A Study to Determine the Appropriate Social Discount Rate for the International Seabed Authority

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Summary

1. This study recommends an appropriate real (inflation-adjusted) social discount rate (SDR) to the International Seabed Authority (ISA). The SDR should be used to calculate the present value of future contractual payments from qualified eligible entities that extract minerals from the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction. Recognising the diversity of ISA Member States, it also provides guidance in adjusting the recommended SDR to fit divergent objectives.

We recommend that the ISA employs a real social discount rate of 3.75%

2. The arguments contained within this study that lead to this recommendation can be summarised as follows:

- The appropriate SDR for calculating the present value of the ISA revenue stream depends on the ISA's objective: financial or welfare valuation;
- For financial valuation, SDRs should be based on market rates. For welfare valuation, the SDR should be based explicitly on welfare principles such as fairness and inequality aversion;
- Different countries, international bodies and expert academic opinions recommend different approaches;
- Growth risks, revenue risk and intra- and inter-temporal inequality are some of the issues that affect the appropriate SDR;
- A global rate is needed for the ISA, which takes into account the range of ISA Member States, and the associated issues of risk and inequality;
- Some motivations for the SDR, such as those used by the World Bank for project appraisal, are not, in our opinions, appropriate to the ISA case;
- Our recommendation of 3.75% is a weighted average of risk free SDRs, risk premiums and inequality adjustments using our subjective judgement on the relevance of each approach to the objectives of the ISA.

Introduction

3. The purpose of this study is to provide guidance on the appropriate SDR to be used by the ISA when calculating the present value of streams of contractual payments from mining operations. The sub-seabed resources in question are owned in common globally, and take the legal status of common heritage of mankind. The resulting present value of this flow of royalties, however calculated, then represents a measure of the resource *wealth* associated with the common heritage of mankind managed by the ISA. The SDR is essential to the wealth calculation.

4. The SDR measures the rate at which the weights placed on future costs and benefits decline over the time horizon. These weights allow the user to compare future events in today's terms. If the SDR is 3.75%, then $1 received in a year has the same social value as 96.4 cents received today, calculated by $1/(1+3.75%). If the $1 arrives in 10 years' time, then this has the same social value as 69.2 cents received today, calculated as $1/(1+3.75%)^{10}. These are the *present values* of the $1 at the two different time horizons.

5. To determine the SDR, a number of questions must be addressed, each of which we discuss below:

- Should the ISA base its SDR on interest rates that can be directly observed from financial markets? Many experts argue that these interest rates reflect the actual opportunity cost of capital and so should form the basis for determining discount rates. Others argue that private investors have fundamentally different objectives than public bodies and so the rates of return that they demand should not help inform *social* discount rates. The ISA, when choosing its SDR, must take a position on this matter.
- If the ISA is reluctant to use market-based interest rates to form the basis for its choice of social discount rate, how can it best address the fundamental ethical issues that must be confronted when considering long-term discounting?
- How should the ISA incorporate into its SDR the highly international nature of its global administered assets?
- How should the ISA adjust its SDR to reflect the risky nature of the underlying income stream?

6. We consider these questions both from first principles and by reflecting on how other governmental and public bodies, as well as academic experts, have confronted related issues. By balancing these considerations, we arrive at our recommendation to the ISA of a real social discount rate of 3.75%. This assumes that operating agreements and contractual payments are agreed and that the proposed mining operations have met international standards concerning transparency and environmental integrity.

7. This study summarises the findings from a more technical report: Freeman, M.C., B. Groom (2020), "A social discount rate for measuring global heritage sub-seabed resource wealth: A report to the International Seabed Authority". Further arguments that support our recommendation can be found in this report.

Part I: Using Market Interest Rates

8. At first sight, determining a social discount rate for the ISA appears to be straightforward. An assumption can be that the ISA knows for certain how much income it will receive in each future year from contractual payments; Part III below addresses how uncertainty over the future income stream affects the choice of discount rate. In the case of certainty, the income that will flow in the future can be used as risk-free collateral for borrowing today. Supposing hypothetically that the amount that the ISA could borrow based on this income stream, which will be determined by the prevailing interest rate, represents its present value since this is the amount of capital that could actually be realised immediately. Therefore, within this setting, the appropriate choice of real SDR for the ISA is given by the real interest rate and this can be directly observed from financial markets. This is referred to as the "positive" (or "descriptive") approach to discounting and, as will be discussed below, many governmental bodies do calculate their social discount rates this way.

9. Should the ISA decide to take this approach, it must decide what interest rate to use. There are effectively three questions that must be addressed: (i) what is the appropriate type of financial instrument to take an interest rate from?, (ii) in which currency should this financial instrument be denominated?, and (iii) what maturity should the instrument have? These questions can be relatively easily answered.

