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The Usefulness of Sustainability Indicators for Policy Making in Developing Countries: The Case of Madagascar

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Abstract

In this article, the authors compare the practical policy implications that can be derived from the calculation, from 1980 to 2004, of three aggregate sustainability indicators for Madagascar. The chosen indicators are the adjusted net saving (ANS), the genuine progress indicator (GPI), and the ecological footprint (EF). The results are twofold. First, these indicators provide very different messages regarding the sustainability of Madagascar's recent development. The first one indicates a development path that is not sustainable, whereas the latter two do not indicate anything to be alarmed about. Second, they yield a set of widely diverse policy implications. The EF provides policy recommendations that are too general for poor countries rich in natural resources, such as Madagascar. The GPI highlights several social issues, but its interpretation in terms of sustainability remains ambiguous as it is a mix between a present welfare and a sustainability indicator. In the end, the authors consider that the ANS provides the most consistent information about the sustainability of Madagascar's recent development path.

Keywords

sustainable development, Madagascar, ecological footprint, adjusted net saving, genuine progress indicator

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Introduction

There is a growing literature on how to measure development and how to assess the sustainability of that development. Welfare economists pointed out many years ago the limitations of the gross domestic product (GDP) as a welfare indicator. There is now a wide consensus in the political sphere that other indicators are needed to measure the evolution of present welfare and the sustainability of actual development paths. One of the most recent example is the Commission on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2009) set up in France.

In the literature on aggregate sustainability indicators, researchers tend either to calculate, improve, or criticize one specific indicator (see, for example, Talberth, Cobb, & Slattery, 2007, for the genuine progress indicator [GPI], or Fiala, 2008, for the ecological footprint [EF]) or else to concentrate on comparing the validation (or not) of a specific sustainability criterion (see, for example, Hanley, Mofatt, Faichney, & Wilson, 1999; Nourry, 2008; Siche, Agostinho, Ortega, & Romeiro, 2008). However, the information provided by these indicators is rarely translated into policy recommendations.

The question we ask is, what use these aggregate indicators are for policy recommendation? Our work focuses specifically on aggregate indicators on a country scale. The chosen indicators are the adjusted net saving (ANS), the GPI, and the EF. We estimated these indicators from 1980 to 2004. Although we are aware of many limitations of the chosen indicators, we wanted to test their usefulness in policy debates by deriving and comparing their main messages. Are these indicators substitutes for one another because they provide the same information and policy recommendations? Or are they complementary because each one provides specific information?

To answer our main question thoroughly, we start by discussing the theoretical and methodological groundings and limitations of the three chosen indicators. We then propose a case study on an African country—Madagascar—since most of the detailed empirical studies on aggregate sustainability indicators have been undertaken primarily in rich or emerging countries, with very little focus on African countries.

Madagascar is very much dependent on its natural resource base. In 2005 the GDP was US$989 per capita, of which agriculture accounted for around 25% (World Bank, 2005); 75% of the population lives in rural areas, and 15% of the rural area is covered with forests (Food and Agriculture Organization [FAO], 2005), which are renowned worldwide for their endemic species and their biodiversity. The environmental degradation of the island is severe. Deforestation rates are high in some parts of the island, soils are being eroded, and many ecosystems have been damaged. As a consequence, Madagascar provides an interesting case to test and analyze sustainability indicators.

First, we analyze the three indicators through an identical analytical grid: (1) we present the definition of the sustainability that the indicator claims to measure, and the indicator itself with its theoretical framework; (2) we briefly review the main criticisms in the existing literature; and (3) we present the kind of information the indicator can theoretically provide to policy makers when applied to a specific country. Then, we present the calculations of the three indicators made for Madagascar (several adaptations had to be made to adjust to data availability) and the policy implications that can be derived from the results. Finally, we draw conclusions about the usefulness of these indicators for policy makers in the context of Madagascar.

Description of the Three Chosen Indicators

Adjusted Net Saving (ANS)

An economy's productive base is defined as the set of four different capital stocks: physical capital (infrastructures, buildings, etc.), human capital (education level, knowledge, health, etc.), social capital (institutions, level of trust, etc.), and natural capital (mineral resources, soil resources, forests, fish resources, etc.). Capital-based indicators such as green national product or the ANS are built on this framework. The definition of sustainable development that these indicators are supposed to assess is an economic transcription of the Brundtland Commission's definition. A development path will be considered sustainable if utility (consumption being frequently used as a proxy) does not decline at any point along the development path.

