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On sustainability:
an economic approach

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On sustainability: an economic approach

‘Sustainability’ is invoked as a desirable objective in a range of contexts, yet its meaning is not always clear. Sustainability can imply vastly different policy responses depending on interpretation, particularly in relation to the degree to which environmental and other resources should be consumed over time. Using an economic framework for exploring the issues, this staff research note illustrates possible interpretations of sustainability and what they imply for policy analysis.

What is sustainability?

At its most general level, sustainability refers to the capacity to continue an activity or process indefinitely. It can be related to any number of economic, social, or environmental activities and can have varied meanings within different disciplines. Unsurprisingly, there is a multitude of definitions of sustainability and sustainable development.¹ The most frequently cited definition is that of the United Nations World Commission on Environment and Development 1987 (the ‘Bruntland’ Commission).

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

In Australia, the National Strategy for Ecological Sustainable Development defines sustainable development as:

... using, conserving and enhancing the community’s resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased. (Commonwealth of Australia 1992)

Sustainability means different things to different people and has entered the vernacular in varying (and sometimes conflicting) ways — for example, it can be used to suggest that something is financially viable, ‘environmentally friendly’, takes a long-term view, or can be continued indefinitely. It has also been adopted by

¹ While there is debate over the distinction between these terms, in general ‘sustainability’ and ‘sustainable development’ are used interchangeably. This paper will not distinguish between these two terms.

private companies through various corporate social responsibility initiatives. As expressed by the NSW Government (2011):

There is no simple definition of ‘sustainability’. It can be an idea, a property of living systems, a manufacturing method or a way of life. In fact, there are as many definitions of sustainability as there are people trying to define it.

Notwithstanding differences in interpretation, there is general agreement that sustainability is related to the objective of maintaining the wellbeing of society over time. However, there is disagreement on how to incorporate sustainability considerations into public policy analysis.

Sustainability from an economic perspective

There are various frameworks for thinking about sustainability. A widely-used approach is to represent sustainability in the context of three pillars — ecological, social and economic (Barbier 1987; Adams 2006). Essentially, this conception proposes that sustainable development can only be achieved when each pillar is promoted in concert with the others. While this approach provides a useful categorisation of the relevant dimensions of sustainability, it is difficult to operationalise, mainly because it lacks an analytical basis to make decisions about any tradeoffs between the three pillars.

Application of the general concept of sustainability can take different forms depending on the framework used. For example, within ecological frameworks, sustainability refers to the capacity of biological systems to maintain their functions and processes over time. This perspective focuses on natural capital and often highlights the irreplaceability of some natural resources and the rights of non-human beings.

Within economic frameworks, sustainability is often thought to be achieved if the wellbeing of society is maintained over time (Arrow et al. 2004; Pezzey 1992; Solow 1993; Toman 1998). There are various formulations of this concept (box 1). Wellbeing is usually broadly defined — in addition to consumption of market goods and services, made possible by economic production (income), it includes household and environmental services and other non-market outcomes, such as social connectedness.

Box 1 **Some economic interpretations of sustainability**

Economists have interpreted sustainability in various ways. Not all of these interpretations explicitly refer to sustainability but nonetheless embody similar ideas — that is, to achieve a non-declining level of wellbeing (sometimes referred to as utility or welfare) over time.

Three seminal contributions to the economic theory of sustainability were provided by Dasgupta and Heal (1974), Solow (1974) and Stiglitz (1974). Their models represented wellbeing over time in terms of welfare maximisation. They showed the maximum level of utility that can be achieved over time with a finite level of natural resources. Utility can be either constant (Solow 1974; Stiglitz 1974) or declining (Dasgupta and Heal 1974) over time depending on what is assumed about the capital stock, technological progress, and the rate at which future utility is discounted.

In particular, Solow (1974) showed that, under certain conditions, constant wellbeing over time can be achieved by maintaining the total stock of capital. That is, the depletion of natural capital can be off-set by investment in manufactured capital, or other types of capital. By maintaining the level of productive capital the largest possible level of constant consumption per person can be achieved over time.

As stated by Pezzey and Toman (2002, p. 7), even though Solow did not explicitly discuss sustainability, ‘his was the first widely read paper to suggest in the context of formal economic growth theory, a sustainability-like objective for society’ and that this differed from the traditional economic approach of maximising the present-value of wellbeing. Solow’s maintenance of the total capital stock is similar to a ‘rule’ proposed by Hartwick (1977). Hartwick’s rule is that if all rents from exhaustible resources are invested in reproducible capital then non-declining consumption over time is achieved. However, such ‘rules’ require that different forms of capital are close, if not perfect, substitutes.