I.1. Identifying the Appropriate Financial Instrument

10. Since, at this point, the assumption is that the future income stream to the ISA is known with certainty, it is appropriate to use a very low-risk asset as the basis for the SDR. Most academics have chosen to use the yield on some type of Government security such as a Treasury bond and the Dutch Ministry of Finance (2015) recommends an SDR of 0% which is based on the real yields offered by their Treasury securities. However, there remains a complication. Standard Treasury Bonds are not inflation-adjusted, instead guaranteeing payment in nominal terms. Therefore, their yields cannot be used directly to infer *real* discount rates. One way to overcome this problem is to estimate future inflation rates and deduct these from nominal yields. But this is a complicated process and likely not appropriate in the ISA's context. Inflation-adjusted bonds, such as Treasury Inflation-Protected Securities (TIPS) in the US, or Index-Linked Gilts (ILGs) in the UK do, however, offer returns that are all but guaranteed in real terms.

11. TIPS and ILGs are natural to consider when looking for market-based real risk-free yields, but they do have limitations. Some are technical issues that relate to the timing and nature of inflation protection. Other issues arise from potential market distortions that are currently making the prices of these bonds "too high". Quantitative easing by central banks has lowered the supply of inflation-protected securities at a time when demand has been increasing. A "scarcity premium", then, may have caused TIPS prices to rise and hence yields to fall in recent years. As a consequence, TIPS and ILG yields may be below the real risk-free SDR. Recently, the yields on ILGs of all maturities were negative and below -1%.

I.2. International Issues for Markets-based Approaches

12. At present, at least 16 governments offer index-linked bonds, while many offer nominal bonds. Yields can vary significantly between countries so it is not immediately obvious which country's yields the ISA should use. Another problem is that some developing countries who will benefit from the distribution of contractual payments do not have well established and liquid bond markets. The

bonds they do offer are unlikely to offer risk-free returns. High and volatile inflation rates further complicate market approaches to real discounting in developing countries.

13. Fortunately, there is a clear solution to the bond selection problem as bond payments are only risk-free in the currency in which the coupon and principal payments are made. So, while TIPS returns are all but guaranteed in real terms for US dollars, they are not in other currencies because of exchange rates uncertainties. We recommend that the ISA bases its market real risk-free SDR on yields in the country that corresponds to the currency of contractual payments. If the ISA receives all income in US dollars, then TIPS yields are most appropriate for estimating the present value of contractual payments. However, the sum of the present value of the benefits of developing countries may be lower than the present value calculated this way because each State will use its own real discount rate. These are likely to be higher than TIPS yields when evaluating their own benefits.

I.3. The Term Structure of Interest Rates

14. TIPS are available at different maturities (5, 7, 10, 20, and 30-year) which each offers its own specific yield. The relationship between bond maturity and yield is known as "the term structure of interest rates". The "term premium" is the difference in yields between bonds of longer and shorter maturities (e.g., 20 versus 10-year). Over the last decade, these term premiums have almost always been positive – longer-maturity TIPS offer higher real rates of return than short-term counterparts. Average real yields have been -0.09% (5-year), 0.18% (7-year), 0.40 (10-year), 0.83% (20-year) and 1.05% (30-year). However, term premiums were lower on average in the second half of the period than the first. This indicates higher average real interest rates at the short end (10-year and shorter maturities) and lower real interest rates at the long end (20-year and longer maturities) versus the first half of the last decade. By the end of 2019, real yields were almost zero at the short end and slightly below 0.6% at the long end.

15. When looking to discount future income streams, it is theoretically correct for the maturity of the chosen bond to match the maturity of the cash flow. This means that funds received in 5 years should, in principle, be discounted at a different rate to those received in 30 years. However, given the relatively small differences in TIPS yields at present, and the many inherent difficulties in precisely estimating the appropriate SDR, this approach is not warranted for the ISA.

16. Under this positive approach to discounting, the SDR should be driven by yields offered on 20- and 30-year maturity TIPS. These yields should be adjusted upwards slightly to account for the scarcity premium related to the poor availability of inflation-protected Treasury securities. At present, this implies a market-based risk-free rate of 1.0% to 1.5%: we take a central value of 1.25%. This is somewhat below recent survey evidence (Drupp et al., 2018: see Part IV), where the mean (median) forecast by experts in social discounting of future real global interest rates was 2.4% (2.0%).

