Wealth, Welfare and Sustainability

Advances in Measuring Sustainable Development

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Preface and acknowledgements

This book is concerned with how current decisions about consumption and saving have an impact upon future well-being, and in particular how current measurable indicators can shed light upon the prospects for future well-being. It is concerned, in short, with the concept and measurement of sustainable development. This task is beset by conceptual and empirical challenges. Yet at the heart of this book lies a very practical concern – if sustainability is to mean anything at all it needs to be measurable. We feel a sense of urgency in this task. Because current systems of economic indicators do not clearly signal whether an economy is on a sustainable path, policy errors based on these indicators will continue to be made and perpetuated. Moreover, these errors have a long reach, since they affect not only current well-being but also the well-being of those living in the future. Our book builds upon a body of knowledge linking growth theory, asset accounting and indicators of sustainable development. Moreover, what we are particularly interested in is the empirical application of this accumulated knowledge.

We last approached the question of measuring sustainable development in Atkinson et al. (1997). With our co-authors in that volume we examined a broad array of proposals for the measurement of well-being and sustainability. The rationale for that approach was that a meaningful picture of whether countries are developing sustainably requires a judicious mix of indicators. Our aim in this current volume is more focused on the *economics* of sustainability and the role that saving in particular plays in determining whether economies are sustainable. There has been solid progress on this topic in the nearly 10 years since Atkinson et al. (1997), progress which merits a fresh look at the economic approach to measuring sustainable development.

This is a project that we began in the early 1990s with David Pearce. Sadly, David passed away suddenly in September 2005. Much has been and will be written elsewhere about David's immense contribution to the development of environmental economics as an academic discipline and a basis for policy. We heartily endorse all of these tributes. David was also famous for the generosity and encouragement that he showed to his many students and colleagues over the years, and we were certainly

beneficiaries. We would like to add our own words of gratitude for David's major contribution to the work that is contained in this volume. David was struck by how the handful of green national accounting studies that had began to emerge in the late 1980s presented both a novel and ambiguous picture of development prospects. The picture was novel because new and exciting data were being presented about economic progress in the presence of resource depletion and environmental degradation. The ambiguity stemmed from the fact that these 'green GDP' estimates (as they became known) did not in practice provide a clear signal about whether development was sustainable or not. David's contribution, published originally in Pearce and Atkinson (1993), was a key insight: focus instead on net saving, the amount of saving over and above the value of *total* asset consumption. If the adjusted net saving rate was negative, it was argued, then this provides an indication that a country is eroding the capital on which its development depends. Much of the data used to add empirical substance to these claims was of a provenance that – at least from today's vantage point – could best be viewed as illustrative. Nor was the theory behind this claim fleshed out in anything more than a rudimentary way, although a handful of notable earlier contributions had certainly pointed in this practical direction. Yet, in setting out his intuitions, David put down an important marker for future work: improve the numbers, tidy up the theoretical details, and an insightful and practical indicator would result. While this original intuition proved correct, the literature of the last 10 years or so shows that 'filling in the details' has been a protracted process. We hope that ours is a useful contribution to this work in progress. We also hope very much that David would have approved of the extensions and refinements of his vision that we set out in this book.

We would like to thank the following people for valuable insights and inputs, particularly in chapters 4, 6, 7 and 9: Susana Ferreira, Giovanni Ruta, Liaila Tajibaeva, Walter Nalvarte and Katharine Bolt. We would also thank our many colleagues, including John Dixon, John Hartwick, John Proops and Jeffrey Vincent, who have been important sources of advice and support as we carried out this work.

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1. Introduction

This book is concerned with how current decisions about consumption and saving have an impact upon future welfare, and in particular how current measurable indicators can shed light upon the prospects for future welfare. We are concerned both with the sustainability of development – with Pezzey (1989), we say that development is sustained along a development path if welfare does not decrease at any point along the path – and with development prospects as measured by the present value of welfare along a development path.[1] This places our emphasis squarely on wealth and what is happening to wealth, broadly construed, along any path.