Sustainability has subsequently been interpreted by some economists to require a separate constraint on the conventional formulations of welfare maximisation (Pezzey 1992; Arrow et al. 2004). However, there is disagreement as to whether concern about sustainability requires any explicit criterion or objective over and above welfare maximisation per se (for example, Beckerman 1994).

In this context — where wellbeing is at least maintained over time — sustainability can be attained by preserving the total stock of capital. The stock of capital is broadly defined as the ‘productive’ base that provides the opportunities from which wellbeing is ultimately derived. It includes all of society’s capital assets — produced (roads, buildings, machinery), natural (ecosystems, minerals, fossil fuels), human (education, skills, knowledge,² health) and social (institutions and relationships that govern interactions between people). People value natural capital

² Knowledge includes basic and applied research and intellectual property, which can also be interpreted as produced capital.

for the services it provides, including the benefit from knowing that certain natural capital exists (‘existence’ or ‘non-use’ value).

Implicit in this interpretation of sustainability is the assumption that natural capital can be depleted, provided that society invests in other forms of capital (to offset this depletion) so the total capital stock does not decline over time. This assumes that different forms of capital are substitutes. For example, the stock of capital could be augmented by investment in produced capital to offset a loss of natural capital. Similarly, human capital accumulation through educational attainment and skill acquisition can be a substitute for produced capital. Technological advancement can also increase the ‘effective’ stock of capital, thereby enabling production with fewer physical capital inputs. This assumption of substitutability lies at the core of the sustainability debate, and is discussed in detail below.

The other defining feature of how sustainability is interpreted relates to the level of wellbeing that is considered sustainable. A sustainability criterion of ‘maintaining wellbeing’ focuses on changes in wellbeing over time rather than on whether the highest possible level of wellbeing is achieved at any point in time (Arrow et al. 2004). Thus, in theory, the achievement of constant wellbeing at a subsistence level of consumption could satisfy this interpretation of sustainability (Stavins, Wagner and Wagner 2003). A broader and more meaningful view of sustainability also requires resources to be used and allocated efficiently over time — where production is carried out at minimum cost and resources are directed to the areas that contribute most to wellbeing (Stavins, Wagner and Wagner 2003). Given economic efficiency at each point in time, then economic sustainability can be interpreted as the allocation of resources over time (savings and investment) in a way that provides the highest level of wellbeing for current and future generations.

Wellbeing is difficult to define

The concept of wellbeing is central to the economic interpretation of sustainability. Conventionally, national statistical accounts, and some economic models, use income or consumption of goods and services that have an observable economic value (market goods and services) as an indicator of wellbeing. This generally excludes the non-market outcomes that contribute to wellbeing — for example, utility that is derived from leisure activities, voluntary work, or social interactions supported by various forms of social capital. This is not to say that economists do not recognise the importance of these for wellbeing (box 2). Rather, many models do not explicitly take non-market outcomes into account due to the difficulty of precisely defining and measuring their value.

Box 2 **Measuring wellbeing**

The Australian Treasury's *Wellbeing Framework* attempts to consider a range of determinants of utility (beyond income and GDP). The framework suggests that, ultimately, all preferences for what is important to people could perhaps be expressed as 'consumption' of a generalised good, even if this good is intangible (Australian Treasury 2004). As noted in the framework, this interpretation of utility can also include other dimensions of wellbeing, such as capabilities and individual personal characteristics (as described by Sen 1999).

However, consideration of these types of outcomes in policy analysis is hampered by a lack of data. Stiglitz, Sen and Fitoussi (2009) recommended more systematic collection of data on these non-market outcomes. The OECD (2012) *Measuring Wellbeing and Progress* project has attempted to do this by building on human development measures that have been around for several decades.

A range of indicators have been used that attempt to measure dimensions of wellbeing beyond income and the consumption of market goods and services (which are measured in GDP). These often incorporate a suite of different metrics of wellbeing. Some examples include:

- the Human Development Index — based on three aspects of human development: health (life expectancy at birth), education (average years of schooling) and income (gross national income per capita)
- the Better Life Index — comprising 11 variables thought essential to wellbeing in terms of material living conditions (housing, income, and jobs) and quality of life (community, education, environment, governance, health, life satisfaction, safety and work-life balance) (OECD 2012).

The Australian Bureau of Statistics has developed *Measures of Australia's Progress* that incorporate three groups of indicators: society, economy and the environment. Within these groups, indicators include life expectancy at birth, the unemployment rate, real net national disposable income per capita, and home ownership rates (ABS 2010).

