Considering future generations — sustainability in theory and practice

Christine Carmody[1]

The concept of sustainability has become increasingly popular in international and domestic debate on social progress; it is also a key dimension of the Treasury wellbeing framework. However, confusion surrounds the concept, its measurement and its application in decision-making. Defined as maintaining or increasing wellbeing between generations, sustainability requires a focus on aggregate stocks of capital. Key features of the sustainability problem are uncertainty about the future, thresholds and substitutability between capital stocks. It is these issues, rather than theoretical paradigms, that are of practical importance to decision-makers.

1 The author is from Macroeconomic Group, the Australian Treasury. This article has benefited from comments and suggestions provided by James Kelly, Simon Nash, Richard Parkhouse, Brant Pridmore, Spiro Premetis, Duncan Spender, Bruce Taplin, and Angela Woo. The views in this article are those of the author and not necessarily those of the Australian Treasury.

Introduction

> 'Because we can expect future generations to be richer than we are, no matter what we do about resources, asking us to refrain from using resources now so that future generations can have them later is like asking the poor to make gifts to the rich.'
>
> Julian Simon

An assumption that future generations will be always better off has permeated economic thinking since the work of Adam Smith and David Hume. It has been used to justify arguments that society need only worry about today because the future will take care of itself. If we begin to consider whether we owe the future something, then, as Abraham Lincoln has said, 'posterity has done nothing for us'.

Such arguments hold only if actions today do not harm future generations; however, this cannot be known with certainty. It is possible that future generations can be made worse off by inheriting fewer resources from the current generation than they need to match our standard of living (Anand and Sen 2000).

Treasury's mission is to improve the wellbeing of the Australian people, and the Treasury wellbeing framework identifies the sustainability of the opportunities available to Australians over time as relevant to that objective (Gorecki and Kelly 2012). In recent years, calls for inclusion of sustainability principles within policy-making and alternatives to Gross Domestic Product (GDP) as a measure of social progress have also increased. If there are reasons to consider future generations, how should this be conceptualised, measured and implemented?

A large literature on intergenerational equity and sustainable development has sought to answer these questions, with significant contributions from the fields of economics, philosophy and environmental science. In economics, it has been part of the economic growth literature since the work of Frank Ramsey (Ramsey 1928).

This literature continues to influence the international and domestic policy dialogue, including the G20 policy agenda;[2] the recent Rio+20 United Nations Conference on Sustainable Development; the work of the Organisation for Economic Cooperation and Development, World Bank and International Monetary Fund; international action on climate change; and the Australian Government's Intergenerational Reports and Measuring Sustainability program. It is linked to ongoing efforts to improve measures

2 The Leaders' Statement from the 2009 Pittsburgh G-20 meeting includes the quote: 'As we commit to implement a new, sustainable growth model, we should encourage work on measurement methods so as to better take into account the social and environmental dimensions of economic development'.

of social progress, examples of which include the Australian Bureau of Statistics Measures of Australia's Progress and the United Nations-adopted System of Environmental-Economic Accounts.[3] It underpins cost-benefit analysis and discounting that are widely used to assess the future impacts of current actions. The related theories of Hotelling and Hartwick are also standard elements of many natural resource management textbooks and are embedded in efforts to measure and apply sustainability concepts.

However, techniques and policy prescriptions derived from this literature are based on particular theoretical models of economic development whose underlying assumptions greatly simplify reality. Applying them without appreciating the consequences of these assumptions — or being aware of the range of alternatives — can lead to false confidence that we understand and are able to manage the impacts of our actions on future generations.

This paper distils the economics literature on sustainability and intergenerational equity concepts and offers insights relevant to their practical application in policy-making. After reviewing the assumption that future generations will always be better off, it offers a simple but broad definition of sustainability that addresses confusion about the concept. Different theoretical constructs for sustainability are then briefly presented and their assumptions contrasted. The consequences of these assumptions for sustainability measurement are explored, revealing complex implications for discounting. The fact that information about the future is lacking is a common theme throughout, and underpins concluding suggestions for improving decision-making in the face of uncertainty.

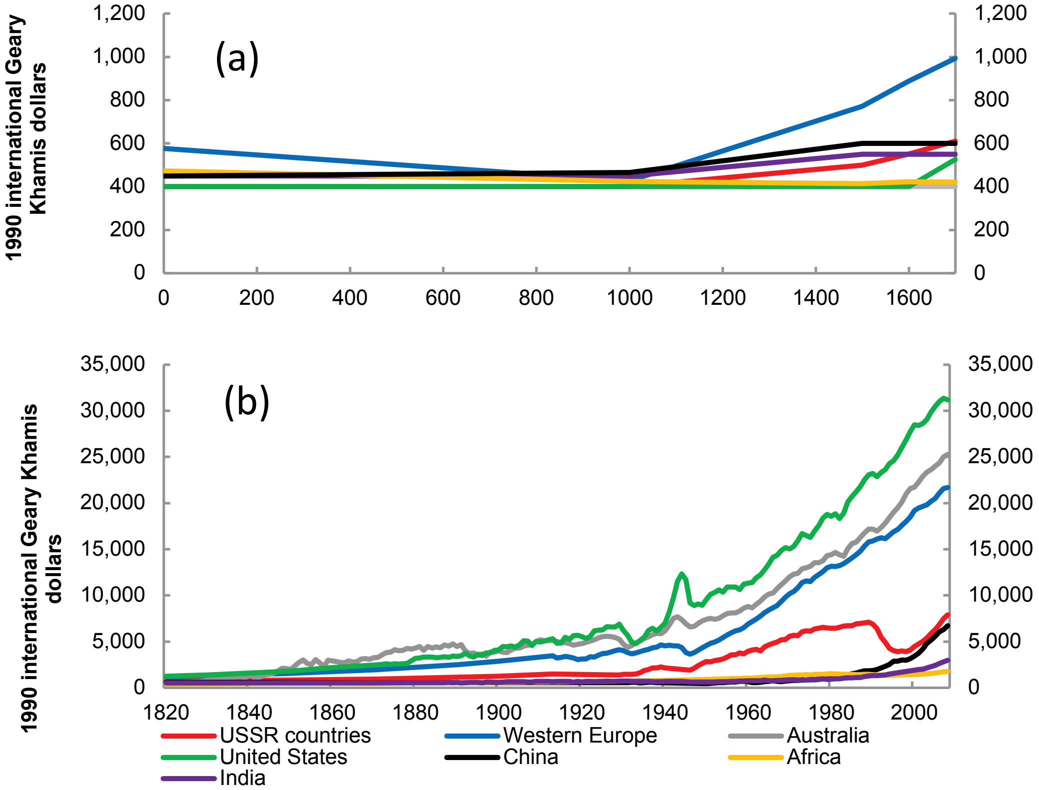
Will future generations be better off?