The question of measurability is thus key. If current systems of economic indicators do not clearly signal that the economy is on an unsustainable path, then policy errors will be made and perpetuated. As will become clear below, this is more likely to be an issue for developing countries than developed, since these countries are more highly dependent on exhaustible resources as a share of economic activity. However, rapidly industrializing or developed economies – by degrading other environmental resources which might affect development prospects – are not immunized against these same questions.

The title of Weitzman's seminal paper on national income accounting – 'On the welfare significance of national product income in a dynamic economy' – neatly captures many of the key concerns of this book. Why, Weitzman asked, when one economic goal is to maximize consumption, do we measure income as the sum of consumption and investment? Weitzman's paper has spawned a very large literature, particularly with regard to the expansion of national income accounting to include a variety of natural assets. We will have occasion in this book to refer to much of this literature, but it suffices at this point to note that Hartwick (1990) and Mäler (1991) initiated the process of building the theoretical foundation for environmental accounting. Before that there was discussion of how a 'green' GNP (gross national product) could be measured and used, but little theoretical rigour was brought to bear on the problem (see, for example, Ahmad et al., 1989). So while these contributions presented a potentially novel and informative picture of development they raised as many (if not more) questions than they answered.

Pearce and Atkinson (1993) were among the first to posit a practical linkage between sustainable development and a measure of national wealth that was expanded to include natural resources. If sustainability is a matter of maintaining levels of welfare, then Pearce and Atkinson proposed that this was in turn a question of maintaining total wealth. They presented the first cross-country estimates of savings rates adjusted to reflect depletion and degradation of the environment. Subsequently Atkinson et al. (1997) and Hamilton and Clemens (1999) have updated both the theoretical argument,[2] linking savings and sustainability, and the empirical estimation of adjusted net savings rates – dubbed 'genuine' saving to distinguish it from traditional national accounting measures of net saving – for a wide range of countries. The World Bank has been publishing estimates of genuine saving as part of its *World Development Indicators* since 1999.

The key insight in the recent literature on an economic approach to national accounting is that future welfare is closely linked to current assets – or, to be more precise, to changes in real asset values. The notion of asset is quite broad, embracing produced capital, natural resources, human capital, knowledge, and pollution stocks (a type of negative asset or liability). A complete accounting must encompass all of these assets if consequences for future welfare are to be measured. This implies that measuring the sustainability of economies must go beyond simply 'greening' the accounts. It is important to note the deficiencies of standard national accounting in this context. The traditional measure of net saving, for example, simply deducts the depreciation of produced assets from gross saving. Since economies depend on a much wider array of assets for their development, this measure of net saving can say little about the changing asset base of the economy. This implies that traditional wealth and income measures are similarly incomplete.

This book is in many ways an extension of our work in Atkinson et al. (1997). But our aim in the current volume is more focused on the *economics* of sustainability and the role that the level of saving plays in determining whether economies are sustainable. The issues we will cover include population growth (existing assets have to be shared with more people), accounting for deforestation – forests are a multiple-use resource – and the effects of exogenous changes, both in technology and in resource prices. We also exploit the 30+ years of data on genuine saving to examine some important empirical issues: whether current saving actually measures changes in future welfare, savings and the resource curse (or 'paradox of plenty'), estimates of how rich economies would be if they had in fact invested resource rents over 30 years.[3] Finally we look at the pattern of international flows of resource rents in international trade using another model derived from the national accounts – Input/Output.

The individual chapters are introduced below. In each chapter we derive the relevant theory and then develop an empirical application of it. For those readers unfamiliar with the former, the resulting technical level may seem demanding. However, rather than relegate these details on each occasion to appendices, we feel that it is important to make it clear how practical, and measurable, insights emerge from seemingly abtruse theory. To reverse the logic, this also shows how empirical efforts to measure sustainability have their justification in the theory of economic growth.

Chapter 2 lays out the basic theoretical framework for the book. It develops a simple model with multiple assets and then derives the links between sustainability, changes in social welfare and genuine saving. It then derives a basic relationship between the change in current utility and the sign and growth rate of genuine saving (see also Hamilton and Hartwick, 2005). With the exception of the final empirical chapter on international flows of resource rents, each chapter can be viewed as an extension or refinement of the basic theoretical model. The general properties of genuine saving, however, do not change as alternative models are developed.