Intergenerational equity

Interpreting sustainability as requiring that wellbeing be at least maintained over time embodies concerns about intergenerational equity. In this context, each generation must make a decision regarding the amount of capital to consume now (for the benefit of the current generation) and how much capital to accumulate or preserve, including conservation of natural capital, for the benefit of future generations. Solow (1993) referred to this decision as a 'trade with posterity' — where the current generation consumes some natural capital, but in exchange they save and invest in produced and human capital so that future generations inherit an equivalent or larger total stock of capital.

Implicit in this interpretation of intergenerational equity is the assumption that maintaining the total capital stock can produce outcomes that would achieve at least constant wellbeing over time.³ This could, however, be achieved through many different consumption paths and mixes of capital. There are two critical areas of uncertainty related to this.

- Possible ‘production’ pathways depend largely on technological developments that allow different combinations of capital to produce particular sets of outcomes. While some technological developments and substitution possibilities can be foreseen, much is unknown.
- The tastes or preferences of future generations are also unknown. Choices at any point in time depend on preferences for different forms of consumption. In addition, preferences, even in the span of a single generation, can change. Given this uncertainty, it is often assumed that future generations have the same preferences as the current generation.

Moreover, some judgement of the importance of future generations’ wellbeing must be made by those making the investment decisions. In general, sustainability is taken to imply that the wellbeing of future generations matters as much as that of the current generation.

What constitutes intergenerational equity is therefore highly subjective, both in the assumptions about preferences and technology, and in judgements about equal opportunities across generations. Consequently, applying the concept of sustainability requires a greater understanding of how the present generation values different forms of capital and also of the technical limits to substitution between the different forms of capital.

How substitutable are natural capital and other forms of capital?

The central issue for the economic view of sustainability is the extent to which different forms of capital can be substituted for each other in order to maintain wellbeing. This is contentious as there are widely conflicting views on whether it is ethically defensible, and technically feasible, to substitute natural capital for other forms of capital.

³ The issues of capital depreciation and population growth are not addressed in this discussion as this would raise the additional complication of ‘sustainable population’. To sustain community wellbeing implicitly requires maintaining outcomes per person, so if the population is growing then the outcomes must match the population growth. Under the economic approach this requires that the net effective capital stock (which includes the contribution of knowledge and adjusts for depreciation) grows at the rate of population growth.

The idea that natural capital can be substituted for other forms of capital is commonly referred to as ‘weak sustainability’. It is often associated with work on the economics of exhaustible resources by Hartwick (1977) and Solow (1974) (box 1). Weak sustainability implies that as natural capital is depleted, other forms of capital can be increased to restore the total capital stock, and hence maintain per person consumption (or wellbeing). This does not require any particular type of capital to be maintained (subject to some minimum amount of each required to support life). In its narrowest form, this suggests that substitution between natural and other forms of capital can occur extensively, even if large-scale depletion of a natural asset occurs. This may be acceptable to a society that wishes, for example, to consume a natural asset such as coal or biodiversity, in exchange (substitution) for, say, more road or health infrastructure. Based on this interpretation, the levels of different forms of capital are unimportant; it is the total stock of capital that matters for sustainability. Weak sustainability is consistent with a view of the world where increased knowledge and technological advancement (increased produced and human capital) will enable more goods and services to be made with fewer physical inputs.

In contrast, ‘strong sustainability’ dismisses the idea of substitution on the premise that natural capital is complementary to other forms of capital, including social capital, and is therefore largely ‘non-substitutable’. This view is commonly promulgated by ecological economists (Daly 1990). Nonetheless, there is a broad spectrum of views on what strong sustainability is. Interpreted strictly, strong sustainability implies that every component of the environment and every species must be preserved indefinitely, and that it is ethically indefensible for future generations to be compensated for losses of natural capital via consumption of services from other forms of capital. This implies that a very high, potentially infinite, value is placed on these resources. Other views suggest that non-renewable and renewable forms of natural capital can be substituted for each other as long as the total stock of natural capital is maintained.

There is some common ground between proponents of weak and strong sustainability. Many agree that some natural capital is essential for production of other forms of capital (produced, social and human), and that it is not possible to maintain all natural capital indefinitely (Neumayer 2010; Solow 1993). Indeed, natural systems evolve and cannot be preserved ‘as is’. Most proponents also accept that certain natural resources are non-substitutable, at least below some threshold — especially those resources that are essential to support life. Thus, despite different views, the two paradigms need not always be in conflict. Indeed, the maintenance of a minimum level of natural capital (an aspect of strong sustainability) could also be consistent with weak sustainability. This would occur because society could be expected to place a high value on scarce natural resources. Moreover, declining

levels of a natural resource, say a certain mineral, would be revealed in a reasonably well-functioning market via higher prices. This would provide incentives for producers and consumers to seek out substitute sources, or to manage the existing stock more efficiently.