Historical trends in wellbeing and projections about the future state of the world can inform a sense of whether future generations will be better off, notwithstanding the significant data gaps associated with each.

Angus Maddison attempted to infer historical trends in wellbeing by drawing disparate and patchy data on the lives of past generations into a measure of GDP per capita, as shown in Chart 1. While GDP is an incomplete measure of wellbeing in that, among other things, it inadequately measures contributions from the environmental and social spheres, it can nevertheless provide some insight.

3 See for example Stiglitz, Sen and Fitoussi (2009).

Chart 1. Estimated country and region GDP per capita, (a) 1-1700 AD, and (b) 1820-2008 AD



Source: Maddison (2010).

GDP per capita appears to have remained at relatively low levels for many centuries, below even levels in the poorest African countries today, before growing rapidly following the industrial revolution. In the first one and a half millennia AD, life was short and marked by disease and famines. Average life expectancy at birth was 24 years in Roman Egypt during the first two centuries AD, and also in Medieval England (Maddison 2001), compared with 80 – 90 years in developed economies today (CIA 2012).

During the World Wars and Great Depression of the 20th Century, the wellbeing of affected countries declined. However, these events did not last for a generation and wellbeing as measured by GDP per capita resumed its growth during the periods of reconstruction that followed. Since the end of the Second World War, average world GDP per capita has more than tripled, driven by strong growth in developed economies and, more recently, Asia (Maddison 2010). Living standards in developing countries remain much lower than those of the developed world, but they are still increasing. Higher incomes have been accompanied by better health, education, longevity, environmental amenity (particularly in advanced economies), and reductions in working hours and absolute poverty. Average world GDP per capita is currently around eleven times that of 1820, while the world population has grown nearly sixfold.

While the Maddison dataset suggests increasing wellbeing over time, there have been periods where the wellbeing of successor generations has decreased. For example, wellbeing in Europe declined between the first and tenth centuries, following the fall of the Western Roman Empire. As the Belgian historian Henri Pirenne described the region covering parts of today's France and Germany during the ninth century:

> 'If we consider that in the Carolingian epoch, the minting of gold had ceased, the lending of money at interest was prohibited, there was no longer a class of professional merchants, that Oriental products (papyrus, spices and silk) were no longer imported, that the circulation of money was reduced to a minimum, that laymen could neither read or write, that taxes were no longer organised, and that the towns were merely fortresses, we can say without hesitation that we are confronted by a civilisation that had retrogressed to the purely agricultural stage; which no longer needed commerce, credit and regular exchange for the maintenance of the social fabric' (Maddison 2001).

So, while recent history supports optimism about future generations' wellbeing, it does not provide certainty.

Looking forward, it cannot simply be taken for granted that the current growth in living standards can be maintained for future generations. The current economic turmoil in Europe risks creating persistent negative impacts on the wellbeing of some European countries that could be felt on a generational timescale. Productivity growth in developed economies has also been undergoing a decline since the 1970s; potentially reducing the momentum that has driven increasing living standards in recent times (TED 2012). For the first time in history, we are affecting our natural environment on a global scale, and the consequences of climate change are another potential source of long-lived declines in wellbeing. Thus, we cannot be sure that future generations will be better off.

Sustainability defined

In the broadest sense, sustainability refers to the problem of allocating scarce resources over the very long term. It is linked, but not identical, to the concept of intergenerational equity, which requires some kind of 'fairness' in such allocations between generations.[4] The Brundtland Report (UNWCED 1987) established a conceptual basis for sustainable development and produced what has become the most widely recognised definition of it as:

> 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

However, beyond this basic idea, there is little common understanding and much confusion of what sustainability means and what it requires in practice, including how it should be measured and how to develop policies consistent with the concept. By the late 1990s, John Pezzey felt that sustainability definitions could readily be counted in the thousands (Pezzey 1997). Such definitions range from 'environmental protection', to 'fiscal sustainability' to 'sustainable economic growth'. Sudhir Anand and Amartya Sen note that while 'economic sustainability is often seen as a matter of intergenerational equity... the specification of what is to be sustained is not always straightforward' (Anand and Sen 2000).

A stock-based approach to sustainability

Such confusion can be resolved by applying the broadest concept of progress, namely wellbeing. This results in an overarching definition that is consistent with the literature and encompasses the range of narrower sustainability definitions already in circulation.

In this view, current *wellbeing*, seen by Treasury as reflecting a person's substantive freedom to lead a life they have reason to value, is supported by economic resources, such as income, and also non-economic aspects of peoples' lives (such as what they do and what they can do, how they feel, and the natural environment they live in). *Sustainability* refers to maintaining or increasing this wellbeing across generations. It depends on whether stocks of capital that matter for our lives are passed on to future generations, including:

- economic and financial stocks — the value of fixed assets such as plant and equipment and financial assets and liabilities;
- human stocks — the productive wealth embodied in our labour, skills and knowledge and in an individual's health;
- environmental stocks — our natural resources and the eco-systems which include water, productive soil, forest cover, the atmosphere, minerals, ores and fossil

4 This can be interpreted as 'just desserts', as discussed Appendix Two of Gorecki and Kelly (2012).

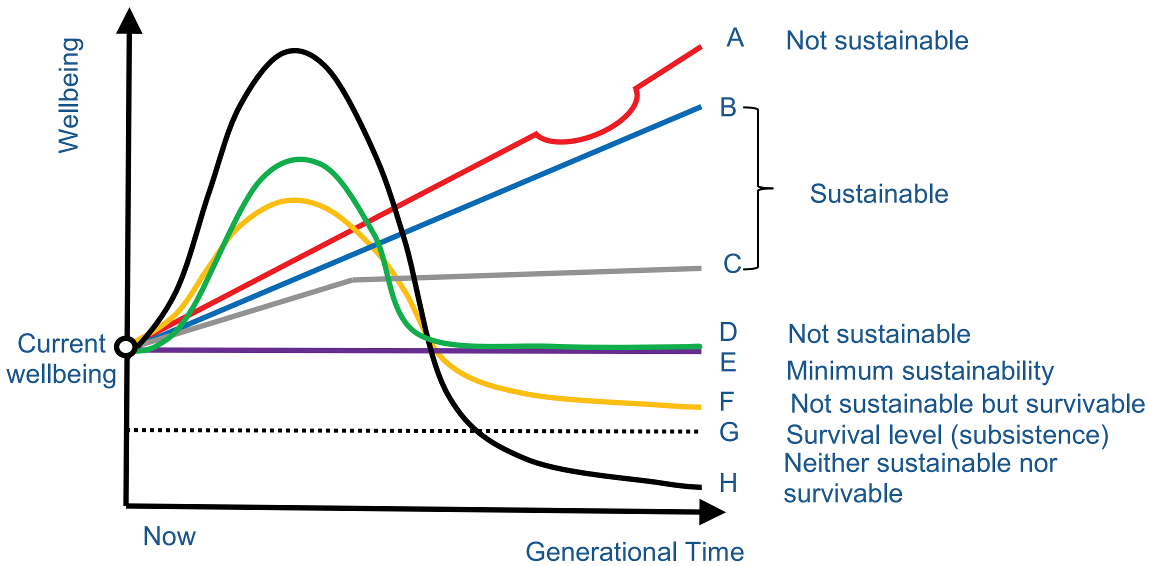
fuels. In other words, all the natural resources that support life and other services to society; and

- social stocks — which includes factors such as openness and competitiveness of the economy, institutional arrangements, secure property rights, honesty, interpersonal networks and sense of community, as well as individual rights and freedoms (Parkinson 2011).

