, Blundell (1998) uses a more thorough and conceptually appealing approach to estimate a value of $\eta = 2$ based on individual inter-temporal consumption-savings decisions. Yet Tol (2010) looks at the level of inequality aversion implied by international transfers of aid and finds values in the vicinity of $\eta = 0.5$. In some cases there are considerable differences depending on the estimation approach taken. Yet for the UK, Groom and Maddison (2018) find that many revealed preference approaches yield values that are not statistically different from 1.5.

The arguments and disagreements concerning pure time preference are also well known, with many academic economists and philosophers arguing for zero pure time preference on ethical grounds, for both intra- and inter-generational projects. The issue of what aspects of risk, if any, should be incorporated in an STP rate, and how, has been and remains an enduring area of academic debate, with significantly diverse arguments (see e.g. Baumstark and Gollier, 2013; Barro, 2006; Arrow et al., 2013).

Ultimately, valuation of the parameters for STP always involves pragmatism. The final number represents a form of consensus on the theoretical, empirical and other literature as well as political and administrative views that prevail at the time. However the figure of STP = 3.5% appears to lie within the middle ground of the current literature, as is explained below.

Part II: The STP: new estimates of parameters and new approaches

The elasticity of marginal utility of consumption: η

For the UK the most relevant new reference is Groom and Maddison (2018). They used several of the methods outlined above to estimate the elasticity of marginal utility, and applied them to updated UK data (up to 2014). Table 1 summarises the results. Their meta-analysis cannot rule out homogeneity among the different approaches and estimates. This means that whether one uses the absolute equal sacrifice method, the Euler Equation approach, or any of the other methods they review, one cannot reject the pooled estimate of the elasticity of marginal utility: $\eta = 1.5$ (confidence interval: 1.42-1.59, albeit ignoring model uncertainty).

Methodology	η	Standard error
Equal sacrifice (Weighted)	1.515	0.047
Equal sacrifice (Historical)	1.573	0.481
Euler equation	1.584	0.205
Additive preferences (Rotterdam)	3.566	2.188
Additive preferences (CEM)	2.011	1.337
Subjective wellbeing	1.320	0.168
Pooled estimate	1.507	

Source: Groom and Maddison (2018)

Table 1. Updated Estimates and Meta Analysis of η

Variable	Mean	StdDev	Median	Mode	Min	Max	N
Real growth rate per capita (g)	1.70	0.91	1.60	2.00	-2.00	5.00	181
Rate of societal pure time preference (δ)	1.10	1.47	0.50	0.00	0.00	8.00	180
Elasticity of marginal utility of consumption (η)	1.35	0.85	1.00	1.00	0.00	5.00	173
Real risk free interest rate (r)	2.38	1.32	2.00	2.00	0.00	6.00	176
Social Discount Rate (SDR)	2.27	1.62	2.00	2.00	0.00	10.00	181
SDR lower bound	1.12	1.37	1.00	0.00	-3.00	8.00	182
SDR upper bound	4.14	2.80	3.50	3.00	0.00	20.00	183
Social Rate of Time Preference (STP)	3.48	3.52	3.00	4.00	-2.00	26.00	172
Number of responses							197

The STP is imputed from the individual determinants: the rate of societal pure time preference, and an interaction term of the real growth rate of per-capita consumption and the elasticity of marginal utility of consumption.

Table 2: Drupp et al. (2018) Survey Results for intergenerational discounting

In the context of climate change Dasgupta (2008) took the personal normative view that the value of the elasticity of marginal utility chosen by Stern (2007): $\eta = 1$, which is also the value used in the previous version of the Green Book, was too low an estimate of the degree of inequality aversion. Dasgupta (2008), Gollier (2008), as well as the French guidelines on discounting (Lebegue 2005,

Quinet 2013), propose a value of $\eta = 2$. Just how much disagreement there is among such prominent experts, and whether experts are the appropriate source for this information, is investigated in Drupp et al. (2018). They undertook a survey of expert economists on the intergenerational Social Discount Rate (for projects with a time horizon of 100 years or more) to establish the extent of disagreement on this issue and found that out of nearly 200 experts, the average response was $\eta = 1.4$ (see Table 2). Ultimately, empirical estimates obtained in the context of social discounting tend to range between 0.5 and 2.