I.4. Critiques to a Markets-Based Approach

17. While this markets-based approach to estimating the SDR is preferred by some academic experts and employed by various governmental bodies (see Part IV), it has also been subject to a number of major criticisms by others, notably Stern (2008). Fundamentally, it is not clear that yields determined through market forces by investors looking to maximise returns on private capital should dictate discounting choices to the ISA. After all, the ISA is aiming to maximising social welfare both internationally at any given period of time and intertemporally across generations, and this is not the objective of investors. Those most affected by the distribution of benefits from the ISA cannot influence US-based interest rates and therefore go unheard within this market-based framework. Further, there are a number of financial market frictions and taxes that distort interest rates away

from the social optimal. This has caused a number of academic experts, led by Lord Stern, to argue that it is the responsibility of public bodies to calculate the SDR from ethical first principles that explicitly reflect considerations of social welfare. Many governmental and public bodies, particularly in Europe, take this alternative "normative" (or "descriptive") approach to social discounting. Because the market-based SDR may not fit with the objectives of the ISA, we now turn to the normative approach.

Part II: Ethical Approaches to Social Discounting

18. As opposed to observing market interest rates, the "normative" approach to social discounting arrives at the SDR by analysing the welfare and consumption sides of the economy and the trajectory of economic growth in consumption (Arrow et al., 1996). Proponents of this approach argue that it is these determinants of well-being that reveal how society weights future costs and benefits.

19. The measurement of society-wide welfare is undertaken by first defining an inter-temporal Social Welfare Function (SWF). This SWF measures welfare over the planning horizon by aggregating measures of well-being at each future point in time. The SWF, in turn, tells us the impact of an additional dollar in the future on welfare today, and hence determines the SDR. If the impact of a future dollar on today's welfare is small, the SDR is high while if the impact is large, the SDR is small.

20. The SWF can be calibrated by using information on how society (or the ISA) measures well-being and how much weight to put on future well-being (a "time" effect), coupled with an estimate of what the future state of the world will look like: richer or poorer (a "wealth effect"). The concept of comparing intertemporal distributions – how we choose between pay-outs and costs today versus tomorrow – has parallels in other decisions that will need eventually to be taken by the ISA. For instance, ISA (2019, 2020) explores the appropriate shares of resource rents that each country should receive.

21. Under a normative approach to discounting, the SDR describes how a small increase in consumption changes social welfare depending on the maturity of the contribution. If the SDR is positive, another unit of consumption in the future is valued less in today's welfare terms than an additional unit of consumption today. Within this framework, the simple Ramsey Rule has become the workhorse model that links the ethics of inter-temporal welfare to the quantitative value of the SDR when there is no uncertainty over the future.

II.1. The Simple Ramsey Rule

22. Under the simple Ramsey Rule, the SDR is the sum of two components: a "time effect" and a "wealth effect".

23. The "time effect" defines what the SDR would be in an economy that remains unchanged over time. This captures a range of factors:

- *Pure impatience*: that "Society as a whole, also prefers to receive goods and services sooner rather than later" (HM Treasury, 2018, 5.33), or, more loosely speaking, that society is just impatient.
- *Hazard rate*: because we may not be alive to receive benefits in the future due to some catastrophe that leads to the end of society.
- *Societal mortality rates*: natural individual mortality rates mean that the current generation may not be alive to see the benefits that future generations enjoy.

- *General project risk*: sometimes, erroneously, the risk of a project failing is embodied in the time effect (Freeman et al., 2018). Instead, we should include project risk as a risk premium within the SDR (see Part III).
- *Intergenerational equity*: the time effect can capture a pure ethical position on how the well-being of future societies, or generations, should compare to the well-being of the present.

24. The "wealth effect" reflects the fact that the economy changes over time, with GDP growing and shrinking through periods of wealth generation and recession/depression. With parallels to ISA's decision-making on intra-temporal fairness, so social welfare is also increased by transferring wealth from richer generations to poorer generations across time. If the ISA believes, as most economists do (Drupp et al. 2018), that the future will be wealthier than the present, then an additional $1 received today has greater benefit to social welfare than the same $1 in the future even if society is not impatient (no time effect) and there is no inflation (real analysis). The reason future welfare is less is that additional units of consumption in the future are worth less today if they accrue to an already more prosperous society than the comparatively poorer present. This occurs in present value terms. The result is that society discounts the future more to offset its richness.

25. The magnitude of the wealth effect will depend on both (i) how much wealthier the future will be than the present, multiplied by (ii) a measure of how strongly society wishes to transfer wealth from richer generations to poorer ones. The latter is determined by the curvature of the social welfare function with respect to changes in consumption and is called the "Elasticity of Marginal Utility" (EMU). As an example, suppose that in the future a society consumes 10% more than the society today – it is 10% richer. The future marginal welfare is then EMU*10% less than today.