Much of the work on greening the national accounts has dealt with changes in total wealth – this is an important question, but it ignores the impact of population growth on measures of total wealth per capita. If population growth is an exogenous process[4] then we can informally express the change in wealth K per capita N as,

$$\begin{aligned}\Delta\left(\frac{K}{N}\right) &= \frac{K}{N}\left(\frac{\Delta K}{K}-\frac{\Delta N}{N}\right)\\ &= \frac{\Delta K}{N}-\left(\frac{\Delta N}{N}\cdot\frac{K}{N}\right)\end{aligned}$$

The first expression says that wealth per capita will be rising or falling depending on whether the (percentage) growth rate of total capital is greater or less than the population growth rate. This is nicely intuitive. The second expression shows that the change in wealth per capita is also equal to saving per person minus a 'Malthusian' term, the population growth rate times the total wealth per capita. The Malthusian term represents the wealth-diluting effect of population growth, whereby existing total assets have to be shared with the population increment each year. Chapter 3 develops the theory of asset accounting with exogenously growing population and shows the considerable effect this has on the sustainability analysis of many developing countries.

Turning from this measurement question, we proceed to a test of the various measures of saving – gross, net, genuine, and genuine minus the

Malthusian term – to determine whether the historical data support the notion that current saving is equal to the change in future welfare, as theory would suggest. In Chapter 4 we develop a less restrictive model of saving and welfare change than the models employed in the literature. This leads to a testable hypothesis: does base year saving equal the present value of future changes in consumption?

Chapter 5 examines another important empirical question on savings and growth. There is a large and growing literature on the 'resource curse', also called the 'paradox of plenty'. Contrary to theory and intuition, resource-abundant countries have generally experienced lower growth rates in per capita gross domestic product or GDP than less resource-rich nations. We test two key propositions: (i) does low genuine saving contribute to low economic growth? and (ii) does the combination of high resource-dependence and negative genuine saving lead to particularly bad growth performance?

There is a close relationship between measuring sustainability and rules for sustainability. As noted above, the Hartwick Rule – invest resource rents – leads to constant welfare over time. This policy rule can equivalently be stated as 'set genuine saving equal to zero at each point in time', so that the indicator of sustainability, genuine saving, actually enters into the rule.[5] Chapter 6 develops an extension of the standard Hartwick Rule, to the effect that genuine saving should equal a positive constant value at each point in time, and shows that this rule leads to unbounded rising consumption in a simple exhaustible resource (Dasgupta–Heal) economy. We then proceed to examine the question 'How rich would countries be if they had followed the standard or extended Hartwick Rules for the past 30 years?' The results are, in many cases, striking.

Forests are a particularly complex resource to treat in accounting systems. However, in order to demonstrate the relevance of the basic framework used throughout this book, these complications merit attention here. The complexity itself is due in part to the multiple functions provided by forests – these resources provide timber and non-timber products, carbon sequestration, external benefits (water regulation and soil protection) and habitat for biodiversity. Moreover, some of these functions are valued by those living outside of countries with such forests, as well as those within the host country itself. Chapter 7 develops a model of deforestation at the frontier, where forested land is cleared, the timber burned, and the land is converted to agriculture. The model suggests how deforestation, entailing a change in multiple services from land, should be accounted for. This approach is applied to empirical data for the Peruvian Amazon.

An issue highlighted in the theoretical literature but not reflected in national accounting systems is the role of exogenous change in economic variables. An example of this would be an improvement in a country's terms of trade. If the improved terms of trade are permanent then the country is better off: it could consume more now without affecting its development prospects (the present value of future consumption). This is just another way of saying that the improved terms of trade should somehow be reflected in current measures of saving.

The next two chapters examine different aspects of exogenous change. Chapter 8 estimates the potential impact on savings and income of exogenous versus (costly) endogenous technological change in developed and developing countries. Chapter 9 measures 30-year natural resource price trends and estimates the impact on saving for natural resource exporters if these trends were to continue into the future.