The pure rate of time preference: δ

Drupp et al. (2018) also obtained data from experts on the pure rate of time preference. They found a modal value of 0%, a mean value of just over 1% and a median value of 0.5%. These estimates typically reflected catastrophic risk associated with the macro economy (consumption not the project risk) as well as pure time *preference*. These estimates are somewhat below those used in the Green Book, which in 2003 had $\delta = 0.5$ (with $L = 1\%$ and $\rho = \delta + L = 1.5\%$). It is likely that the modal response of $\delta = 0$ in the Drupp et al. (2018) survey was because their survey explicitly about long-term public projects in which a commonly held ethical position is that of impartial Utilitarianism. Lowe (2008) discusses how this position, also held by the Stern Review (Stern, 2007), is compatible with the Treasury Green Book position on the SDR.

As discussed above, the Green Book definition of catastrophic risk, L , contains a number of conceptually distinct concepts: i) exogenous risk of societal collapse; and, ii) catastrophic project failure. Other interpretations of catastrophic risk include that of Barro (2009) and Weitzman (2009) who consider low probability deep recessions and large climate change impacts. In neither case are these catastrophic events included in the utility discount rate, but they are thought of as being exogenous shocks to the underlying growth process, and therefore an additional dimension of uncertainty to be priced in. Further details on this issue are provided below.

Growth in per capita consumption: g

It is questionable whether the time horizon of 1949-1998 remains the relevant time horizon over which to calculate per capita consumption growth. Yet, forecasting growth is fraught with difficulties. There are both growth pessimists and optimists among economic experts. Recent events such as the financial crisis of 2008 may give rise to more cautious estimates from some parties. Groom and Maddison (2018) calculated per capita consumption growth for the UK for the period 1949-2009, thereby updating the post-war Green Book estimate, and found that the average real annual growth over this period was 2.3%. Over the longer time horizon from 1830-2009, Groom and Maddison (2018) estimate that per capita consumption growth was only 1.1%. How relevant such historical estimates are to the prospects for growth today is debatable. Some would argue that the recent past is more relevant to immediate prospects. Others argue that only long time horizons can pick up the full range and frequency of potential economic outcomes, including deep recessions and other catastrophic outcomes, or large infrequent technological advances. In the UK context, per capita consumption growth has fluctuated widely. Table 3 updates and harmonises the estimates to 2016 and shows the per capita consumption growth rates for different historical periods.

Historical Period	Annual average (compound) growth rate of real per capita consumption (%, 2013 prices)
1830-2016	1.29 (1.24)
1949-2016	2.20 (2.15)
1949-1998	2.50 (2.44)
2000-2016	1.30 (1.28)
2007-2016	0.21 (0.19)

Source: <https://www.bankofengland.co.uk/-/media/boe/files/statistics/research-datasets/a-millennium-of-macroeconomic-data-for-the-uk.xlsx?la=en&hash=73ABBF603A709FEEB1FD349B1C61F11527F1DE4>

Table 3. Historical growth in per capita consumption in the UK⁸

In the context of expected long-term global growth the Drupp et al. (2018) survey of expert economists found that on average experts predicted growth of 1.7%, but responses ranged from -2% to 5% with a standard deviation of 0.91. Drupp et al. (2018) note that “this (mean) is close to the 2 percent growth rate of consumption per-capita in the western world for the last two centuries and the 1.6 percent growth rate in GDP per-capita over the period 1900 to 2000 in non-OECD countries.”