The weak versus strong sustainability debate is therefore more usefully characterised as a debate about the *degree* of substitution, and the mechanism to ascertain the appropriate degree of substitution, rather than whether any substitution can occur at all. From an economic perspective, relative prices (broadly defined, where they reflect the social value of all forms of capital to the community), are the primary mechanism through which decisions regarding substitution across capital types can be made. However, as discussed below, while prices are revealed where there are markets and the markets function effectively, this is not the case for some types of capital, most notably natural capital. This means that other approaches, such as taxes or regulation, may be needed to protect natural capital that is deemed vital. However, the strong sustainability approach offers no obvious analytical framework or mechanism for determining when this might be the case, or for establishing community values of different types of capital.

The effectiveness of markets, or any other mechanism, in achieving a sustainable allocation of resources over time is hampered by the high level of uncertainty regarding the degree to which substitution is actually possible. Substitution possibilities are determined in part by future technical advancements and the preferences of future generations, two factors which are not unrelated. As previously noted by the Commission:

... we do not know with any precision what the resource needs of future generations will be, so it is difficult to know what needs to be conserved. Further complicating this issue, it is likely that technological change will mean that we will be able to do more with less, and we might be able to switch our dependence on some non-renewable resources to other non-renewable, or renewable resources. (PC 2006, p. xxx)

Applying sustainability concepts in practice

As noted previously, sustainability can be taken to mean that all resources are used efficiently — both within and between generations — and that the productive base of society (the total capital stock) is more or less preserved over time. Markets and prices have an essential role to play in this context. When markets are complete and function well (that is, all capital is traded through efficient markets so the price reflects the relative value), they provide a mechanism for allocating resources to their highest value uses and users. Prices will also reflect the value placed by society on individual resources. Where they rise in response to resource scarcity,

prices provide an incentive for consumers and producers to use resources more efficiently or to seek out substitutes. These processes contribute to improving wellbeing and are therefore relevant to sustainability.

However, there are several reasons why market processes may not deliver an optimal level of sustainability. First, there are various imperfections in markets ('market failures') that mean that some resources are misallocated or overused (examples are provided in the following section). This has implications for sustainability as it means that the capital stock is being used inefficiently, and as a consequence, wellbeing is not as high as it otherwise could be. In particular, incomplete information on the value the community places on capital services that are not traded in markets reduces the efficiency of market allocation.

Second, even if resources are used efficiently by the current generation, capital investment may be deficient (relative to the amount of capital depleted), or not the 'right' type of capital. This may leave future generations with inadequate resources to sustain a level of wellbeing that is equivalent to that of the current generation. Decisions by the current generation may be deficient because of incomplete information about ecological processes or the extent to which the different forms of capital can be substituted for one another. In addition, as discussed earlier, there is uncertainty about the preferences of future generations and, hence, the mix of capital they will prefer.

Notwithstanding these problems, previous generations have shown a strong willingness to provide for their descendants and have made numerous innovations and investments in capital that have benefited ensuing generations (PC 1998). This is reflected in the actions that have already been taken to incorporate the idea of sustainability into Australian policies (box 3). The challenge for public policy is to identify when policy intervention could deliver net benefits. There are a number of practical steps that have the potential to improve decision making in this context. They involve improving:

- the efficiency of resource use (for example, through appropriate pricing or regulation where this delivers net benefits)
- our understanding of ecological systems
- our ability to measure the capital stock.

These steps are interrelated as improvements in one area will assist our understanding of the other areas. Practical endeavours in the second and third areas are important to understand the rates of substitution between the different types of capital now and in the future as the levels of capital change. They are also important to inform policies that improve the efficiency of resource use.

Box 3 **Sustainability in Australian government policies**

The *National Strategy for Ecologically Sustainable Development* (NSED) was released in 1992. It set core objectives and guiding principles for ecologically sustainable development and put in place a broad national agenda for sustainable development in Australia (Commonwealth of Australia 1992). The NSED principles are widely referenced and have been incorporated into many state and Australian Government policies and legislation.

Prior to the release of the NSED, all levels of government agreed to the *Intergovernmental Agreement on the Environment* (IGAE) to facilitate a cooperative national approach to the environment, improve environmental protection, reduce disputes between the Australian and state and territory governments on environmental issues, and define the roles of different levels of government (COAG 1992). While presented differently, the IGAE principles significantly overlap with those outlined in the NSED, though they are more focused on the integration of environmental and economic considerations.