Thus the wellbeing of future generations depends on the flow derived from stocks passed on to them.

Some of the confusion surrounding sustainability arises from efforts to combine current wellbeing, environmental and sustainability concepts, such as in green growth and green GDP measures.[5] For example, the green GDP concept falls short of addressing sustainability as defined in this paper as it only focuses on economic and environmental flows, ignoring human and social aspects and whether wellbeing can be maintained over time though an assessment of aggregate stocks.

Chart 2. The relationship between possible economic paths, sustainability and intergenerational equity



Source: After Pezzey (1992).

5 Green growth refers to economic growth that emphasises the use of natural resources in an 'environmentally sustainable' manner. The green gross domestic product (green GDP) charges GDP for depletion of or damage to environmental resources, as valued in monetary terms.

A definition of sustainability as maintaining wellbeing across generations does not always coincide with *intergenerational equity*, which is commonly interpreted as meaning that resources are allocated across generations so that the wellbeing of each is equal. Different development paths can therefore be described as survivable, sustainable or equitable, as shown in Chart 2. A path of constant wellbeing defines the minimum sustainable path E, which is also equitable. This may be different to the subsistence level G, another equitable path below which there are insufficient resources to survive. Development paths with rising wellbeing across generations, such as paths B or C, would be classed as sustainable but not strictly equitable.

Sustainable paths with the highest wellbeing overall are preferred (for example path B). Paths A, D, F and H are neither equitable nor sustainable, because wellbeing is neither constant nor rising continuously.

Substitutability between stocks has important implications for sustainability

In seeking to improve and maintain wellbeing, trade-offs may be necessary between or within environmental, social, human and economic stocks. Accordingly, the substitutability of individual stocks must be considered in relation to the effects on future generations, which leads to different policy prescriptions according to two 'types' of sustainability. Weak sustainability at its most basic applies when all the different forms of capital are completely substitutable. In this case, wellbeing can increase or be maintained so long as depletion of one type of capital is at least offset by increases in the other types. By contrast, strong sustainability applies when there is no substitutability between the different types of capital. This implies that each form of capital must at least be maintained to ensure that future wellbeing does not decrease. Since we live in a world where some stocks are substitutable and others are not, the relevant policy prescription lies somewhere between these two extremes.

Although relevant to all stocks, substitutability has been linked in particular to environmental stocks as an argument for strong sustainability. Environmental stocks (such as plants and animals) are argued to have limited substitutability — because their loss is irreversible or they are critical for human survival — requiring that they are preserved in their entirety. However, wellbeing could conceivably be maintained or even increase following irreversible loss of some stocks, or parts of stocks, provided the accompanying benefits of a trade-off at least offset the environmental losses.[6] The question of substitutability is better characterised as whether a trade-off will be made that involves loss of or damage to individual stocks. This depends on the relative

6 Natural extinction rates must also be considered in relation to some environmental stocks, such that their management may not always be within human control, regardless of which sustainability prescription (strong, weak or in-between) is applied.

contribution to current and future wellbeing of the stocks in question, the quantities involved and whether the loss is irreversible.[7]

A stock or part of a stock is not substitutable when the negative impacts on wellbeing from its irreversible loss cannot be compensated for. Appropriate quantities of environmental stocks needed to sustain human life such as a supply of breathable air, drinkable water and conditions for growing food (such as soil quality and climate) provide a critical contribution to wellbeing. Certain amounts of trust and freedom (social stocks), and minimum amounts of health and knowledge (human stocks), are also critical for human survival, and once lost, cannot be readily regained. There is a strong justification for ongoing protection of appropriate quantities of such stocks.

Determining these quantities depends on threshold effects. For example, an ecosystem may be reduced to a certain size and still remain 'healthy', below which key organisms will have insufficient resources to survive. At this size, the stock is vulnerable to unforeseen events (such as natural disaster) reducing it below the threshold. Similarly, once trust is reduced below some critical point, society would cease to function. If a stock is not substitutable beyond some threshold, the appropriate risk-management response is to maintain the stock above that threshold, with a sufficient buffer to minimise vulnerability.

Damage to some stocks can be reversible and, depending on the costs and times involved, may increase the likelihood that a trade-off involving damage would be chosen. For example, loss of habitat or pollution of a waterway could be rehabilitated over time.

Maintaining or improving wellbeing over generations should therefore involve applying weak sustainability where possible, and strong sustainability for stocks, or parts of stocks, that are not substitutable. As argued by Anand and Sen 'Preserving productive capacity intact is not…an obligation to leave the world as we found it in every detail [strong sustainability]. What needs to be conserved are the opportunities of future generations to lead worthwhile lives' (Anand and Sen 2000). Similarly, Robert Solow felt that 'recognition of the fact of substitutability or fungibility converts a matter of 'simple justice' into a complicated question of resource allocation' (Solow 1986).

To make effective trade-offs, information on the relative contributions to wellbeing of alternate courses of action is needed. However, this information is often not available or incomplete. Because future generations' preferences and technology are unknown, we are unable to determine with certainty whether a stock, or parts of a stock, will be

7 It is also worth noting that the increasing scarcity of any stock will increase the marginal costs of its loss (assuming it is measured).

substitutable. Current experience regarding fundamental determinants of wellbeing can serve as a guide to stocks that are likely to not be substitutable below a certain point — for example basic freedoms and education, supplies of breathable air, drinkable water and food. Beyond this, identification of thresholds and reversibility of damage will be important in improving our ability to make such judgements in the face of uncertainty.

Theoretical approaches to sustainability

The main approach to intergenerational allocation of resources within economics was pioneered by Frank Ramsey in 1928, and defines economic growth as being 'optimal' when resources are allocated between generations to maximise the summed present value of utility (or wellbeing) of all generations, according to:

$$\int_0^\infty e^{-\rho t} u(c_t) dt, \tag{1}$$

where ρ is the rate of pure time preference and $u(c_t)$ is wellbeing as a function of consumption. Here consumption can include enjoying the existence of stocks without necessarily using them, for example freedom of speech or a national park. It is assumed that the wellbeing of a generation is the summed wellbeing of all the individuals in that generation.