Emmerling, Groom and Wettingfeld (2017) ask whether growth of the *average* household is the appropriate growth rate to use when in reality many households do not experience average (per capita) levels of consumption growth. That different households experience different growth rates is an indication that income inequality is changing over time. Emmerling et al. (2017) argue that if society is averse to *intra*-temporal income inequality the SDR can be easily augmented to reflect secular changes in inequality by an inequality correction term:

$$STP_{ineq} = \rho + \eta g_{ave} + \eta^2 (g_{med} - g_{ave})$$

Here, g_{med} and g_{ave} are the growth rates of consumption for the median and average (per capita) person in society respectively. The term $(g_{med} - g_{ave})$ captures how inequality is evolving over time: growth of the average person is greater (less) than the median person if inequality is increasing (decreasing). In the discount rate this latter term is scaled by inequality aversion, η , and aversion to intertemporal fluctuations, which is also η in the Ramsey framework, hence η^2 , to give the inequality correction term: $\eta^2 (g_{med} - g_{ave})$. One interesting special case is when $\eta = 1$ and the growth rate of the median household is the relevant growth rate for social discounting. Growth of the median agent is the appropriate representative growth rate for welfare analysis in this case.

Emmerling et al. (2017) show that for inequality aversion parameters of 0.5, 1 and 2, combined with historically higher average growth than median growth in the UK (increased inequality of income), the discount rate would be lower by approximately 0.25%, 0.5% or 1%. A similar outcome is true for the US, while in Spain for instance, a higher discount rate is recommended due to declining income inequality (See Emmerling et al. 2017, Table 1, p. 80).⁹

⁸ Calculations taken from Sheet A12. GDP(E) column F entitled “composite volume measure” divided by the column G entitled “Great Britain and Northern Ireland” in sheet A18 (divided by 1000).

⁹ See Federal Reserve Bank of St Louis: <https://research.stlouisfed.org/fred2/series/MAFAINUSA672N#>

Discounting and Risk

The STP approach taken by the HM Treasury Green Book guidelines only takes into account certain types of risk. Three distinct elements of risk are important to consider when determining the discount rate for public projects, which we deal with in turn. These are:

- i. **Growth or macroeconomic risk:** economy-wide uncertainty in the growth rate of consumption, g ;
- ii. **Project risk:** Contains ‘systematic’ and ‘unsystematic’ risk. Systematic risk is the component of project risk that is correlated with macroeconomic risk and affects the discount rate. Unsystematic risk can be diversified away across projects and so does not affect the discount rate;
- iii. **Catastrophic risk:** An extreme element of macroeconomic risk including the risk of societal collapse or other rare disasters (deep recession), as opposed to more ‘everyday’ economic volatility. Treatment of this risk has implications for the risk-free discount rate and discount rates that take into account systematic project risk.

Macroeconomic risk: Consider uncertainty about the growth rate, g . Gollier (2012, ch3) shows that when growth is uncertain and uncorrelated over time, projects with sure benefits should be discounted using the following risk-free STP:¹⁰

$$(3) \quad STP = \rho + \eta\mu_c - 0.5\eta^2\sigma_c^2$$

where μ_c and σ_c^2 are the mean and variance of growth. This is a simple extension to the Ramsey Rule to reflect the precautionary rationale for investing in the future in the face of uncertainty. The prudence term is given by $-0.5\eta^2\sigma_c^2$ and can be easily calibrated in this special case. The prudence term reflects the fact that uncertainty about future growth (reflected by the variance of growth σ_c^2) causes an increase in the demand for safe assets in the future. This can be seen as a precautionary savings effect of uncertainty which reduces the discount rate. In the UK the volatility of consumption growth has been around 2.73%. With $\eta = 1$ this leads to a prudence correction factor of 0.037%, leading to an STP of 3.46%. The absence of significant volatility in estimated average consumption growth means that this correction factor is small in the UK. In the US by contrast, volatility has been slightly higher at 3.6%, which would lead to a correction of about 0.13%.