The ANS is a measure of the variation of the wealth (or aggregate capital) of a country, as indicated in Equation 1:

$$ANS = p_{Kp}.K_p + p_{Kn}.K_N + p_{Kh}.K_H \quad (1)$$

where K_P is physical capital, K_N is natural capital, K_H is human capital, and p_{Ki} are shadow prices of capital K_i.

As demonstrated in Hamilton and Hartwick (2005), under some simplified assumptions, the variation of the ANS equals the variation of the present value of future consumption. Therefore, 1 year of positive ANS does not signal sustainability. Weak sustainability is obtained only if the ANS stays positive over all the period examined. A negative ANS in a given year indicates that development is unsustainable in the sense that the variation of consumption will be negative in the future.

According to some critics, most of the theoretical green accounting literature from which capital-based indicators like the ANS derives relies on a large set of critical simplifying assumptions such as constant population, no technological change, closed economy, economy at a full optimum, and convex commodity transformation possibility (Dasgupta & Mäler, 2000). However, although these assumptions may seem unrealistic and render the indicators poorly reliable, there is continuous progress toward relaxing these assumptions (see, for example, Hamilton & Bolt, 2004, or Vouvaki & Xepapadeas, 2008).

Some critics also believe that the ANS can be only a weak-sustainability indicator since it relies on the assumption of perfect substitutability between the different assets. This implies that a loss of natural capital, in welfare terms, can be made up for by an increase in other forms of capital. The issue was raised early in the debate on sustainability and is disputable especially for developing countries that may not have access to the technologies to substitute natural with physical capital. Few people having attempted to empirically assess the degree of substitutability between different forms of capital, the question remains open (Markandya & Pedroso-Galinato, 2007, is an important recent attempt). However, the computation of the ANS is a mere first step toward assessing sustainability. A country that is not weakly sustainable will not be strongly sustainable, as strong sustainability requires not only nondeclining wealth (the total amount of capital) but also nondeclining natural capital (or at least "critical natural capital"). Moreover, many of the concerns voiced by strong sustainability proponents can be introduced theoretically into a weak sustainability framework. In the real world, ecosystems have highly complicated dynamics, often nonlinear with threshold effects (Muradian, 2001), whereas the dynamics of natural capital in economic models remain very simple. For example, in Madagascar such ecological shifts could occur in the dry spiny forests of the Androy region. As the forest area is already fragmented, an ecological shift could rapidly reduce connectivity between forest patches, with consequences for pollination and thus for crop production (Orjan, Maria, Norman, Lundberg, & Elmqvist, 2006). In theory, shadow prices should be able to reflect the possibility of crossing a threshold in the rates of substitution between the different forms of capital. Determining such shadow prices is, however, a difficult exercise that provides room for collaborative work between ecologists and economists.

Some critics are concerned about the comprehensiveness of the capital assets considered in the different empirical applications. For example, in World Bank calculations (World Bank, 2006), human capital variation can be seen as poorly integrated into the ANS. For example, human capital gains or losses are calculated only from education expenditures and damage to health by air pollution, not from variations of the quality of the educational system or of the life expectancy. Health expenditures, critics say, should be considered not as consumption expenditures but as investments that increase life expectancy and workers' productivity in the long term, like research and development expenditures that build a form of "knowledge capital." Moreover, there is actually no consensus on the different required adjustments, such as, for example, on how to include defensive expenditures and pollutions in the accounting framework (Hamilton, 1996) or on how to value natural capital depletion, because several competing methods exist.[1]

In the end, the usefulness of the ANS as a sustainable development indicator seems questionable, considering the theoretical restrictive framework and the poor treatment of such capital assets as intangible (i.e., human and social) capital. Compared to many other indicators, however, one considerable strength of the ANS is that it can be empirically tested. Several authors have been testing the relationship between the sign of ANS and trends in observed future consumption or welfare (Ferreira, Hamilton, & Vincent, 2008; Gnegne, 2009; Hamilton, 2005). Results show that, even with all the imperfections stressed earlier, the ANS indicator can be used as a proxy of future welfare changes, particularly in developing countries.[2]

What Is the Role of the Adjusted Net Savings (ANS) Indicator for the Policy Debate on Sustainability?