It is natural to want to consider the wellbeing of different generations as having equal weight. However, adding the wellbeing of an infinitely long stream of different generations would result in an infinite sum. To make the optimisation tractable, the wellbeing of different generations is typically weighted by the discount factor $e^{-\rho t}$.

Under appropriate conditions, the optimising approach selects a 'golden rule' path in which output and consumption per capita and stocks are at maximum feasible levels.[8] For a hypothetical economy with only reproducible stocks, such as plant and equipment, this typically results in consumption per capita increasing according to the rate of technological change. For hypothetical economies with only depletable stocks, such as mineral resources, no golden rule could exist because there is no reproducible capital, and the optimal path if it exists tends to result in declining consumption per capita.[9] The optimal path for economies with reproducible, depletable and naturally renewable resources (such as forests) depends on a number of factors such as the rates of population growth, technological change, natural resource extraction, natural resource renewal and discovery, and the degree of substitutability between the different types of resources.

8 Phelps (1961) described the golden rule as the growth path that gives the highest indefinitely maintainable level of consumption per head. This requires a balance between consumption and capital accumulation.

9 Assuming no discovery or recycling.

Because this approach (hereafter referred to as the Ramsey optimising approach) selects the greatest sum of wellbeing across generations, the wellbeing of one generation can be traded off against that of another, so long as the loss to some generations is outweighed by gains to other generations.

Optimal growth is not necessarily sustainable

However, Ramsey's requirement that the present value of all generations' wellbeing is maximised does not rule out unsustainable outcomes. Since the worst off generation is allowed to exist at any point in time, optimal growth can result in future generations being relatively worse off than current generations, as illustrated by paths D, F and H in Chart 2. Moreover, since the use of discounting results in the wellbeing of generations further into the future being given less and less weight, this approach has been argued to represent a 'dictatorship of the present'. Sustainability is not necessarily implied by optimality.

The 'maximin' approach

An alternative approach has evolved from John Rawls' *A Theory of Justice* (Rawls 1971), which argues that the fairest allocation of 'primary social goods' in a society can be identified using a 'veil of ignorance', where if an individual does not know what her allocation of primary social goods is, she will choose to maximise the position of the worst-off member of society.[10] This is also known as a 'maximin' principle.

Although Rawls did not explore this concept in relation to intergenerational questions, Kenneth Arrow (Arrow 1973), Robert Solow (Solow 1974) and many others have, arguing that under a similar veil of ignorance, an individual would choose to ensure that the welfare of the least well off generation was maximised. Here the implication is that the consumption of all but the worst-off generation should be reduced to benefit that generation; the optimisation is sensitive only to the wellbeing of the poorest generation. This approach will be pro-future if the future is relatively poor, and pro-present if the present is relatively poor. While inequality between generations is allowed under maximin as long as the wellbeing of the poorest generation is improved, this approach has been used to argue that the fairest outcome is when wellbeing (or consumption) of all generations is equal, but at the maximum feasible level, for example path E in Chart 2. Thus, the 'fairest maximin' approach is defined as an optimising approach with the added constraint that consumption is constant.

Solow showed that, for a hypothetical, fully substitutable economy with both renewable and depletable resources (and ignoring trade), achieving constant consumption requires that the total capital stock is maintained — in other words zero

10 Primary social goods are defined by Rawls as liberty, opportunity, income, wealth, and the bases of self-respect.

net saving — in cases where technology is constant, and negative net saving when technology is growing (Solow 1974). In the latter case, it is assumed that growing technology will create more capital in the future, such that future generations will be sufficiently compensated for a reduction in aggregate stocks today. However, this approach does have some undesirable properties, including that an initially poor economy would be locked into maintaining low levels of wellbeing.

Other approaches to considering future generations

Graciela Chichilnisky sought to generalise the Ramsey optimising approach so that neither current nor future generations are preferred, by maximising (Chichilnisky 1997):

$$\propto \int_0^\infty \Delta(t)u(c_t)dt + (1-\propto)\lim_{t\to\infty} u(c_t),\ 0 < \propto < 1. \quad (2)$$

The first term of Equation (2) represents Ramsey's approach and favours the selection of the maximum sum of the wellbeing across generations, weighted using a general discount factor $\Delta(t)$. The second term favours the path with the highest wellbeing level in distant periods. The two approaches are weighted through $\propto$, determining which approach dominates. Depending on the choice of $\propto$, economies that begin with low levels of wellbeing are not locked into them.

With a similar intent, sustainable discounted utilitarianism resolves intergenerational conflicts by imposing on Ramsey optimisation that the evaluation is insensitive to the interests of the present generation if the present is better off than the future. This approach trades off present and future consumption if and only if the present is worse off than the future, while it gives priority to the interests of future generations otherwise (Asheim and Mitra 2010).

Alternatively, the rank-discounted utilitarian approach gives priority to worse off future generations not only in terms of their absolute level of wellbeing but also their relative rank in wellbeing, by applying a negative discount rate. If the future is better off than the present, this criterion is the same as the Ramsey optimising approach, whereas if future generations are worse off, it calls for more protection of the future (Zuber and Asheim 2012).

While these approaches seek to weight different generations more equitably, all of them require knowledge about future generations' wellbeing to be implemented.

The Hartwick and Hotelling results appear to provide a prescription for sustainability

Shortly after the first oil shock in 1973, John Hartwick sought the fairest maximin outcome for a hypothetical economy with one perfectly non-renewable and one perfectly renewable resource, assuming constant population and no technological progress (Hartwick 1977). He showed that, if the competitive rents from consuming the non-renewable resource are invested into the reproducible resource, constant consumption can be maintained. The competitive rents are given by Hotelling's result that the shadow value of the resource rises at a rate equal to the current marginal product of reproducible capital in a perfectly efficient economy (Hotelling 1931). Thus, Hartwick showed that accumulation of reproducible capital through investment of the Hotelling rents exactly offsets the (efficient) depletion of the exhaustible resource.

However, critics of Hotelling's rule have pointed out that observed resource prices do not move along a smooth price path, rising with the interest rate. This can be attributed to several factors, such as producers continually adjusting expectations regarding present and future demand and supply conditions, and imperfect competition.

Further, because markets do not fully reflect the needs of future generations and the technologies available to them, Hartwick's rule does not provide certainty that our actions today are sustainable (see for example Asheim, Buchholz and Withagen 2003). Determining whether short-run behaviour is compatible with sustainability requires understanding the long-run properties of an economy's path. This calls for complete knowledge about the future behaviour of the economy, which is impossible to obtain.

Theoretical conclusions should be applied with care

The theoretical approaches reviewed above have provided useful and popular insights regarding the requirements of sustainability. However, care must be taken in applying them to the real world, given their assumptions of perfect markets, closed economies, constant technology and population, costless extraction of resources, absence of discovery and simple fully-substitutable two-stock economies.