II.2. Calibrating the Simple Ramsey Rule

26. Calibrating the Ramsey Rule requires both forecasts and ethical judgements. On the former, we must estimate the likelihood of societal collapse (e.g. Newbury, 1992; Stern, 2007, 2008) and, more fundamentally, how much richer or poorer than today future society will be. The estimated real growth rate in global per-capita GDP is a core input into the Ramsey Rule. On the ethical side, when determining the time effect, we must decide whether society *should* be impatient, and, if so, to what extent. We must also determine how strongly we believe that wealth should be transferred from richer to poorer generations. There are no objectively correct answers to these ethical questions and therefore this normative approach to discounting is fundamentally different to the "positive" markets-based approach of just observing bond yields. This is why it is sometimes referred to as the "prescriptive" approach; it is necessary to *prescribe* our own ethical judgements into the calculation of the SDR.

II.2.a. The Time Effect

- *Pure impatience.* Econometric work on aggregate savings estimates that pure impatience adds 0.3% to 0.5% to the SDR. HM Treasury (2018) uses a value of 0.5%. In a major survey of expert opinion on this matter (Drupp et al., 2018; see Part IV), the mean (median) value was 1.1% (0.5%).
- *Hazard risk.* Estimates of the risk of the extinction of *society* as a whole vary between 0.1% and 1.5%. Newbery (1992) estimates the "perceived risk of the end of mankind in 100 years" as 1%. The UK Treasury use this estimate as a component of its discount rate (HM Treasury, 2018).
- *Life chances and survival rates.* Pearce and Ulph (1999) estimate life chances as the average probability of death for an average individual and estimate it at 1.3% for the UK. Fenichel et al. (2019) also calculate country-by-country mortality risks.

- *Intergenerational equity.* In the view of Ramsey (1928) and others from the Utilitarian tradition, society should not be fundamentally impatient based on the fair treatment of future generations. The Stern Review (Stern, 2007) also held this view in the analysis of climate change. Yet Arrow (1999) points out that these moral values are fine up until the point at which they imply too much cost to the present generation such as burdensome savings rates.

II.2.b. The Wealth Effect

- *Economic growth.* General economic growth, representing consumption growth, can be calibrated in several ways. Decisions to make regarding method include (i) whether to use forward or backwards-looking (historical) estimates; (ii) which regions of the world to consider; and (iii) how to aggregate various national estimates. We discuss some of these aggregation issues further below. However, using World Bank Data, we estimate real global per-capita GDP growth of around 1.9% over the interval 1960-2016. Experts responding to the Drupp et al. (2018) survey forecast long-run growth in per-capita consumption with a mean (median) of 1.7% (1.6%).
- *EMU.* Groom and Maddison (2019) estimate the elasticity of marginal utility, which determines the strength of our desire to transfer wealth from richer to poorer generations, using a number of different approaches. They find, irrespective of the approach taken, an estimate of EMU close to a value of 1.5. Estimates by others range from 0.5 (Tol, 2010) to 4 (Gollier, 2012). On ethical grounds, Dasgupta (2008) instead recommends a value of 2 as reasonable for the EMU. Gollier (2012) shares Dasgupta's viewpoint, and there is something of a consensus that the value should lie between 1 and 2 for social discounting. The mean (median) response in the Drupp et al. (2018) survey was 1.35 (1.0).

II.2.c. A Calibration of the Simple Ramsey Rule

27. Combining these findings together suggests that a time value of 0.5%, estimated future real per-capita economic growth of 2% per annum, and an estimate of the EMU of 1.5 appears to be reasonable. The latter two multiplied together give the wealth effect of 3%. When this is added to the time effect, it gives a Simple Ramsey Rule estimated SDR of 3.5%. This normative value is much higher than current yields on TIPS and therefore the estimated SDR is sensitive to whether the ISA wishes to take a markets-based or normative approach to social discounting.

II.3. Extensions to the Simple Ramsey Rule

28. While the Simple Ramsey Rule has played a central role in determining social discount rates in a number of jurisdictions, it is also a simplified model and there are a range of potential extensions to it that the ISA might wish to consider. Three are of particular relevance:

II.3.a. The Extended Ramsey Rule

29. In the discussions so far, it has been assumed that the future is known with certainty. This is clearly not the case in practice. There are two key sources of uncertainty and it is necessary to be clear about this distinction. The first, which is the focus of attention in the Extended Ramsey Rule, is that macro-economic growth cannot be forecast with perfect knowledge. We do not know for sure how much richer or poorer future societies will be than today. The second, which is considered in Part III, is that the contractual payments income stream is also uncertain and this may require the ISA to use a risk-adjusted rather than risk-free SDR. In this sub-section, though, the continued assumption is that the income stream that the ISA is discounting is known with certainty.