The observation that the correction for prudence is small, leaving a relatively large risk free discount rate is related to the “risk-free rate puzzle” (Weil, 1989). The risk-free puzzle arises from the fact that the *theoretical* risk free rate shown in equation (3) when calibrated with standard parameter values and measures of volatility, is typically larger than the risk-free rate observed in the market. That is certainly the case in the UK at the time of writing (Feb 2018), where observed **real** returns on government bonds are significantly negative, and have been hovering around 0% for several years prior.¹¹ It is important to notice that this is only really a *puzzle* if a ‘positive’ approach is being taken. From a ‘normative’ perspective there is no obligation for the theoretical model to coincide with observed market rates. There really is no puzzle in this case.

¹⁰ For the simple case where the growth process is independently and identically distributed with: $\ln c_t - \ln c_0 = \tilde{x}_t t$, $x_t \sim N(\mu_c, \sigma_c^2)$ and utility is isoelastic.

¹¹ http://www.bankofengland.co.uk/statistics/Pages/yieldcurve/default.aspx#chart_real

Project risk: The Green Book takes into account some elements of risk at the level of the project via:

- i. Scenario analysis to reflect the uncertainty surrounding estimates of costs and benefits
- ii. A premium for optimism bias

Both of these approaches alter the estimated net benefits from the project but not the discount rate. However, the Green Book also adjusts the discount rate for risk through the component L . This term, though, is not fully defined in the Green Book. Some argue that it incorporates an element of project risk: the possibility that projects fail or become obsolete. Such an approach is equivalent to having a constant risk premium across all projects. We return to this element of the discount rate in the next section.

In financial economics, project risk is generally decomposed into systematic risk and unsystematic risk. Systematic risk is not diversifiable across projects, whereas unsystematic risks (e.g. unexpected additional costs or benefits for, say, specific technical reasons) can be diversified away. Systematic risk reflects the relationship between the macro-economy and the uncertainty associated with the net benefits of any given project. This correlation is measured by the project 'beta'; e.g., if $\beta = 1$ then a 1% increase in consumption growth will be expected to lead to a 1% growth in the project net benefits. If $\beta > 1$ then the project benefits are expected to increase by more than 1% when consumption grows by 1%, reflecting greater systematic risk.

In many countries, France, Norway and The Netherlands included, adjusting the discount rate for systematic project risk is an accepted element of social CBA. Gollier (2012) illustrates that a simple Consumption CAPM (CCAPM) approach to discounting would advocate the following structure for the discount rate as an extension to the Ramsey Rule:¹²

$$(4) \quad \begin{aligned} SDR &= r_{rf} + \pi(\beta) \\ &= \rho + \eta\mu_c - 0.5\eta^2\sigma_c^2 + \pi(\beta) \end{aligned}$$

where r_{rf} is the risk free discount rate in the presence of growth risks, as shown in equation (3), μ_c and σ_c^2 are the mean and variance of growth as before, $\pi(\beta)$ is the **risk premium** and β is the **consumption beta**.

Gollier (2012, ch12 p185-196) shows that one simple representation of the discount rate in these circumstances is:

$$(5) \quad SDR = \rho + \eta\mu_c - 0.5\eta^2\sigma_c^2 + \eta\beta\sigma_c^2$$

Where the risk premium is given by: $\pi(\beta) = \eta\beta\sigma_c^2$. In principle each public project has its own specific beta. However, one pragmatic, but theoretically incorrect, way to proceed here is to think about projects in general, ex ante, and not discriminate among them by their beta. A typical

¹² Again, in the simple case where the growth process is i.i.d. with: $\ln c_t - \ln c_0 = \tilde{x}_t$, $x_t \sim N(\mu_c, \sigma_c^2)$ and utility is isoelastic.

assumption is that the aggregate portfolio of social projects has a beta of 1.¹³ Thought about this way, one could impute a uniform risk premium of 1 times $\eta\sigma_c^2$. In the UK case, where volatility has been 2.73%, the risk premium when $\eta = 1$ becomes 0.075% using this method.¹⁴ This could then be adjusted to be higher or lower depending on the specific project β . By and large though, these theoretical risk premia are tiny when using the Green Book parameters, as was the correction for prudence.