A further integration of sustainability into Australian Government decision-making processes occurred through the introduction of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act). This Act provides a legal framework for national environmental and heritage protection, and biodiversity conservation. It contains principles of ecologically sustainable development that are similar to those in the IGAE and NSED.

Public policy concerns about sustainability have often encompassed a range of issues in addition to environmental conservation, including population growth, migration, cultural issues, and urban and regional development. An example is the *Sustainable Population Strategy*, which is intended to ensure that 'future population change is compatible with the economic, environmental and social wellbeing of Australia' (DSEWPC 2011, p. 6). Another example is the *Intergenerational Report*, which is released every five years and is intended to assess the long-term sustainability of Australian Government finances and examine the impact of current policies and trends, including population ageing and slower population growth (Australian Treasury 2010). An example of how sustainability is thought about in terms of cultural values is the recent declaration of the Southern Tanami as Australia's largest Indigenous Protected Area. This area was declared as protected partly on the grounds of sustainability — under the International Union for the Conservation of Nature's category six, which 'ensures the conservation of natural and cultural values while enabling sustainable use of natural resources' (DSEWPC 2012).

In October 2012, the Australian Government established the *National Sustainability Council* to provide advice on sustainability issues and to report biannually against a set of sustainability indicators for Australia. The indicators are intended to provide stock and flow information about social, human, natural and economic capital (DSEWPC 2013).

Improving the efficiency of resource use

Where markets function efficiently, scarce resources — including environmental resources — are directed to the uses, and users, which value them most highly. In principle, this can result in an allocation of resources that maximises the wellbeing of society. However, where markets do not function well (for example, due to a lack of effective competition or lack of information) or are not complete (for example, as a result of externalities, or the public-good characteristics of some goods and services) (box 4), then wellbeing may not be as high as it could be. Indeed, what the market values need not accord with what *society* values, or even with the interests of the economy as a whole in the long run (Banks 2009). As a consequence, there may be a role for governments to address externalities, facilitate the operation of efficient markets, and take into account the public-good aspects of the environment and other resources.

Box 4 **Some sources of market failures**

Externalities arise where an activity involves ‘spillovers’ of positive or negative impacts on others in the community who are not party to the activity. As a result, these impacts are not taken into account by the parties undertaking the activity. For example, there are a number of positive externalities associated with education (investment in human capital). These external benefits are typically not considered in an individual’s decision to study. As a result, if education levels were determined by the market only (with no government assistance), the highest level of community wellbeing possible might not be achieved.

Public goods are goods where one person’s consumption does not reduce consumption by others, and where it is not possible to exclude individuals from using them (for example, national defence). These goods tend to be underprovided or not provided at all in private markets because people can consume the good without paying for it. For example, emergency services for fire and flood control, and some natural capital, such as biodiversity, all exhibit public-good characteristics. The value of some capital, such as a pristine wetland, landmark building, or language and culture, come from their public-good characteristics.

Inadequate information can arise where information has public-good characteristics and as a result may be underprovided by the market. This is especially the case for some environmental research including information on biological processes. Uncertainty about many aspects of the environment (and people’s preferences for the environment) can further exacerbate information failures.

Policies to address market failures can be promoted purely on economic efficiency grounds. However, there may be many circumstances where actions that are taken today may impose costs on future generations that are not taken into account. In

these cases, it may be necessary to explicitly consider the effect on intergenerational welfare when formulating policy responses. An example is climate change, where the effects of greenhouse gases emitted today will be experienced mostly by future generations.

But market failure per se does not justify government intervention. Government action to address market failures is warranted only where it brings benefits to society that outweigh the costs of the intervention. Making this assessment can be complicated due to the long-term nature of sustainability issues, inadequate information, changing priorities over time, uncertainty, and confused governance arising from the involvement of different levels of government (PC 1999). Given these conditions, policy options may or may not be able to improve outcomes for the community as a whole and will need to be assessed carefully to ensure that government intervention does not make matters worse. Moreover, within the context of sustainability, there can often be calls for highly indirect and poorly targeted policies (box 5).

The most appropriate form of intervention will depend on the underlying source of market failure and an assessment of the costs and benefits of the different policy options. The Commission has generally advocated targeting policies at the source of the problem as this will usually be more efficient — for example, using a broad-based cap and trade scheme for greenhouse gas emissions (directly internalising the source of the externality by pricing it) can be a lower-cost and more effective option than setting technology-specific requirements to reduce emissions (PC 2011b).