Chapter 10 employs a different accounting framework, Input/Output accounting, in order to detail the inter-country flows of natural resource rents in international trade. The methodology accounts for both direct flows of rents, in the form of exports of resources, and indirect flows in the form of resources that are used to produce non-resource exports. The approach is applied to an empirical data set on international trade and resource rent generation to determine which countries are net exporters, and which net importers, of resource rents and to examine the dependence of economies such as the United States, the European Union and Japan on direct and indirect resource inputs from other countries. Finally, Chapter 11 sums up and offers some concluding remarks.

In this book we aim to reflect the progress that has been made in the literature on asset accounting since Atkinson et al. (1997). Understanding the centrality of net saving measures in assessing both the sustainability of development and the prospects for social welfare has been a major step forward in the theory of asset accounting. This provides a strong motivation for the chapters which follow dealing with *how* to measure net saving. But it also provides the basis for the empirical chapters which examine the links between savings and growth.

NOTES

1. We will use 'welfare' and 'utility' interchangeably in this introductory chapter.
2. Other key theoretical contributions include Dasgupta and Mäler (2000) and Asheim and Weitzman (2001).
3. The Hartwick Rule (Hartwick, 1977) states that economies can enjoy constant welfare, even in the face of essential exhaustible resources and fixed technology, as long as they invest resource rents in produced capital.
4. This means that population is growing independently (that is, outside the control) of other factors. We discuss the implications of relaxing this assumption in Chapter 3.
5. We note the point in Asheim et al. (2003) that current governments concerned with sustainability cannot commit future governments to behave sustainably, so that applying the Hartwick Rule *today* cannot ensure sustainability. But we would argue that the Hartwick Rule still has value as a prescription that, if followed at each point in time, will yield sustainability.

2. Wealth and social welfare

INTRODUCTION

This chapter will lay the basic theoretical foundation for much of the empirical work featured in the balance of the book. It proceeds from the consideration of measures of current utility to the problem of maximizing the present value of future utility. The properties of the constructs underlying this maximization problem provide the necessary framework for linking wealth, welfare and sustainable development.

If total wealth is related to social welfare, then changes in wealth should have implications for sustainability – this is the basic intuition of Pearce and Atkinson (1993). For optimal economies – economies where a planner can enforce the maximization of social welfare (that is, the maximization of the present value of utility) – a number of results have made the link explicit. Aronsson et al. (1997, equation 6.18) show that net saving in utility units is equal to the present value of changes in utility, using a time-varying pure rate of time preference. Hamilton and Clemens (1999) show that net or 'genuine' saving adjusted for resource depletion, stock pollutant damages and human capital accumulation is equal to the change in social welfare measured in dollars. They also establish that negative genuine saving implies that future utility must be less than current utility over some interval of time.

These results depend on the assumption that governments maximize social welfare. Dasgupta and Mäler (2000) show that net investment is equal to the change in social welfare in a non-optimizing framework where a resource allocation mechanism is used to specify the mapping from initial capital stocks to future stocks and flows in the economy. This result depends on accounting prices for assets being defined as the marginal changes in social welfare resulting from an increment in each asset (that is, accounting prices are the partial derivatives of the social welfare function). Arrow et al. (2003a) explore the accounting issues under a variety of resource allocation mechanisms.

The result linking net saving to changes in social welfare in Aronsson et al. (1997) can be extended to show that current saving equals the present value of changes in consumption in an optimizing economy. Dasgupta (2001) shows that the same is true in non-optimal economies where accounting prices are defined as above. Hamilton and Hartwick (2005) show that this relationship holds in an optimal economy, but their proof clearly only requires that the economy be competitive. This relationship between current saving and the present value of future changes in consumption is exploited in an empirical test of genuine saving in Chapter 4.

These main results on net saving and social welfare are derived below for a general multi-asset optimizing model.

In most of this book we assume that there is a fixed population. This permits us to focus on the pure asset accounting aspects of the problem, rather than the interaction between changes in assets and population growth. If population grows over time, as in virtually all developing countries, then changes in total wealth should take into account the change in population. Dasgupta (2001) shows that wealth per capita is the correct measure of social welfare if certain conditions are met: (i) population grows at a constant rate; (ii) per capita consumption is independent of population size; and (iii) production exhibits constant returns to scale. This book calculates wealth per capita as the measure of social well-being under these assumptions, as do Arrow et al. (2004). The measure of the change in wealth per capita derived in Chapter 3 below includes a specific adjustment for the immiserating effects of population growth. Arrow et al. (2003b) identify the correct welfare index in more general situations.