30. Uncertainty about future economic growth reduces the SDR through something known as a "prudence effect". The intuition is that if future consumption is uncertain, then we want to save a little extra or plan to receive more in the future just in case consumption growth is lower than we expect. Equivalently, an additional unit of (expected) future consumption becomes more valuable because it might help us out in an economic downturn. The size of the prudence effect depends both on the curvature of the welfare function (the EMU) and the magnitude of our uncertainty about future growth.

31. While it is generally accepted that this prudence effect lowers the theoretical SDR, in practice the magnitude of the effect is generally estimated to be small in developed economies since consumption growth is not very volatile. We have reduced our Simple Ramsey Rule estimate of the SDR by 0.1% to account for this prudence effect, reducing it from 3.5% to 3.4%. Barro (2009), though, suggests that this adjustment, even for developed economies, may be too low. This is not because of general year-to-year volatility but instead because of rare but severe depressions; for example, the 30% loss in GDP associated with the Great Depression of the 1930s, and the 10-15% loss related to the Financial Crisis of 2007. The economic impact of the current Covid-19 pandemic seems likely to offer another example of a severe depression. Even for a risk-free income stream, Barro (2009) shows that concerns over large economic losses can reduce the risk-free SDR by around 1%.

II.3.b. Internationalising the Extended Ramsey Rule

32. There are issues with the ethical approach as described above when we move to an international context. One is that much of the literature on both the ethical and markets-based approaches focus on European States and the United States, the latter not being an ISA member. Another is that most applications of the Ramsey Rule occur at the national level, not internationally. The implication is that estimates do not account for international effects such as the sharing of risk across many States. It also means that estimates do not generally account for inequality aversion at the international scale. If the ISA is primarily interested in a global discount rate, then the volatility of growth between countries is likely to be a more appropriate measure. This will, in principle, lead to a significant global prudence effect and a lower global SDR.

33. Because of stabilisation policies, developing countries often have periods of low growth volatility, yet they also experience long periods of volatile growth at other times. Gollier (2011) shows that for many developing countries, the volatility of growth is much higher than for developed countries and so the prudence effect can cause a significant adjustment to the SDR.

34. Gollier (2011) estimates the global SDR under three different assumptions concerning international risk sharing: one with efficient risk sharing and two with imperfect risk sharing (one population-weighted). The SDR is broken down into the wealth effect (Gollier assumes that the time effect is 0%) and a prudence effect. Given the different assumptions, the global SDR that takes into account growth risk and prudence lies between 0.7%-2.5% compared to the Extended Ramsey Rule estimate from the previous sub-section which was 3.4%. The global prudence effect is therefore a potentially important adjustment to the SDR.

35. Our recommendation is to take a conservative approach to the prudence adjustment and take the calculation that assumes efficient risk-sharing for the appropriate global prudence factor. This suggests a prudence adjustment of 1% leading to a risk-free ethical-based SDR of 2.5% based on World Bank data. This recommendation is lower than in the previous sub-section because of the higher prudence factor resulting from the international framework.

II.3.c. Growth-Inequality Adjustments to the Ramsey Rule

36. Under the Simple Ramsey Rule, economic growth is estimated at a global average per-capita level, based on a single representative agent who always consumes the average. The use of a representative agent in such circumstances comes from the assumption that the current distribution of income is optimal. Yet debates about inequality point to this assumption being rather heroic. The debate has included several analyses that focus on society's aversion to inequality and the welfare costs of it (Piketty, 2015; Stiglitz et al., 2010). There are concerns in society about both current income inequality (e.g. Stiglitz et al., 2010; ISA 2019, 2020) and inter-temporal inequality (e.g. Stern, 2007; Gollier, 2012). When it comes to evaluating social welfare, particularly at the international scale, both dimensions are important.

37. In the context of social discounting, Emmerling et al. (2017) show that, relaxing the typical representative agent approach and incorporating both intra- and inter-temporal inequality aversion, the optimal SDR changes. This can result in an increase (decrease) in the SDR compared to the Simple Ramsey Rule depending on whether median household consumption growth is above (below) mean growth. Intuitively, this accounts for the fact that the SDR should be higher (lower) when inequality is decreasing (increasing). This has parallels with the prudence effect in the Extended Ramsey Rule: the greater the potential for bad outcomes, the lower the SDR. Here, though, it is bad outcomes at the individual household level rather than across the economy.