Market-based approaches will often be the most efficient means of addressing a market failure. These involve creating financial incentives to direct resources to the areas where they are most highly valued by putting prices on environmental outcomes — either through market creation (for example, tradeable emissions permits), or by using taxes or subsidies. It may not always be possible to use an explicit market-based approach to address market failures where property rights are difficult to define or enforce, or where outcomes are difficult to measure. For example, some ecosystem services cannot be traded in markets because ownership of the ecosystem service cannot be defined or enforced (Murtough, Aretino and Matysek 2002). In these circumstances, direct regulatory approaches may be more appropriate, effectively imposing an ‘implicit’ price on the relevant resource.

Box 5 Policy prescriptions in waste management

Some participants in the Productivity Commission's 2006 inquiry into waste management argued for reductions in waste, through policies such as recycling subsidies and landfill levies, on the basis that current consumption is unsustainable and that this is reflected in excessive waste. Two issues underlying these concerns are the:

- depletion of natural resources. For example, some materials present in waste and recycling streams are non-renewable, such as aluminium cans produced from bauxite. The depletion of these resources may raise sustainability concerns as their use reduces the stock of resources available for future generations.\
- environmental impact of mining, forestry, processing and manufacturing (that occur prior to the point at which material becomes waste). The link with waste is that some of these impacts might be avoided if less waste were generated and more recycling undertaken.

In response to these concerns, the Commission argued that:

The environmental impacts of resource extraction, processing and manufacturing, raise more significant sustainability concerns than the depletion of material resources. However, waste management policies are an indirect, imprecise and generally ineffective means of addressing these issues. Direct policy intervention is strongly preferred. (PC 2006, p. 114)

Regarding resource depletion, the Commission noted that scarcity is reflected in high world resource prices, which make recycling more attractive and encourage substitution to other materials, exploration for new supplies, and more economical use. If it were decided that some government action to slow the rate of extraction of resources was required on sustainability grounds, the most direct means available would be to use natural resource policy, such as taxes or quantitative restrictions on the extraction of non-renewable resources.

Source: PC (2006).

Assessing policy options

In assessing the merits of different policy options, the Commission has consistently promoted the use of a cost-benefit framework (with the objective of achieving the greatest net benefit for the community). Cost-benefit assessment provides a means for identifying and evaluating the trade-offs in policy options in a way that produces the best overall outcomes for the community. It should encompass consideration of economic, environmental, and social costs and benefits, and the distributional implications of policy options, both for the current generation and over time. Cost-benefit analysis can therefore provide a good guide to identifying whether a policy option is consistent with the objective of sustainability (PC 1999, 2006).

Despite broad acceptance of cost–benefit analysis as a decision-making tool, it is rarely easy to quantify all the costs and benefits of policy options, especially where non-market outcomes are involved. The challenge is even greater in a sustainability context, particularly when assessing environmental policies when there is uncertainty about the outcomes from complex physical systems. Assigning values to environmental outcomes and other non-market outcomes that affect wellbeing, particularly social dimensions, is also problematic. While tools have been developed that can provide an indication of these values, such as stated preference and revealed preference techniques (PC 2011c), valuations tend to be context dependent, and the cost of undertaking such studies can limit their application.

There are also difficulties in incorporating values for costs and benefits that extend far into the future, especially where there is considerable uncertainty regarding outcomes and values. Thus, addressing the uncertainty of what the future will bring is a key challenge in undertaking cost–benefit analysis of policy options that have long-term impacts.

Dealing with uncertainty

Sustainability considerations involve a number of uncertainties. There is uncertainty about the nature of ecological processes, especially those that are subject to irreversibility. There is also uncertainty about the preferences of future generations and future technological advancement that may reduce (or exacerbate) the effects of current environmental problems or provide additional consumption opportunities. Unlike risk, which can be managed within conventional cost–benefit frameworks (by using the distribution of expected values), uncertainty is more problematic as the information required for decision making does not exist or is inconclusive. Consequently, objective probabilities cannot be assigned. Despite this, there are various methods for considering uncertainty within cost–benefit frameworks. Empirical approaches include options valuation, conversion of uncertainties into subjective risks (certainty equivalents), and sensitivity and scenario analysis. Precautionary approaches, such as minimum standards, can also be applied where there is considerable uncertainty and high costs associated with failure (box 6).