Of course, the magnitude of this *theoretical* risk premium is in stark contrast to *observed* private sector risk premia, which should also, in theory, be calculated in an analogous way. This observation is a manifestation of the well-known 'equity premium puzzle': the simple theoretical model does not fit the observed market outcomes (Mehra and Prescott, 1985).

The equity premium puzzle is a potential puzzle for discounting too. To reiterate, the fear for the government is that without accounting for project risk, the specific risk profiles that each project has (reflected by the project beta), and the returns available in the market place, the Government will take on too much risk in the selection of its projects. Some have argued that this might be true when engaging in joint public/private financing (Baumstark and Gollier, 2013). Yet it is clear that the risk premia calculated above would not make a huge difference to the portfolio of public projects selected. So, the question becomes one of how to incorporate the risk premia observed in the market, or indeed whether to do this at all.

The French guidelines take a different approach by starting with the observed rates of return on equities, and observed risk free rates in the market and then calibrating the public risk premium so that the discount rate reflects this observed rate of return. The Quinet Report of 2013 (Quinet, 2013) proposes a risk premium of $\beta * 2\%$ based on this exercise (Gollier, 2012, p196; 2011). The discount rate for an average project ($\beta = 1$) is therefore 4.5%, and 2.5% for risk free projects, but varies across projects according to β (OECD 2015). For similar reasons, although less explicit, the Norwegian guidelines of 2012 propose a risk free rate of 2.5% and an additional 1.5% to adjust for risk for horizons of less than 40 years (NMOF 2012, OECD 2015).

At present, the view taken in the Green Book is that systematic risk is generally not sufficiently important to necessitate an explicit treatment in CBA. The implicit assumption therefore is that the correlation between public investments and the net benefits are sufficiently spread throughout the populous that such risks are irrelevant to the public sector. This general position, which stems from the Arrow-Lind theorem and has been popular in the public sector, remains a matter of debate. Some recent work argues that the position is untenable in general (Baumstark and Gollier, 2013).

If the Arrow-Lind theorem does not hold then systematic project risk ought to be accounted for in some way. The fear for the public sector is that by ignoring such risks two problems arise: (i) the welfare consequences of such projects are not correctly evaluated; and, (ii) the government may take on greater risk in its portfolio of projects than social welfare maximisation would justify. This might be particularly true for projects with large procyclical risks.

¹³ This is more likely to be true when public and private projects are combined in the overall portfolio, and even then one must assume that these projects generate all of the consumption good. But this is not generally true for public projects as much consumption comes from the private sector.

¹⁴ This comes from $\eta\beta\sigma_c^2 = 1*1*0.0273^2 = 0.075\%$

Catastrophic Risk: Finally, there is the issue of how catastrophic risk affects the risk free rate of return, r_f , and individual project risk premia. In principle catastrophic risk is simply an extreme element of systematic risk discussed above. However, there are several ways in which catastrophes can be thought about, and they are often overlooked in discounting analysis.

As discussed above, the Green Book includes an element of catastrophic risk in the utility discount rate in addition to societal pure time preference. At present the rationale for this is:

“the likelihood that there will be some event so devastating that all returns from policies, programmes or projects are eliminated, or at least radically and unpredictably altered. Examples are technological advancements that lead to premature obsolescence, or natural disasters, major wars etc. The scale of this risk is, by its nature, hard to quantify HMT (2003, p 97)”

The essential idea is that L is a hazard rate which governs the probability of a catastrophic event in the near future such that:

$$\Pr(\text{catastrophe}) = 1 - \exp(-Lt)$$

With $L = 1\%$, this implies that the probability of ‘survival’, i.e. no catastrophe (using the Treasury definition) beyond 30 years is about 75%. The Stern Review used a hazard rate of 0.1%, but defined catastrophe more narrowly, and referred to a long-run intergenerational context. The implied probability of survival after 100 years in this case would be 90%.