Apart from simplifying assumptions, lack of knowledge about the wellbeing of future generations prevents confident application of any of the theoretical approaches described in this paper to the real world. Despite these practical limitations, all of the approaches allow earlier generations to draw down the stock of exhaustible resources so long as they add sufficiently to the stock of reproducible capital (where the stocks that are being depleted and those that are being produced are substitutable), such that overall stocks are maintained. While it is possible that future generations could indeed be better off, such that negative net savings could be more appropriate, maintaining aggregate stocks represents a 'no regrets' approach in the absence of certainty about future wellbeing. This provides a practical basis on which to focus effort, as already highlighted in the definition of sustainability presented above.

Sustainability measurement

The difficulties in selecting an appropriate framework for sustainability are reflected in efforts to measure it. Several decades of international effort on this front have resulted in a large variety of sustainability measures influenced by the range of sustainability definitions that have been developed.

Depending on the underlying concepts, some measures may not reflect sustainability as described in this paper. For example, those measures with a strong environmental focus that ignore social aspects, such as institutional arrangements, would be incomplete measures. Thus there is a risk that using the wrong measure will mislead decision-makers about the impacts of their decisions on future generations (Gorecki *et al.* 2011).

Beyond these concerns, developing an ideal and comprehensive sustainability measure is likely to be impossible given intractable information gaps regarding future and current wellbeing. Identifying and comprehensively quantifying the factors that make up current wellbeing is costly and accurate knowledge about the future is impossible. This means that, while sustainability measures will continue to be refined, it is important that decision-makers maintain awareness about their particular limitations. Estimates of impacts on future wellbeing will always be based on incomplete, though improving, measures of current stocks and best estimates about future preferences, consumption and technology.

Comprehensive Wealth and Adjusted Net Savings

An economy's *comprehensive wealth* represents a single measure of its aggregate stocks and thus is directly relevant to the measurement of sustainability. Comprehensive wealth is defined as the shadow value of all economic, natural, human, and social stocks, where true shadow values of these stocks should reflect the entire future of the economy. A change in comprehensive wealth at constant shadow prices is defined as comprehensive investment.

Assuming a constant population and constant shadow prices, non-declining comprehensive wealth, in other words non-negative comprehensive investment, amounts to a variation of the Hartwick Rule. Notwithstanding the already-described practical limitations of the Hartwick Rule, attempting to improve the underlying data for this measure can provide useful information regarding changes to stocks over time.[11]

---

11 Recent efforts to generalise this for a varying population have shown that non-declining comprehensive wealth per capita is only consistent with intergenerational equity and sustainability under restrictive conditions, including that population grows at a constant rate (Arrow *et al.* 2010).

Since the 1990s, the World Bank has produced estimates for comprehensive wealth and comprehensive investment, known as Adjusted Net Savings (ANS). Australia's comprehensive wealth (in 2005 United States dollars) increased from around $8 trillion in 1995 to $11 trillion in 2005, and comprehensive wealth per capita increased from around $416,000 to $519,000 in the same period (WB 2011). This provides some comfort regarding Australia's levels of aggregate stocks; however, data limitations mean that only tentative conclusions about sustainability can be drawn. Because of a lack of data, the estimates exclude natural resources such as diamonds, uranium, lithium, fisheries, hydro-power, ground water, wetland ecosystem services, the aesthetic value of natural landscapes, biodiversity and carbon storage. The values of protected environmental areas are also underestimated and measures of social and human stocks are lacking. Non-market valuation techniques were used to value stocks which are not traded in markets in monetary terms, bringing further uncertainty. Moreover, as information about future generations' wellbeing is lacking, an estimated future consumption stream was used to generate net present values of stocks.

Sustainability measurement using a dashboard

Given problems associated with converting all stocks into monetary equivalents, the 2009 Report of the Commission on the Measurement of Economic Performance and Social Progress recommended that a single sustainability measure may not be appropriate. Rather, the state of various stocks should be reported in a 'dashboard' format, presenting stocks in monetary units where appropriate but otherwise in physical units (Stiglitz, Sen and Fitoussi 2009). The ABS Measures of Australia's Progress is one such attempt to do this for Australia, with measures for both stocks and flows grouped within social, economic and environmental domains.

This approach avoids contestability associated with aggregation or making assumptions about the future, although its accuracy is still influenced by methodologies for measuring individual stocks. The downside is that no guidance is provided on how to weight the various stocks to assess the state of overall wellbeing at a given time. This seems appropriate where aggregation methodologies cannot be rigorously defended, and a variation on this approach would be to aggregate where possible and provide separate measures otherwise.

Sustainability has implications for discounting and cost-benefit analysis

The use of a discount rate to allow the value of economic effects occurring at different times to be compared — by converting each future dollar amount associated with a project (or an action, trade-off, or non-action) into a present dollar amount — is a key feature of efforts to measure impacts of current actions on future generations.

In the ANS approach to monitoring the sustainability of society as a whole, discounting is used to estimate present values of stocks. Discounting is also used to evaluate the future impacts of decisions by individual social agents by looking at the associated costs and benefits. Factoring future effects into cost-benefit analysis (CBA) is seen by many as sufficient to meet the requirements of sustainability. However, the theoretical approaches explored earlier have implications for discounting that suggest otherwise.

The Ramsey optimising approach is typically used to derive an expression for a social rate of time preference. Although the other theoretical constructs described in this paper could also be used, use of Ramsey optimisation automatically implies that the resulting discount rate and CBA may not be consistent with sustainability. The discounted utility flow is maximised according to Equation (1), where ρ is the rate of pure time preference and $u(c_t)$ is utility as a function of consumption. This leads to an expression for social rate of time preference (SRTP), also known as the consumption discount rate:

$$SRTP = \rho + \eta g \tag{3}$$

where η is the elasticity of marginal utility with respect to consumption and g is the rate of growth of per capita consumption.[12, 13] η reflects concern for equity between generations, such that if g is large and positive, a high η leads to a greater SRTP and the consumption of future generations is given less weight. If income is increasing, each successive generation will be better off than the previous generation. In such circumstances, it makes sense that the present generation would discount the future, preferring an extra unit of consumption today to consumption tomorrow, since the latter is relatively more plentiful and so less valuable. Conversely, a low η reflects a greater concern for future generations. It is possible that the SRTP can vary over time, depending on the behaviour of g, although it is often assumed that g is constant.

Arriving at a value for the SRTP requires judgements about its constituent elements and a range of values have been advocated between -3 and 27 per cent (Weitzman 2001). A key reason for the variation in recommended values occurs because Equation (3) can be interpreted positively or normatively. This has driven ongoing debate regarding the choice of a discount rate that effectively captures concern for intergenerational equity or sustainability, most prominently in relation to climate change.

---

12 See Heal (2005), for example, for a derivation.

13 Along an optimal path, a planner equates the marginal return from saving, represented by the market rate of interest, r, with the marginal cost of saving, represented by $\rho + \eta g$. In cost-benefit analyses it is common to compare present values of time streams of money values of consumption, using a 'consumption discount rate', rather than the so-called 'utility discount rate' (the pure time preference rate), ρ (Creedy and Guest 2008).