Box 6 **Approaches to dealing with uncertainty**

The precautionary principle

The precautionary principle features prominently in policy documents relating to sustainability. Common formulations of the principle state that lack of full scientific evidence should not be used as a reason for postponing cost-effective action. However, there is a difference between applying precautionary measures and invoking the precautionary principle (Weier and Loke 2007). While flexible definitions of the principle (that consider the cost-effectiveness of measures) can be compatible with the objective of maximising community wellbeing, they do not necessarily compel policy makers to take a particular course of action. However, they do reinforce the sensible principle that lack of certainty about the future is not a justification for inaction. More prescriptive versions of the principle can amount to prioritising one interest over all others (PC 2012).

Safe minimum standards

A safe minimum standard involves the adoption of a rule (or 'ecological safeguard threshold') for the preservation of a natural resource, as long as the economic costs of imposing the standard are not unacceptably high (Neumayer 2010). Safe minimum standards are similar to the precautionary principle in that they do not provide a strong theoretical foundation on which to base policy decisions. However, they can provide strong technical limits that can then be used in cost–benefit analysis. They may be appropriate in circumstances where there is considerable uncertainty and a high likelihood of significant damage if certain thresholds or tipping points are reached. Exceeding these thresholds could affect the productive capacity of future generations.

Options valuation

An important aspect of dealing with uncertainty in decision making is recognising that, as time elapses, some uncertainties are partially or fully resolved (PC 2011a). There can be value in delaying action until more information becomes available. This value is likely to be larger the greater the uncertainty regarding the social value of the resource to future generations and the greater the irreversibility of a decision. A 'real options' approach incorporates this value into decision making (within a cost–benefit framework). It involves a decision taken today that makes it possible for policy makers to take a particular action in the future (PC 2012).

Conversion of uncertainties into subjective or qualitative risks, and sensitivity and scenario analysis

Where sufficient information exists, it may be possible to convert uncertainties into subjective risks to make them amenable to standard risk-assessment techniques (Weier and Loke 2007). This generally involves attaching subjective probabilities to various outcomes based on the best available expert advice. This can enable cost–benefit analysis to be conducted even where there are uncertainties regarding variables. Further, given the uncertainties involved, performing sensitivity analysis on key assumptions, and/or undertaking scenario analysis, can illustrate the impact of assumptions on results and provide a range within which results may lie.

Assessing costs and benefits over time

An important consideration for sustainability is society's preferences for consumption, and consequently saving and investment, over time. These preferences are commonly reflected by the social discount rate — the appropriate rate to discount future consumption used in cost–benefit analysis. There is considerable disagreement on what the rate should be (Zhuang et al. 2007). The higher the discount rate, the lower the weight placed on future consumption. There are two major schools of thought to discount rate selection — descriptive (positive) and prescriptive (normative) (box 7).

Box 7 Approaches to discount rate selection

The **descriptive approach** is widely favoured for short and medium term analyses and is consistent with traditional cost–benefit analysis (Baker et al. 2008). This approach involves selecting a discount rate that reflects the opportunity cost of capital (the social returns that would have been generated if the funds had been invested in an alternative use). A key characteristic of this approach is that it explicitly separates efficiency and equity considerations. It views all dollars as the same no matter to whom they accrue, and as such it separates resource allocation from distributional effects. However, even within this approach, there is debate about which market estimates of the cost of capital should be used.

In contrast, the **prescriptive approach** derives the discount rate from the Ramsey equation. This sets the social discount rate at the pure rate of time preference plus the growth rate of income multiplied by the marginal utility of income. While empirical estimates can be used to inform these parameters, more often ethical judgements are applied to set the pure rate of time preference at zero or a low rate (more or less weighting the future generation's utility the same as that of the current generation's). The prescriptive approach generally results in a lower than market value rate being chosen. This reflects a judgement that future generations should be treated similarly to current generations. These issues are subjective, and as a result there is no agreement on what the rate should be based on.

Sources: Baker et al. (2008); Harrison (2010).

The choice of discount rate can have a profound effect on the assessment of costs and benefits when they are received in different time periods, as is the case with sustainability considerations. Policy options that impose a net cost on the current generation but yield net benefits in the future could pass a cost–benefit test using a low discount rate but may not if using a high one. For example, the Stern Review of Climate Change included headline estimates of climate change damage costs that were much higher than most other studies, principally due to the low discount rate used. Adding one percentage point to the discount rate reduces the damage cost

estimates by more than half (Baker et al. 2008). Given these effects, and the many competing uses of government funds, the choice of a particular rate should be based on a transparent assessment of the social opportunity cost of capital. Sensitivity analysis on the selected discount rate should be undertaken to illustrate the impact on project cost–benefit ratios. Indeed, performing sensitivity analysis of key parameters, including discount rates, is part of good practice cost–benefit analysis (box 6). This provides transparency to the analysis. Decision makers can then consider the range of these estimates and make a decision about which response is likely to increase community wellbeing, taking into account uncertainty about the future.