In this framework, the risk of a major drop in consumption leads to a strong precautionary savings motive, reducing the theoretical risk-free rate. This helps overcome the risk-free rate puzzle of Weil (1989). It also introduces very high levels of correlation between most procyclical projects and macroeconomic risk as these projects fail when society needs the benefits from them most. This addresses the equity premium puzzle of Mehra and Prescott (1985). Together, this framework implies that the risk-free STP should be low, but that the risk-premium is non-trivial for social projects and that the Arrow-Lind theorem can no longer be applied.

The Barro approach is a specific interpretation of a catastrophic risk which overlaps somewhat with the definition used by the Green Book but primarily focuses on project risk and the associated risk premium. The Stern Review dealt with this type of systematic risk differently by introducing scenarios of deep recession (30%+ losses in GDP) in its Monte Carlo analysis of climate change outcomes (Stern, 2007). Hence this type of risk was not included in their 0.1% estimate of the exogenous catastrophic risk that appeared in the utility discount rate.

In conclusion, in the standard Ramsey-type theoretical framework for estimating the STP, the theoretical risk-premia associated with most social projects are assumed to be near zero. This is either due to low levels of observed volatility, which ignore rare disasters to growth, the normative view that social preferences have a lower η than individual behaviour suggests, or due to the assumption that project net returns are not correlated with any element of macroeconomic risk. Taken together these views approximate the position taken in the Green Book guidance in relation to catastrophic risk of this type.

However, if either (i) risk premia are estimated directly from financial markets rather than theoretical consumption-based asset pricing models, or (ii) there is the non-trivial threat of a major depression that will simultaneously affect both project outcomes and aggregate consumption, then it may be appropriate to incorporate a non-trivial risk premium into the STP.

Summary on Discounting and Risk

Ultimately there are many different dimensions of risk that are relevant for social discounting. There are macroeconomic risks which reflect uncertainty about future average consumption growth. There are project risks which, when correlated to macroeconomic risks, affect the welfare properties of the project itself. There are risks associated with the obsolescence or failure of the project itself, although if these are not systematic, then these ought to be accounted for in the estimation of expected benefits and are not relevant to the discount rate. Special treatment may be required for catastrophes and rare disasters which affect growth, such as major recessions which affect both GDP and the expected returns from the project simultaneously. Finally, there are catastrophic risks associated with the complete collapse of society. Stern (2007) thought of the latter as including asteroid strikes or disease outbreaks, the Green Book thinks about this in terms of the mortality of individuals in society. In general it is important to deal with these aspects of risk separately and coherently.

Discount Rates for Intergenerational Projects

Since the HM Treasury's pioneering change to its discounting policy for long term projects to incorporate a declining discount rate (DDR), the theoretical and empirical literature has tended to confirm that this is the correct approach for long-term risk free discount rates. Expert summaries of the state of the literature can be found in Arrow et al. (2013, 2014), Gollier and Hammitt (2014) and Cropper et al. (2014).

Arguments that focus on uncertainty in the risk-free interest rate have had further empirical justification both in the UK and beyond. Hepburn et al. (2008) provide an analysis across countries, Groom et al. (2007) show that the original results found in Newell and Pizer (2003) for the US are robust to different empirical methodologies, while Freeman et al. (2015) show that the Newell and Pizer (2003) results are also robust to their assumptions concerning the historical data on treasury bond returns and the treatment of inflation. More recent work has focussed on the long-run housing contracts and the discount rates implied by the different prices of freehold and leasehold contracts of varying lengths up to and beyond 100 years (Maggiore et al., 2015).

Some empirical results point in the other direction though. Freeman and Groom (2015) show that the results in the original 'Gamma Discounting' paper by Weitzman (2001), which together with Weitzman (1998) was influential in shaping the 2003 Green Book guidance, are not robust to different treatments of the expert responses (Groom and Hepburn, 2017). In short, if experts were providing forecasts of the future long-term mean interest rate then the weight placed on each expert should be centred more on those forecasts near the mean, rather than the equal weights placed on experts by Weitzman (2001). Weitzman's equal weighting approach is potentially acceptable for subjective normative opinions, which could arguably be given equal weight (Freeman and Groom, 2015).