If the development process is conceived of as the management of a portfolio of assets, with growth occurring through the accumulation of the different forms of capital, it is possible to identify different policy levers that can be inferred from the components of the ANS. In order to avoid a negative ANS, one should invest to increase or to reverse a decrease of the capital assets. However, the different investment options should be prioritized by means of a social cost–benefit analysis. Such an analysis would provide a framework for balancing investments between the different capital assets (through macro or more sectoral policies). Therefore, the ANS is a tool that helps to focus on long-term determinants of development and raises the awareness of politicians (particularly those not involved in environmental management, such as finance ministries) on key environmental issues.

Genuine Process Indicator (GPI)

The GPI is an indicator that combines two tasks: "to define and measure 'consumption' in a way that provides a better approximation of actual welfare than the simple measure of marketed goods and services that appears in the national accounts; and to account for the sustainability of consumption by incorporating measures of changes in the value of capital stocks" (Hamilton, 1997). Equation 2 gives the general structure of the indicator:

$$GPI = C_p + F + \Delta p_K.K \qquad (2)$$

The starting item is private consumption expenditures, C_p, which is adjusted with an index of inequality to account for the fact that one more unit of consumption yields a greater marginal utility for the poor than for the rich, that is, the fact that US$100 more in income is of much greater importance to a poor person then a rich person. F accounts for all the other flows of services (or disservices) contributing, positively or negatively, to present welfare: nonmarketed services (derived from unpaid household labor, volunteering, etc.), services provided by durable goods, services provided by public capital, defensive private expenditures (which offset environmental degradation but do not improve welfare), social problems that affect present welfare (such as crimes, divorces, underemployment, etc.), and some environmental degradations that affect present welfare. Finally, several capital stock variations $\Delta p_K.K$ are added, such as natural capital depletion. Some additional adjustments are made to account for net capital growth and net foreign lending or borrowing. A net positive capital growth as well as net foreign lending implies an increased consumption in the future (in the case of lending when the loans will be reimbursed) and therefore are added to the GPI. Conversely, net foreign borrowing will reduce consumption and/or capital growth in the future and is therefore subtracted.

We focus here on the GPI instead of the Index of Sustainable Welfare, which belongs to the same family of indicators. Although they are quite similar, there are some differences.

As compared to the GPI, the Index of Sustainable Welfare excludes both public and private defensive expenditures on health and education and includes deductions of cost estimates for loss of leisure time, underemployment, and loss of forests for the computation of the index of sustainable welfare.

The interpretation of the GPI in terms of sustainability is not straightforward, as the actual definition used for sustainability is not always very clear. Hanley et al. (1999) considered that "a rising path of the index of sustainable welfare over time would indicate that an economy was becoming more sustainable,"[3] reflecting a vision of sustainability as an equilibrium between economic, social, and environmental factors. But such a definition gives no information on the ability of the society to maintain this level of present welfare. Lawn (2003) proposed a theoretical framework based on the Fisherian income concept, which can be described as the services or "psychic income" enjoyed by the consumers of human-made goods. This would be some form of utility-based measure of income, as opposed to a production-based measure that would correspond to a Hicksian income. Actually, there is still much confusion regarding the terminology used and the difference between Hicksian and Fisherian income. In the end, the link between the indicator and sustainability remains unclear.

The GPI has thus been criticized for its lack of any theoretical foundation, particularly in terms of sustainability interpretation. First, Neumayer considers it a present welfare indicator that cannot be considered as a sustainability indicator. Harris (2007) likewise considers that "Fisher's concept says nothing at all about sustainability." In the end, one can consider that the GPI is a mix between a present welfare indicator, based on current flows of utility, and a sustainability indicator, based on the variations of a stock producing utility in the future. The interpretation of the GPI (particularly the natural capital stock variation) in terms of sustainability policies is thus quite ambiguous, and the GPI must not be confused with some form of Hicksian income. Second, the chosen adjustments and contributors to present welfare can seem arbitrary and subjective, reflecting mainly a specific idea of how society should be. Finally, because of data limitations, many technical assumptions are made to calculate the GPI. Several competing methods exist, for example, concerning the valuation of the depletion of natural resources, the deduction of defensive expenditures, or the cumulative cost of long-term environmental damage (see Neumayer, 2004).

What is the role of the genuine process indicator (GPI) for the policy debate?