Improving our understanding of ecological systems

The existence of natural thresholds beyond which environmental damage is irreversible means there may be limits to the substitutability of natural capital. In many cases, these limits are unknown. Improving our understanding of the effects of using up a particular resource (for example, water) on the functioning of ecological systems would be beneficial, both from the perspective of governments making environmental conservation decisions, and also to improve accounting of natural capital. Considerable work is already being conducted by scientific agencies in this regard. Nevertheless, continued support by governments for this research is a practical step that can be taken to improve their ability to implement sound policies to achieve sustainability objectives.

Improving our ability to measure the capital stock

If it is accepted that capital (produced, natural, human and social) provides the basis for consumption (broadly defined) and hence contributes to wellbeing, then approaches that measure changes in the total stock of capital can provide an indication of sustainability and can inform policy analyses. Measures of the capital stock need to include estimates of volumes as well as value so that changes in capital stocks can be assessed over time.

There have been some attempts to augment estimates of produced capital in traditional national accounts with estimates of natural, social and human capital. These are sometimes referred to as ‘extended wealth’ measures or ‘adjusted net savings’. An example is the Australian Bureau of Statistics’ (ABS) System of Environmental–Economic Accounting. This approach includes experimental values for some natural assets (such as subsoil assets, timber in forests, fish and land) on the National Balance Sheet (ABS 2012). The ABS has also developed experimental

values for human capital (based on expected future labour market income) and estimates of the volume of social capital using survey data (Wei 2008; Biddle et al. 2009).

There are various limitations and practical difficulties in estimating extended wealth measures (box 8). One of the major challenges is assigning prices to natural capital. While some exhaustible environmental resources, such as coal and oil, are traded in markets and have observable prices, these prices might not reflect the full value of the resource due to the existence of market failures, such as unpriced externalities. Moreover, in most cases, environmental resources are not traded in markets and therefore do not have an observed market value. It is therefore necessary to estimate accounting (or ‘shadow’) prices for these resources. These prices must take into account the varying contributions of natural capital to wellbeing — both direct (as objects of natural beauty) and indirect (the contributions of ecosystem services such as water purification) (Arrow et al. 2004).

Box 8 Measuring capital stocks

Adjusted net savings (also known as genuine savings) measures changes in capital stocks or wealth over a given time period — where the stock of wealth includes all forms of utility-generating capital, including natural resources, produced capital and human capital. Adjusted net savings is derived by adjusting standard national accounts measures of gross national savings for investments in human capital (for example, using current expenditures on education), natural resource depletion (for example, based on estimates of resource rents) and pollution costs (for example, from carbon dioxide emissions).

While adjusted net savings is based on a consistent conceptual framework it does have some significant and, within a sustainability context, familiar shortcomings. In particular, the relevance of adjusted net savings measures depends on what is counted (the types of capital) and on the prices used to evaluate these stocks where markets provide imperfect values and accounting prices must be derived.

Source: Stiglitz, Sen, and Fitoussi (2009).

Some natural capital is also very difficult to measure in quantity terms. For example, it is very difficult to measure stocks of soil compared to say stocks of fish, which are more easily counted. A similar issue applies to the more intangible dimensions of social capital, such as cultural diversity, social cohesion and self-esteem (Barbier 1987). Thus, while extended measures of capital stocks can incorporate investments in some forms of capital, such as human capital (through education and its effect on labour income) and natural capital (through environmental conservation), the more intangible social assets are much harder to define, let alone quantify. Moreover, social capital is often not ‘produced’ through

intentional investment strategies. It is a function of complex social and cultural interactions and thus the same inputs of produced and human capital can produce vastly different outcomes in terms of social capital. Given the inherent difficulty associated with deriving comprehensive measures of capital stocks and the uncertainty about future preferences (and hence, the future values of different forms of capital), Stiglitz, Sen and Fitoussi (2009) recommended a ‘dashboard’ of indicators to assess sustainability (box 2). This includes physical indicators of the state of the environment.

In addition to better measures of capital across all its forms, there is a need to determine the desirable composition of the capital stock to bequeath to future generations. This requires consideration of the community’s willingness to substitute between the different forms of capital and, in particular, an understanding of the value people place on different aspects of wellbeing, particularly those relating to natural and social capital. A critical component of this assessment is an evaluation of the welfare implications associated with losses of natural capital. This requires difficult decisions about trade-offs that could be better informed if more was known about how society values environmental outcomes relative to other goods and services.

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