From a positive perspective, the appropriate question might be: 'To what extent can the return on investments be maximised to benefit future generations?' (Arrow *et al.* 1995). As such, the SRTP is selected according to how individuals behave in the market or in experiments — in other words, observing market rates of return. Alternatively, a normative approach selects the parameters g, η and ρ according to what the population's preferences should be on an ethical basis. The key question from this perspective might be: 'How (ethically) should impacts on future generations be valued?' For example, ρ is often specified as equal to zero (or very close to zero) under a normative approach.

Both of these questions are valuable, and in a hypothetical economy with perfect (Pareto optimising) markets, sustainable transfers between generations and full information about all future states, they should provide equivalent results.[14] The disagreement between these approaches relates to judgements about how markets reflect the interests of future generations. It is exacerbated by confusion about concepts and the fact that there is no escape from fundamental judgements made by individual analysts about the current and future state of society.[15] 'Society' itself cannot be thought of as a decision-maker, since no one agent controls the whole of society; accordingly, such judgements must always be attributed to analysts, who should be transparent about their use (Creedy and Guest 2008).

Positive discount rates are unlikely to adequately consider future generations

The positive approach focuses on the opportunity cost of capital — what benefits to society or individuals would the funds return if left in the private sector — and the need to direct investment to the most productive uses, given that even small differences in rates of return result in large differences in the long run. As market rates of return are positive, the implication is that future generations will be better off, and that compensation from one generation to another for any loss of stocks will occur automatically. Thus, the positive approach argues for choosing the path that maximises the market value of consumption, making transfers between generations separately out of the larger present value of consumption.

Under a positive approach, the nature of individual costs and benefits associated with different stocks, for example their risk profile (if not using a certainty equivalence approach), may warrant the use of different discount rates according to the relevant market rate of return.

14 Sustainable transfers between generations are taken to mean transfers that ensure that wellbeing of subsequent generations is maintained at current levels or increases.

15 One confusing concept is the difference between discounting one's own wellbeing and discounting the wellbeing of others in the future.

Market returns for a small, open economy such as Australia are determined by global interest rates, or essentially global saving behaviour (Harrison 2010). However, observed market rates of interest reflect how individuals are willing to trade-off consumption over time, and there may or may not be a close correspondence to how a hypothetical ethical social planner would be willing to trade-off consumption across generations. Dietz, Hepburn and Stern (2008) note the difficulties in observing ethics from behaviour, listing four conditions necessary for revealed preferences to perfectly guide ethical social policy decisions:

- the observed behaviour reveals a unique preference;
- the revealed preferences are 'true' preferences, based on full, correct information without decision-making error;
- the preferences are derived from a context that can map appropriately to the ethical judgement being made (that is, the preferences are 'contextually relevant'); and
- the preferences are appropriate for social rather than private ethical choices.

Therefore, market interest rates may not provide a robust indicator of the marginal trade-offs to society over the long term.

This is exacerbated by market imperfections and the challenges in making appropriate transfers to future generations, which can be made through taxes, regulations and fiscal policy.[16] For dollars invested today, the intervening generations must keep investing for the benefit to be passed to future generations, and there is no guarantee that the transfer will reach the intended recipients when there are many intervening generations.[17]

There is a case for variable normative discount rates

The normative approach assumes that market measures are insufficient to indicate whether a project is worth undertaking, and that the right discount rate depends upon

16 A large literature on 'Sen's Isolation Paradox' (Sen 1967), according to which an individual will only sacrifice consumption in favour of future generations if others are guaranteed to do likewise, explores reasons why private saving behaviour fails to provide the right amount of bequests to future generations, including that such bequests represent a public good which is undersupplied by the free market.

17 Harrison argues that the risk that intervening generations would not keep investing could be included in a risk component (Harrison 2010).

judgements (which can be supported by empirical evidence or ethical considerations) about the correct distribution of resources between generations.[18]

The Ramsey optimising approach is usually assumed in the selection of the parameters g, η and ρ, which then may not be consistent with sustainability despite the intention of analysts to reflect the interests of future generations in their values. The resulting normative discount rate is usually set as a constant value below the market rate of return to capital that would be selected using the positive approach. Ramsey argued that, because there is no ethical or moral basis for giving less weight to the wellbeing of future generations, ρ should be equal to zero (Ramsey 1928). However, even if ρ is equal to zero, the SRTP will not be zero if g and η are nonzero. Others have argued that ρ should be adjusted for the probability of extinction, although plausible estimates to this effect would result in a very small value (Arrow *et al.* 1995). Moreover, economists don't know what the likely rate of future per capita economic growth g will be over the very long term, and different rationales exist for the choice of η based on distributional and intergenerational concerns and relative risk aversion.

The other theoretical approaches discussed in this paper will result in different versions of the SRTP that are consistent with sustainability, and generally lead to the conclusion that the discount rate should vary with time. Under the fairest maximin approach, the optimising process results in a sequence of variable discount factors ρ_t, which are derived as a price support of the constant consumption path (Withagen, Asheim and Bucholtz 2003). The Chichilnisky criterion, requiring that the ranking of consumption paths be sensitive to consumption in both the present and the very long run, has been shown to lead to a declining discount rate (Chichilnisky 1997). Even the Ramsey optimising approach can lead to a variable discount rate through the parameter g; for example if g is declining, this implies a decreasing SRTP, all else equal.

Moreover, the degree of substitutability between stocks can affect the social discount rate. When there is perfect substitutability between a produced and a depletable stock, the social discount rates associated with both stocks has been shown to equal the rate of pure time preference. For limited substitutability between produced and depletable stocks, the discount rates of each can be constant, increase or decline over time depending on the degree of substitutability between them (Traeger 2011).

18 As argued by Harrison, the normative approach "implies that the current generation goes not save and invest enough for the future and makes a case to reduce private and public-sector consumption and increase savings and investment instead" (Harrison 2010). Harrison feels that the appropriate response is to increase savings and investment until the rate of return on private capital falls to the advocate's prescribed ethical discount rate. However, this still requires a judgement about the appropriate prescribed rate.

A declining SRTP is consistent with observed behaviour, which suggests that individuals apply higher discount rates in the short term and lower rates for longer time horizons, leading to a so-called 'hyperbolic discount function' (Frederick *et al.* 2002).[19, 20] In 2003, the United Kingdom Green Book began to recommend hyperbolic discount rates for the evaluation of long term projects, starting at a rate of 3.5 per cent and declining to 1 per cent beyond 300 years (HM Treasury 2003).

While varying discount rates would be consistent with sustainability in theory, the correct sequence can only be determined using full information about all future states of the economy. The lack of this information means there is no obvious way to choose between theoretical approaches with which to derive the discount rate sequence. The consequences are that it is difficult to evaluate relative impacts through time in a way that adequately considers future generations; such impacts can only be assessed on a best-estimates basis.