By defining development more widely than simply income, the value of the Genuine Progress Indicator in terms of its policy implications lies in its questioning of development orthodoxy and creation of a space in which alternative development prescriptions are encouraged. (Clarke & Lawn, 2008)

Cobb and Daly (1989) considered that the GPI highlights policy areas that are usually poorly integrated, such as income inequality reduction or pollution. We also believe that the GPI should be used mostly as a descriptor of the evolution of current welfare and cannot be considered as a sustainability indicator. If we consider that the societal objective is to increase the GPI so as to balance economic, social, and environmental policies, it is possible to derive several policies limiting negative contributors and improving the positive ones. However, as mentioned earlier, the substitutability of the different components of welfare can be questioned, especially for nonmonetary welfare. Like the ANS, the GPI should also be completed with cost–benefit analysis.

The Ecological Footprint (EF)

In the most recent report of the Global Footprint Network on Africa (Global Footprint Network, 2008), sustainable development is "a commitment to improving the quality of human life while living within the carrying capacity of supporting ecosystems" (quoted from International Union for Conservation [IUCN], 1991). Here again, we have the development dimension, "improving the quality of human life," distinct from its sustainability: "living within the carrying capacity of supporting ecosystems." This dichotomy is often represented as a graph, with the Human Development Index (HDI) as an indicator of current welfare (quality of human life) on the x-axis versus the EF as a measure of human demand on the biosphere on the y-axis. Specific thresholds for the human development index (above 0.8) and the EF (below 1.8 per capita) characterize a sustainable development quadrant (Global Footprint Network, 2006). We focus hereafter on the sustainability dimension, through the analysis of the EF.

The EF was introduced by Wackernagel and Rees (1995) as a measure of the sustainability of a population's consumption. It compares the actual human consumption of natural resources with the carrying capacity of the earth. This human consumption (mainly energy, food, and timber) is translated into the amount of productive land required to produce this consumption, which is called an EF, like the indicator itself. It can be compared with the existing land area to assess the sustainability of the actual consumption pattern. The ideas transmitted by the EF are clear and easily understandable.

> Having a global Ecological Footprint lower than the global biocapacity has been proposed as a minimum criterion for sustainability, not a guarantee of it. A global Ecological Footprint higher than global biocapacity (which means harvesting resources or emitting wastes faster than the planet can produce or absorb them, respectively) ensures unsustainability. (Kitzes, Moran, Galli, & Wackernagel, 2009).

There are several criticisms of the indicator (Van den Bergh & Verbrugen, 1999; Fiala, 2008; Neumayer, 2003). First, it is a static indicator. It cannot accommodate long-term effects and the stock dimension of natural capital (i.e., the depletion of the stocks of natural assets will reduce consumption in the future and not necessarily affect current flows). It is based on flow accounts and not stock accounts, for the bioproductivity of land can increase at the expense of longer-term impacts. For example, mechanized agriculture will increase land yields in the present time, leading to a greater biocapacity. However, it can lead to soil degradation, with impacts on long-term yields. Second, another criticism is that the comparative advantages of countries rich in natural resources cannot be accounted for by the EF indicator. Whereas trade can distribute the environmental burden spatially, this indicator possesses an antitrade bias. This point can be taken further, to take into consideration the fact that the EF can be interpreted only at a global level. At the individual countries level, the variations of the different parts of the footprint over time are the only useful information. Another problem with this indicator is that it cannot cover impacts for which no regenerative capacity exists (e.g., pollution in terms of waste generation, toxicity, etc.). Third, the EF is claimed to be a strong sustainability indicator because it somehow insists on preserving natural capital. This is true, irrespective of how important substitutability between the different components of natural capital is assumed to be. Finally, two important disputed methodological issues are the choice of the conversion factors used to convert consumption into global hectares and the way energy consumption is treated. For many countries, the EF is dominated by energy, translated into global hectares through the amount of land necessary to sequester greenhouse gases emitted to produce energy.

What is the role of the ecological footprint (EF) for the policy debate on sustainability?

The Footprint Network website claims that

National governments using the Footprint are able to: (1) Assess the value of their country's ecological assets; (2) Monitor and manage their assets; (3) Identify the risks associated with ecological deficits; (4) Set policy that is informed by ecological reality and makes safeguarding resources a top priority; (5) Measure progress toward their goals.

Table 1 presents more specifically the framework used to interpret the EF in terms of policy implications, distinguishing the supply side and the demand side. On the supply side, several policies are presented to increase the biocapacity such as land management policies. On the demand side, policies to decrease the EF are introduced such as family planning to decrease the population growth or technological innovation to increase resources' productivity.

Table 2 presents a synthesis of the main issues tackled for each indicator, summarizing the results of the analytical grid that we used.