At the time the theoretical justification for Gamma Discounting was never clear. Much of the analysis since has shown that Gamma Discounting is an unusual theoretical framework, and also that the related Expected Net Present Value approach has only limited theoretical appeal (see Gollier and Hammitt (2014), Gollier (2015), Freeman and Groom (2016)). It is in extensions to the Ramsey Rule, within the standard theoretical framework that most progress has taken place.

The other highly influential contributions in the case of the 2003 Green Book were Gollier (2002a, 2002b) (see for instance Oxera 2002). The essence of these highly technical pieces has since been distilled into the standard Ramsey framework to allow the argument for DDRs to be seen in terms of extensions to the Ramsey Rule. Gollier (2012) provides a thorough explanation of these extensions. The basic message is that a prudent planner would like to save more for precautionary reasons. With persistent growth shocks the future looks ever more uncertain and this precautionary effect increases with the time horizon under consideration. This is reflected in a declining term structure of discount rates. This rationale underpins the French guidance on the term structure of risk free discount rates (see e.g. Lebegue 2005, Quinet 2013, Gollier 2008).

Practical guidance on intergenerational project appraisal

For intergenerational projects many have argued that simple NPV or BCR calculations are insufficient and pay too little attention to the distributional consequences of projects over time. The survey by Drupp et al. (2018) provides qualitative expert evidence on the variety of different possible approaches to incorporate intergenerational concerns. Sustainability, scarcity of environmental resources, uncertainty and irreversibility, and decision criteria other than CBA, are just some elements of decision making that the expert respondents recommend to be included in long-term CBA (Drupp et al. 2018). However, it is also safe to say that discounting cash flows for the entirety of the project's life is viewed as a central input to intergenerational decision-making by many experts on cost-benefit analysis. Careful study of the qualitative aspects of long-term projects, and Net Present Values and the implied Benefit Cost Ratios of the project as a whole, are still considered to be useful parts of the decision making process.

Risk premia and the long-run

As discussed above the French, Norwegian and recently Dutch governments have updated their guidelines on discounting to include a risk premium. The French and Norwegian governments have term structures for the risk premium for reasons similar to those underpinning the DDRs. In the French guidelines while the risk-free rate declines with the time horizon from 2.5% to 1.5% after 2070, the risk premium for a project with a β of 1 rises from 2% to 3% over the same horizon. This reflects the fact that the returns from most government projects are positively correlated with the economy at large, and that with persistent uncertainty in growth this correlation increases with the time horizon. The overall risk premium ($\pi(\beta)$) increases as a result. Details of this recent theoretical result can be found in Gollier (2012, 2014) and Freeman (2016).

The implications for the Green Book

There are clearly many different routes that could be taken to specify the discount rate for the UK in the new Green Book. We now present some potential positions that could be supported by the latest research, and show that the current 3.5% is a good consensus position both numerically and procedurally.

Possible values of the risk free STP

Following Groom and Maddison (2018), the STP could be updated to reflect the latest estimates of the elasticity of marginal utility. With no other changes, this leads to an STP of 4.5%:

$$(G\&M) \quad STP = 1.5\% + 1.5 * 2\% = 4.5\%$$

Alternatively, at the lower end of the parameter estimates one could take the approach of the Stern Review to obtain a social discount rate of 2%:

$$(Stern) \quad STP = 0\% + 1 * 2\% = 2\%$$

A more pessimistic outlook for growth of 1%, as found for instance in Groom and Maddison (2018), would lead to values of 3% and 1% respectively for the STP. Thus we arrive at an upper value of 4.5% and a lower bound of 1%. Although we would have to recognise that the value of STP = 1% is based on ethical assumptions that are more relevant to inter-generational projects.