Beyond this difficulty, CBA encounters similar measurement issues as comprehensive wealth, in that it requires valuing stocks in monetary terms.

Implications for policy and measurement

An exploration of the rich literature on theoretical and practical approaches to sustainability has revealed three common, interlinked elements that are critical to appropriately designing public policy on this issue. These elements are: uncertainty about the future, a focus on stocks, and an understanding of the degree of substitutability between those stocks.

Decision-making in the face of uncertainty

The most difficult of these elements is uncertainty, a number of sources of which have been raised in this paper. For example, while economic forecasts play a very important role in public policy, the uncertainty associated with such forecasts increases with lengthening timescales. Modelling risk several hundred years into the future is likely to give spurious results, because we simply don't know what the probabilities are (Dasgupta 2008). There are fundamental uncertainties about the rate of economic growth, the amount of capital that will be accumulated, the degree of diminishing returns, the state of the environment, the state of international relations, the level and pace of technological progress, the rate of pure time preference, the degree of

19 Noting that individual behaviour may not reflect ethical social behaviour, as previously described.

20 A well-known consequence of non-constant rate of time preference is continual revision of (formerly) optimal plans, otherwise known as time inconsistency (see for example Phelps and Pollak 1968 and Traeger 2011), although this may not occur when it is associated with uncertainty (Weitzman 1998, Dasgupta and Makin 2005).

substitutability of stocks, and the many other features that might be relevant to determining the impacts of current actions on future generations (Weitzmann 1998).

We cannot even say for certain whether future generations will be better off. This in turn hampers our ability to select the right theoretical framework for considering future generations, with consequences for selection of discount rates. We know that discount rates should probably be variable, and they should probably be different depending on the substitutability of stocks being assessed, but we lack the information to be able to say how they should vary.

Accordingly, discounting and cost benefit analysis should not be expected to provide more than a best-efforts guide to impacts on future generations, regardless of whether the discount rate is chosen using a positive or normative framework, or using different theoretical constructs such as Ramsey optimisation or the Chichilnisky criterion. It is also clear that a normative discount rate could be inconsistent with sustainability if based on the commonly-used Ramsey optimising approach. The policy implications are that decisions will continue to be made with a high degree of uncertainty and on the basis of 'best estimates'.

This result does not materially change the current realities of decision making; rather, it highlights them. It does not preclude decision makers seeking as much information as possible about the impacts of decisions on future generations. What is important is that decisions affecting future generations are made in a transparent way. This requires making underlying assumptions clear; choosing and using discount rates appropriately for the particular issue being addressed; and testing an array of scenarios covering whether, and by how much, future generations will be better off. For example, the *Intergenerational Report 2010* presents a wide range of information relevant to the wellbeing of future generations (AG 2010). No net present value analysis is applied to those estimates. Instead, the data for future years is presented so that readers can make their own assessments. While transparency by itself does not guarantee appropriate transfers to the future, it should increase awareness that a choice about transfers is being made.

Decision-makers should be aware of the risk and uncertainty associated with decisions that affect future generations, and design policy to manage this by allowing scope for revision when better information about future impacts becomes available. In the absence of full information, doing 'nothing', in the sense of not considering future generations, is not a way of minimising risk that they will be worse off, because it nevertheless implies a choice about transfers to the future.

Maintaining aggregate stocks according to substitutability and thresholds

The second and third elements, the maintenance of appropriate stocks of social, human, economic and environmental capital for future generations, and the substitutability of those stocks, describe both a fundamental approach to achieving sustainability and further practical opportunities to reduce uncertainty.

The stocks that we have and are able to produce today represent the totality of what we are able to leave to future generations, should we choose to do so. The more we know about the quantity and quality of these stocks, and the more we are able to monitor the rate at which they are being used or replenished, the more informed we will be regarding that choice. Understanding the degree of substitutability between stocks will further enable informed decisions about trade-offs between them. As such, ongoing improvements to sustainability measures (whether they are dashboards or measures of comprehensive wealth) and forecasting techniques are of value. Efforts to better understand how the various contributions to wellbeing might be weighted, and how those weights might change over time, are also important.

While we cannot know what future generations will value, we can know whether a particular non-renewable stock is near to being entirely consumed or destroyed. This should send signals to decision-makers regarding the potential loss of opportunities for future generations associated with the loss of that stock. A precautionary approach might then be taken, where an appropriate amount of the stock is preserved for posterity. In some cases this could also provide incentives to find substitutes — through market signals or government decisions — for example through research and development.

We can also be better informed regarding thresholds associated with those stocks. In the absence of such knowledge, neither market prices nor calculated shadow prices will appropriately identify when a non-substitutable stock is at risk, and a threshold could be passed without the opportunity being taken to decide whether this is the right choice.

International efforts to address climate change are a clear example of policy action in response to information about thresholds, and work on better identifying thresholds at the global, regional and local levels continues. For example, the 2009 paper by Rockstrom, Steffen and others (Rockstrom *et al*. 2009) proposes a framework of nine planetary boundaries that define a 'safe operating space for humanity' as a precondition for sustainable development. The authors argue that some of these boundaries have already been crossed, while others are in danger of being crossed. The concept of planetary boundaries has grown in popularity, and appears in the United Nations Environment Programme's Global Environmental Outlook reports. Whether all of the boundaries identified by Rockstrom *et al*. represent accurate global boundaries beyond which human wellbeing is threatened remains the subject of debate, however, such efforts are a first step. Work on global boundaries must also be complemented by improved understanding of thresholds at the local and regional levels, which may be more applicable for particular stocks such as localised ecosystems.

While the number of stocks that are relevant to wellbeing is very large, this does not necessarily imply an impossible monitoring and research task. Assuming that many stocks will be substitutable, attention could focus in particular on stocks that are being depleted and are not substitutable, especially those for which market valuation is poor or non-existent. Priorities for policy action, identification of thresholds and searches for substitutes could be established as follows. Stocks that have no substitute, which exist in small quantity and which are being depleted rapidly or are nearing their threshold, should be protected unless there is certainty that future generations' wellbeing will not be adversely affected. Protection and research on thresholds should be the focus for stocks which are being depleted rapidly but for which a threshold is unknown. Research on substitutes should be a priority for stocks which may be substitutable but are being depleted rapidly, whether or not thresholds are known. Stocks which exist in large quantity, are substitutable and are being depleted slowly require no action.

Conclusion

While history suggests an increasing trend in wellbeing, we cannot take for granted that future generations will be better off. Sustainability — requiring that wellbeing is at least maintained for future generations — is therefore an important consideration for decisions that have long term impacts.