38. We note ISA reports in 2019 and 2020 where measures of inequality in the distributions of pay-outs are compared on the Member State scale. Here we apply the Emmerling et al. approach internationally – across different countries, based on World Bank Data. Between 1985 and 2000, per-capita growth was outstripped by growth in the median country's income implying a pattern of inequality-reducing growth across countries. But post-2000 the opposite occurs: mean per-capita growth has outstripped growth in the median state and so growth has been inequality-increasing. This inequality-increasing growth has been due to substantial income growth in wealthy countries, coupled with an almost unchanged modal level of income. The impact on the recommended SDR is that it decreases.

39. Unfortunately, the analysis shows that the correction to the SDR for this growth-inequality adjustment should be between -2.4% and +1.2% depending on the timeframe over which the inequality trend correction is calculated. The decision of whether to include such a correction, its scale, and even direction, then, depends on the sort of inequality trends that ISA Member States expect to occur in coming decades.

Part III: Revenue Risk and the Discount Rate

40. In sub-sections II.3.a-b. on the Extended Ramsey Rule, we described the role that uncertainty over future macro-economic growth plays in determining the SDR. But this is not the only source of uncertainty that affects the appropriate discount rate. It is also necessary to account for the fact that the future income stream from contractual payments is itself unknown. This will lead to a risk-adjusted, rather than risk-free, discount rate.

III.1. Markets-Based Estimates of Risk Premiums

41. As a generality, under a markets-based approach, the greater the risk of the income stream, the lower the amount of money that can be borrowed today using this as collateral. Lenders will require a higher interest rate to compensate for the lending risk they bear and therefore the present value will be lower. Nordhaus (2007), taking this approach, suggests an SDR of 6%. When

implementing market-based discount rates, the Office of Management and Budget (OMB) in the United States has a 'default' real discount rate of 7% (OMB, 2003). They describe this as "an estimate of the average before-tax rate of return to private capital in the U.S. economy" (ibid., p. 33). However, using such rates would only be appropriate for the ISA if the uncertainty in benefits from contractual payments has similar characteristics to the general risk to private investment in the US. There is no reason to believe that this will be the case.

42. Theoretically, within a market-based approach, the risk-adjustment to the discount rate (or "risk premium") will depend on two things: (i) the "beta", or systematic risk, of the income stream, multiplied by (ii) an estimate of how much additional return investors require for each unit of beta risk. This latter term is known as the "equity premium" and we estimated a value of 5% for this (see, for example, Avdis and Wachter, 2017; Graham and Harvey, 2018; Fernandez et al., 2019) based on developed economies.

43. "Beta" depends on two things: (i) the overall uncertainty about the income stream itself, and (ii) how correlated the income stream is with broader financial market movements. Essentially, investors are concerned about the incremental risk that new projects contribute to their existing portfolio of assets. If the new income stream "adds" to the overall portfolio risk – as in the case of pro-cyclical projects – then the risk premium for the project is positive and the SDR increases. Pro-cyclicality is the situation in most cases. Occasionally, however, a new project lowers overall portfolio risk – when the project is counter-cyclical. In these situations, the appropriate risk premium is negative because of the hedging properties that the new project adds to the overall portfolio and the SDR is reduced. It is the *correlation* between the income stream of the contractual payments and that of the existing portfolio of assets that determines the risk premium that the ISA should apply within this markets-based approach.

44. In our earlier report (Freeman and Groom, 2020) we estimated the beta of the future income stream using metals prices and input this into the Capital Asset Pricing Model (CAPM: the workhorse model for this type of problem) to estimate an appropriate markets-based risk premium for the ISA's SDR. Although metals prices are volatile, they are not highly pro-cyclical. This means that their "beta" is quite low, and therefore the risk adjustment to the SDR for the ISA also appears to be low. We estimated a risk premium of 1% for the ISA using this markets-based approach. Taking a more international approach, and using equity premiums for developed markets, would likely lead to a larger estimate.

III.2. Normative Estimates of Risk Premiums

45. The normative approach to estimating risk premiums is, in many ways, similar to the markets-based approach. In this case, though, rather than estimating systematic risk ("beta") against market assets, it is instead estimated against all assets that will deliver a future stream of consumption. These include, for example, labour income derived from human capital. The workhorse model in this case, which is widely employed for estimating SDRs, is known as the Consumption CAPM (CCAPM). The risk premium is again determined by multiplying this beta by an estimate of how much additional return investors require for each unit of (consumption) beta risk. This latter term is calculated by multiplying the curvature of the social welfare function (the EMU) by the variance of aggregate consumption growth. But because average global aggregate consumption growth is very smooth, the market price of risk is also exceptionally low compared to observed returns in financial market. This is known in the literature as the "Equity Premium Puzzle" (Mehra and Prescott, 1985). Therefore, consumption-based approaches to estimating the risk premium consistently come out with very low estimates; often so low that they are ignored in practice by those setting SDRs for policy purposes. Using metals price data, we estimate an appropriate consumption based risk premium of only about 0.1% for the

ISA. Even based on consumption growth in developing economies, the normative estimate of the risk premium is likely to remain low.