MAXIMIZING WELFARE OVER TIME

For a fixed population we will be concerned with maximizing the welfare of the 'representative individual'. This individual's utility function is assumed to embrace both consumption C and the levels of a series of N assets such as knowledge, healthfulness and natural and environmental resources. These assets are denoted as X_i and the utility function as $U(C, X_i)$. Assets can be 'bads', such as a stock of carbon dioxide, as well as goods such as a pristine natural area or commercial resources such as stocks of timber and minerals. While it is unlikely that individual welfare would depend directly upon the size of a reserve of oil in the ground or the stock of produced assets, it is convenient to define the problem in this very general way, since particular issues can easily be defined as special cases of the general problem.

Production proceeds via a production function $F(K, X_i, \dot{X}_i)$ which yields output of a homogeneous good which may be consumed, invested in produced capital K, or spent in amounts e_i for the control of the levels of the different stocks. That is, we assume control functions f^i such that $\dot{X}_i = f^i(X_i, e_i)$.

Util-denominated social welfare V is defined to be the present value of future utility, so that $V = \int_t^\infty U(C(s), X_i(s))e^{-\rho(s-t)}ds$. The pure rate of time preference ρ is fixed, while all other variables are assumed to be functions of time t, unless explicitly subscripted otherwise. This gives rise immediately to the following relationship:

$$U + \dot{V} = \rho V. \tag{2.1}$$

This expression hints at the linkage to national income accounting, since it states that utility plus the change in welfare is just equal to the 'return' on welfare.

The economic problem for this simple economy is to maximize the present value of future utility, that is, to maximize util-denominated welfare. This can be stated formally as follows:

$$\text{Max } V = \int_t^\infty U\big(C(s), X_i(s)\big)e^{-\rho(s-t)}ds \text{ subject to:}$$
$$\dot{K} = F - C - \sum e_i$$
$$\dot{X}_i = f^i(X_i, e_i).$$

THE HAMILTONIAN FUNCTION AND GENUINE SAVING

Solving this optimal control problem requires application of the Maximum Principle, which implies, among other things, that in order to maximize util-denominated welfare it is necessary to maximize the current value Hamiltonian function H at each point in time. For shadow prices γ_i this function is defined as follows:

$$H = U + \sum \gamma_i \dot{X}_i.$$

Note that for notational convenience we are assuming that $X_0 \equiv K$ – the stock of produced capital is not assumed to enter into the utility function, however. The shadow prices γ_i are defined in utils, with $\gamma_0 = U_C$ (the marginal utility of consumption). Shadow prices in consumption units can be derived by dividing these prices by the marginal utility of consumption:

$$p_i = \frac{\gamma_i}{U_C}.$$

Now it is possible to define genuine saving G precisely: it is equal to net investment[1] valued at shadow prices, so that,

$$G = \sum p_i \dot{X}_i. \tag{2.2}$$

From this it follows immediately that,

$$H = U + U_C G. \tag{2.3}$$

The Hamiltonian may be described as the utility prospect for the economy, since it combines both current utility and the contributions to future utility from current investment.

KEY RESULTS CONCERNING SAVINGS, WELFARE AND SUSTAINABILITY

The fundamental link between the Hamiltonian function and util-denominated welfare is derived in Appendix 2A.1. There it is shown that,

$$H = \rho V, \tag{2.4}$$

expressions (2.1), (2.3) and (2.4) together imply that,

$$U_C G = \dot{V}. \tag{2.5}$$

Genuine saving is equal to the change in social welfare divided by the marginal utility of consumption.

The third principal result on welfare and saving is also derived in the Appendix, where it is demonstrated that,

$$\dot{U} = U_C G\left(F_K - \frac{\dot{G}}{G}\right). \tag{2.6}$$

Here F_K is the interest rate for the economy. By rearranging terms and expanding the expression for the change in utility, this yields

$$\dot{C} + \sum \frac{U_{X_i}}{U_C} \dot{X}_i + \dot{G} = F_K G. \tag{2.7}$$