A range of theoretical approaches to sustainability have been developed, however, lack of information about the future makes choosing between them difficult, with implications for the choice of discount rates. Notwithstanding this uncertainty, a focus on maintaining aggregate stocks represents a no-regrets approach to sustainability. As concepts and techniques for measuring sustainability continue to be refined, a practical, best-efforts way to consider future generations appropriately requires monitoring changing levels of stocks, their substitutability and their thresholds, and protecting parts of stocks where future compensation for their loss is uncertain.

References

Asheim, G 2011, 'Hartwick's Rule', *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, Elsevier.

Asheim, G Buchholz, W and Withagen, C 2003, 'The Hartwick Rule: Myths and Facts', *Environmental and Resource Economics*, vol 25, pp 129-50.

Asheim, G and Mitra, T 2010, 'Sustainability and discounted utilitarianism in models of economic growth', *Mathematical Social Sciences*, vol 59, pp 148-69.

Anand, S and Sen, A 2000, 'Human Development and Economic Sustainability', *World Development,* vol 28, pp 2029-49.

Arrow, K 1973, 'Rawls' Principle of Just Saving', *The Swedish Journal of Economics*, vol 75, pp 323-35.

Arrow, K Cline, W Maler, K Munasinghe, M Squiteri, R and Stiglitz, J 1995, 'Intertemporal Equity, Discounting and Economic Efficiency', *Climate Change 1995: Economic and Social Dimensions of Climate Change, Second Assessment of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 135-44.

Arrow, K Dasgupta, P Goulder, H Mumford, K and Oleson, K 2010, *Sustainability and the Measurement of Wealth*, NBER working paper 16599.

AG 2010, *Intergenerational Report 2010*, Australian Government, Canberra.

CIA 2012, *The World Factbook*, Central Intelligence Agency, United States.

Chichilnisky, G 1997, 'What is Sustainable Development?', *Land Economics*, vol 73, pp 467-91.

Creedy, J and Guest, R 2008, 'Discounting and the time preference rate', *Economic Record,* vol 84, pp 109-27.

Dasgupta, P 2008, 'Discounting climate change', *Risk and Uncertainty,* vol 37, pp 141-69.

Dasgupta, P and Maskin, E 2005, 'Uncertainty and hyperbolic discounting', *American Economic Review,* vol 95, pp 1290–99.

Dietz, S Hepburn, C and Stern, N 2008, 'Economics, ethics and climate change', London School of Economics.

Frederick, S Loewenstein, G and O'Donoghue, T 2002, 'Time Discounting and time preference: a critical review', *Journal of Economic Literature,* vol 40, pp 351-01.

Gorecki, S Johnson, S and Gruen, D 2011, "Measuring Wellbeing in Theory and Practice", *Treasury Working Paper* 2011-02.

Gorecki, S and Kelly, J 2012, "The Treasury Wellbeing Framework", Economic Roundup, Treasury, forthcoming.

Harrison, M 2010,' Valuing the Future: the social discount rate in cost-benefit analysis', Visiting Researcher Paper, Productivity Commission.

Hartwick, J 1977, 'Intergenerational Equity and the Investment of Rents from Exhaustible Resources', *American Economic Review*, vol 67, pp 972-74.

Heal, G 2005, 'Intertemporal Welfare Economics and the Environment', Chapter 21 in *Handbook of Environmental Economics,* vol 3, pp 1121-27.

HM Treasury 2003, *Green Book*, p 98-99.

Hotelling, H 1931, 'The Economics of Exhaustible Resources', *Journal of Political Economy*, vol 39, pp 137-75.

Maddison, A 2001, *The World Economy: A Millennial Perspective*, Organisation for Economic Cooperation and Development, Development Centre, Paris.

Maddison, A 2010, *Historical Statistics on the World Economy: 1-2008 AD*, The Groningen Growth and Development Centre.

Neumayer, E 1999, 'Global warming: discounting is not the issue, but substitutability is', *Energy Policy,* vol 27, pp 33-43.

Parkinson, M 2011, *Sustainable wellbeing – An economic future for Australia*, Shann Memorial Lecture Series, 23 August.

Pezzey, J 1992, 'Sustainable Development Concepts', World Bank Environment Paper No.2.

Pezzey, J 1997, 'Sustainability constraints versus "optimality" versus intertemporal concern', *Land Economics,* vol 73, pp 448-66.

Phelps, E 1961, 'The golden rule of accumulation: A fable for growthmen', *American Economic Review*, vol 51, pp 638-43.

Phelps, E and Pollak R, 1968, 'On Second-Best National Saving and Game-Equilibrium Growth', *Review of Economic Studies,* vol 35, pp 185-99.

Ramsey, F 1928, 'A mathematical theory of saving', *The Economic Journal*, vol 38, pp 543-59.

Rawls, J 1971, *A Theory of Justice*, Harvard University Press, Cambridge, Massachusetts.

Rockström, J Steffen, W Noone, K Persson, A Chapin, F Lambin, F Lenton, T Scheffer, M Folke, C Schellnhuber, H Nykvist, B de Wit, C Hughes, T van der Leeuw, S Rodhe, H Sörlin, S Snyder, P Costanza, R Svedin, U Falkenmark, M Karlberg, L Corell, R Fabry, V Hansen, J Walker, B Liverman, D Richardson, K Crutzen, P and Foley, J 2009, 'A safe operating space for humanity', *Nature,* vol 461, pp 472-75.

Sen, A 1967, 'Isolation, Assurance and the Social Rate of Discount', *The Quarterly Journal of Economics,* vol 81, pp 112-24.

Solow, R 1974, 'Intergenerational equity and exhaustible resources', *The Review of Economic Studies*, vol 41, Symposium on the Economics of Exhaustible Resources, pp 29-45.

Solow, R 1986, 'On the Intergenerational Allocation of Natural Resources', *Scandinavian Journal of Economics*, vol 88, pp 141-49.

Stiglitz, J Sen, A and Fitoussi, J 2009, *Report by the Commission on the Measurement of Economic Performance and Social Progress*.

TED 2012, Total Economy Database, The Conference Board.

Traeger, C 2011, 'Sustainability, Limited Substitutability and Non-Constant Discount Rates', *Journal of Environmental Economics and Management,* vol 62, pp 215-28.

UNWCED 1987, *Our Common Future*, United Nations World Commission on Environment and Development, Oxford University Press, Oxford.

Weitzman, M 1998, 'Why the far-distant future should be discounted at its lowest possible rate', *Journal of Environmental Economics and Management,* vol 36, pp 201-08.

Weitzman, M 2001, 'Gamma Discounting', *The American Economic Review,* vol 91, pp 260-71.

Withagen, C Asheim, G and Buccholtz, W 2003, 'On The Sustainable Program In Solow's Model', *Natural Resource Modelling,* vol 16, pp 219-31.

WB 2011, *The Changing Wealth of Nations*, World Bank.

Zuber, S and Asheim, G, 2012, 'Justifying Social Discounting: The Rank-Discounted Utilitarian Approach', *Journal of Economic Theory*, vol 147, pp 1572-601.