46. Our view is that a market-based risk premium as given from the CAPM may be too large for an organisation such as the ISA. On the other hand, the Equity Premium Puzzle literature suggests the normative CCAPM risk premiums may be too low. Therefore, we recommend adding a weighted risk premium to account for systematic risk in metals prices.

Part IV: Evidence from Surveys and Practice

47. Up to this point, we have assumed that the ISA will wish to calculate an SDR from first principles using either a markets-based positive approach or an explicitly ethics-based normative approach. The ISA may, however, prefer to look at recommendations from academic experts or the practice of other intergovernmental bodies and public bodies.

IV.1. Survey Data

48. Two central papers have reported survey responses from academic experts on the appropriate risk-free social discount rate (with no consideration given to risk premiums): Weitzman (2001) and Drupp et al. (2018).

49. Weitzman (2001) received responses from over 2,000 PhD-level economists. His question was explicitly about climate change but is otherwise relevant to the issue that the ISA is considering. The mean, median, and modal SDR responses from the Weitzman survey were approximately 4%, 3%, and 2%, respectively. However, these measures of the average hide extensive spread in expert opinion. The lowest and highest responses were -3% and +27%, and a standard deviation of 3% suggests zero, negative, and much higher values are possible. Restricting the responses to Weitzman's "blue-ribbon panel" of the 50 most outstanding economic experts at the time did not improve the precision of the estimate – the mean was 4% with a standard deviation of over 3%. This heterogeneity naturally leads to a question of why experts disagree so strongly over the matter.

50. In response, Drupp et al. (2018) ran a survey with framing highly influenced by Weitzman (2001). Instead of sampling general PhD-level economists, Drupp et al. had a narrower definition of experts – sampling those whose publication record indicated genuine expertise in SDRs. While this led to a smaller sample of 185 quantitative responses, it enabled the researchers to ask more detailed questions including on the time effect, economic growth, the curvature of the welfare function (the EMU) and forecasts of future market interest rates; we have summarised these findings in previous sections. By asking about these matters, they could explore each expert's opinion to understand the causes of disagreement.

51. The mean, median, and modal social discount rates that Drupp et al. received were 2.3%, 2.0%, and 2.0%, respectively. The mean and median are somewhat below the values reported by Weitzman. This difference potentially reflects a change in opinion over time or the different compositions of experts sampled. The standard deviation and range around the SDR estimate, while large, are also smaller than in Weitzman (2001).

52. We believe that Drupp et al. (2018) provides the most appropriate survey data for the ISA to use when determining its SDR. Their recommended rate is based on the median value of 2%, but the ISA may wish to use a slightly higher value because Drupp et al. were considering horizons of a century

or more and there is evidence that very long-term discount rates should be lower than at medium horizons (e.g., Cropper et al., 2014). On balance, this survey evidence points to a recommended range of 2% to 2.5% for the ISA.

IV.2. Social Discount Rates in Practice

53. A number of governments and other public-sector bodies already give detailed recommendations on the appropriate SDRs that should be used within their contexts. We summarise a range of governmental guidance in Table 1. This table demonstrates that different agencies have taken very different approaches to a number of the issues that we have discussed above, again showing that there is no objectively correct way for the ISA to set its discount rate. Despite this, the rate that we recommend for the ISA of 3.75% sits towards the centre of the range of values that are used across OECD countries.

Country	***Risk-free discount rate (%)***	***Rationale***	***Risk premium (%)***	***Overall discount rate (%) (short to medium term)***	***Long-term discount rate***
United Kingdom	3.5%	Normative approach. Growth risk not incorporated.	0%, although 3.5% contains 1% for "catastrophic risk"	For all projects and regulatory analysis: 3.5%	Declines to 1% after 300 years
United States	3%, with sensitivity up to 7% for cost-benefit analysis	3% = risk-free normative value 7% = average corporate returns	7% is a risky rate of return, but no project-specific risk premia,	Depending on the source of funding, projects and regulatory analysis: 3 - 7%	OMB (2003) recommends a lower rate for 'intergenerational' projects, for USEPA (2010) recommends 2.5%.
United States	2% for cost-effectiveness analysis	Normative approach	None	2%	No guidance
France	2.5%	See Quinet (2013). Normative risk-free rate of return.	$\beta * 2\%$ 2% comes from the estimated risk of "deep recession", see Barro (2006).	For risky projects: $2.5\% + \beta * 2\%$	Risk-free rate: declining to 1.5% for a 75-year horizon. Risky premium: 2% for $\beta = 1$ rising to 3.5% after 75 years.
Norway	2%	Markets-based approach	1% equity premium, β=1, fixed for all projects	Risky projects and regulatory analysis: 3%	Risk-free rate declining to 1% after 100 years.
Netherlands	0%	Markets-based approach	3% systematic risk premium, fixed for all projects.	All projects and regulatory analysis: 3%	0% and fixed systematic risk premium.