It should be noted that the survey undertaken by Drupp et al. (2018) the mean STP response was 3.48% (median 3%, mode 4%) when separate answers for δ, η, g were used to calibrate the Ramsey Formula. As shown in Table 2, the recommended SDR (not necessarily STP), was 2.3% (median 2%, mode 2%). However, this survey was concerned with long-term (100 years) projects explicitly in mind.

Possible Values of the Discount Rate incorporating growth risk

When growth is uncertain it is in principle correct to have a correction for prudence. When the effects of growth risk are incorporated into the discount rate, the following baseline formula can be used from equation (3) above:

$$SDR = \rho + \eta g - 0.5\eta^2 \sigma_c^2$$

As discussed this makes practically no difference given the low volatility of consumption growth in the UK (Groom and Maddison, 2018). Even if $\eta = 2$, the upper end of estimates for the UK, the theoretical prudence correction is only 0.15%, conditional on the assumptions of log-normality of growth.¹⁵ However, low probability but highly severe potential shocks to consumption would materially increase the precautionary savings motive, reducing the implied SDR.

¹⁵ Given volatility of $\sigma = 2.73\%$ and $\eta = 2$, the prudence correction is: $0.5 * 4 * 0.075\% = 0.15\%$.

Possible Values of the Discount Rate incorporating project risk.

When the effects of project risk which is correlated with macroeconomic risk are incorporated into the discount rate, the following Consumption CAPM baseline formula can be used from equation (5) above:

$$SDR = \rho + \eta g - 0.5\eta^2 \sigma_c^2 + \eta\beta\sigma_c^2$$

Once again, the theoretical risk premium would be small for most of the values of η discussed above, but would of course depend on the project beta, and the potential presence of catastrophically bad project and macroeconomic outcomes.

Suppose instead that the discount rate moves away from the theoretical and normative underpinnings and takes a positive position, such as was taken by the French, Norwegian and Dutch Governments. This would lead to an approximate risk premium of $\beta * 2\%$. For $\beta = 1$, with all other assumptions remaining the same this leads to:

$$(CCAPM 1) \quad SDR = 1.5\% + 1 * 2\% + 2\% = 5.5\%$$

For $\eta = 1.5$ the SDR becomes 6.5%. Alternatively, if we take a similar view to Stern, and argue that some of the elements that the Green Book include in catastrophic risk should be removed when we account for risk and equity premia, so that $\rho \approx \delta \approx 0$, then we have:

$$(CCAPM 2) \quad SDR = 0\% + 1 * 2\% + 2\% = 4\%$$

A more coherent *positive* approach might be to simply calibrate the risk premium around the observed risk free rate of return. With real-risk free currently negative (January 2018) and having been close to zero for several years now, this would lead to a risk free rate of 0-0.5% and a SDR for risky projects in the order of 2-2.5%. This is similar to the approach taken in the Netherlands and Norway, who shy away from the Ramsey Rule and STP. As discussed above, the French Guidelines of 2013 stick with the STP approach, but settle on a risk free discount rate of 2.5% coupled with the risk correction $\beta * 2\%$. The overall rate is 4.5% for a beta = 1 project with relatively short maturity.

Pragmatic justification of the 3.5% STP

The motivation of the simple Ramsey Rule and the choice of the parameters in the Green Book lead to an STP of 3.5% and, as the analysis above shows, this is well within the range that could be justified by different approaches which variously disentangle the treatment of different types of risk, propose different values for the parameters based on more recent analysis, or take a more markets-driven framework.

One thing that seems clear from this analysis is that the Green Book STP is an attempt to calibrate the underlying social welfare function, rather than calibrate the discount rate to observed market rates. It is a more distinctly normative approach. What is missing from the discount rate when taking this approach is a treatment of project systematic risk.

This approach can be contrasted to the more *positive* approaches in Norway, France and the Netherlands where risk premia for public projects are made explicit.

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