Table 1: Country Experience with Social Discounting: Government Guidance on the SDR in selected OECD countries. Source: OECD (2018).

54. Entirely different from the SDR approaches discussed so far, the World Bank uses a rate of 10% to 12% in project appraisal. These rates are substantially out of line with other international practices that we are aware of. This rate is a "rule-of-thumb", with allowance for discretion by project managers, and the precise calculation that the World Bank undertakes to arrive at this rate is unclear. We know, though, that it takes into account several issues associated with the projects that it funds including (World Bank, 1998):

- Rationing Device: the World Bank has a fixed budget and so from the perspective of its overall portfolio of projects, any new project must have a rate of return at least as high as the marginal project to increase overall returns in present value terms;
- Cost of Capital: the borrowing costs for the World Bank and sometimes the countries in question depend on the task manager's discretion;
- Country-level risk premium: associated systematic project risks and political risks are likely captured in a generalised, non-country specific, risk premium. Given the nature of most World Bank-funded projects – large infrastructure projects with pro-cyclical benefits – this premium could be substantial;
- Consumption rates of interest: savings rates for the population.

55. It does not, however, appear that the determinants of the World Bank's choice of a discount rate are relevant to the case at hand as the ISA is not necessarily interested in using the SDR as a rationing device. Unless the ISA is considering borrowing outside the US based on the resource rents that it receives, the cost of capital in developing countries is probably not relevant either. Our advice is to ignore the World Bank discount rate. The SDR should instead be organised around the circumstances of the ISA – the flow of benefits it receives and the countries that will be recipients of these benefits. In terms of World Bank guidelines, this would also fall within a 'justifiable departure' from their rule of thumb.

Conclusion

56. This study shows that there are many different, defensible approaches to social discounting. Based on the options available, policymakers generally decide on the appropriate method for their circumstances. In practice this means that different countries and organisations draw upon different aspects of the theoretical literature and rationales for social discounting. Often the approach taken by each country is due to historical reasons (Groom and Hepburn, 2017). When it comes to global issues where the intergenerational dimension is important, ethical issues are more frequently included in deciding on an SDR. Examples include climate change mitigation and biodiversity conservation. In particular, where international distribution and development issues are of interest, issues of fairness, inequality aversion, and international risk become important.

57. Ultimately, the SDR should be chosen based on the institutional and other circumstances of the ISA. These should include the specific objectives of the organisation and the constraints it faces in terms of borrowing, redistribution, and intergenerational goals. At present, our weighted average approach is the obvious starting point for a broader discussion of the ISA's circumstances and objectives.

58. Our advice to the ISA stems from the observation that the circumstances of the ISA seem to straddle issues of finance, fairness, redistribution, and intergenerational equity. How ISA Member States prioritise these aspects should result in a weighted average of different approaches emphasising each aspect. We have proposed such a weighted average and emphasized the debate between market-based approaches versus ethical approaches in deciding on appropriate weights. A mixed approach is consistent with the advice given by many experts as reported by Drupp et al. (2018).

59. We report the underlying rates in Table 2 that are used to arrive at a weighted average. There is no impartial principle that tells us how to combine these rates into a summary value. However, we believe that an SDR of 3.75% appropriately balances the strengths and weaknesses of each approach. If the ISA opts to weight these sources and their underlying emphases differently, this table would be informative during the process.

	Risk-free rate	*Weighting*	*Risk premium*	*Weighting*	*Total SDR*
Ethical	3.4	30%	0.1	30%	
Market	1.25	15%	1	30%	
Survey	2.25	20%	n/a	0%	
Policy	2.25	20%	2.25	30%	
International	2.5	15%	2.75	10%	
Total		2.48		1.28	3.76

Table 2. Combining different discounting frameworks into a single real SDR for the ISA.

60. We round our recommended rate to 3.75% when reaching our final recommendation to the ISA. Broadly, this consists of a real risk-free discount rate of 2.5% and risk premium of 1.25% reflecting the relatively low systematic risk of metals prices. Because of this low risk, the recommended rate falls below, but close to, the mean and median values of approximately 4.5% that are applied in many countries.[4] One note of caution is that, because we are using prices and not total contractual payment income, the risk premiums we estimate may not accurately represent the risks faced.

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