Results

Adjusted Net Savings (ANS)

To compute the ANS, we adjust GDP with final consumption (gross saving = GDP – final consumption), physical capital depreciation (net saving = gross saving – physical

Table 1. Policy Implications Derived From Ecological Footprint Interpretation

	Policy levers	Derived policies
Supply side	Quantity of biologically productive area	• Good land management (to limit degradation and thus loss of bioproductive land)
	Bioproductivity of these land	• Good land management • Technology
Demand side	Population	• Women education, economic opportunities, health care, family planning to reduce family size
	Per capita consumption	• Need to increase for African countries
	Resource intensity	• Technical innovation to reduce material use and waste in the production process

Source: Global Footprint Network, 2008.

Table 2. Synthetic Comparison of the Different Indicators

	Adjusted net saving	Ecological footprint	Genuine progress indicator
Theoretical framework	• Neoclassical growth models	• "Carrying capacity" (Rees, 1992; Wackernagel, 1994)	• "Measure of economic welfare" (Nordhaus & Tobin, 1972) • "Fisherian income" (Lawn, 2003)
Sustainability definition	• Nondeclining capital stock (weak sustainability)	• Nondeclining "natural capital" (strong sustainability)	• A development that increases present welfare
Unsustainability condition	• Adjusted net savings < 0	• Ecological footprint > biocapacity	• No indication
Advantages	• Theoretically consistent • Empirically testable	• Easy to understand • Intuitive	• Exhaustive • Social adjustments
Main limitations	• No consensus on all adjustments • Unrealistic assumptions • Not exhaustive • Substitutability of assets	• Static • No technological change • Externalities not considered	• Normative • No agreed theoretical foundations • Not a sustainability indicator

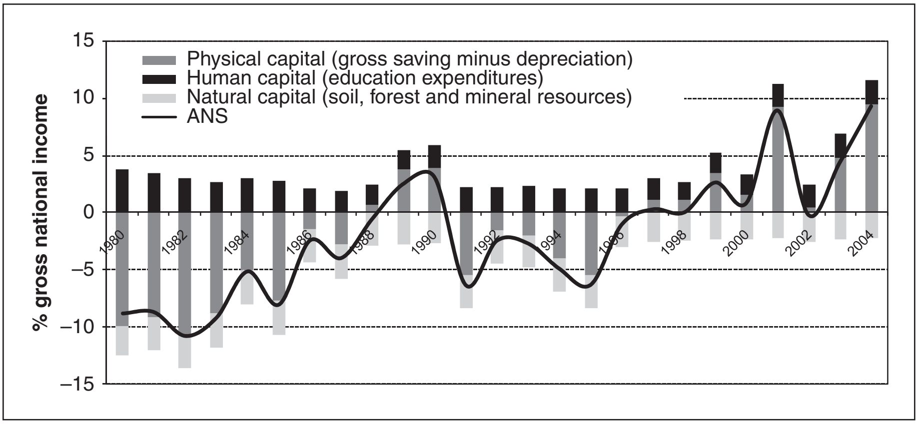

Figure 1. Adjusted net saving breakdown between 1980 and 2004 for Madagascar

capital depreciation); then we subtract natural capital depletion (subsoil assets, forests, and soils) and pollution costs (indoor and outdoor air pollution), and finally, we add human capital increase (measured by education expenditures). Compared to previous World Bank calculations (World Bank, 2005), ours have several improvements. We use more local data, and we add soil degradation and indoor air pollution costs. Soil depletion was valued as net nutrient depletion multiplied by the price of lost nutrients. A human capital approach was used to assess the impact of indoor air pollution impact. Damages to humans in terms of mortality were assessed. We also improve on the methodology to assess damages from carbon dioxide emissions, building on the methodology developed in Arrow, Dasgupta, Goulder, Mumford, and Oleson (2007). Our estimate is thus more complete as it covers a broader set of assets.

In the end, ANS = gross saving – physical capital depreciation – natural capital (cropland and forest) depletion + education expenditures – air pollutions damages (outdoor and indoor) – CO_2 damages. More details are given in Appendix A.

The evolution of the ANS is presented in Figure 1,[4] and its detailed composition in Table 3 (for the year 2005). It shows that the ANS has been negative throughout most of the period, indicating an unsustainable development trend. However, since the early 1990s, it has been on an upward curve and even becomes positive after 2002 (it was very negative in 2002 because of political unrest). Because a negative ANS indicates the growth rate of consumption will become negative in the future, one can say that Madagascar's growth was unsustainable in the 1980s and 1990s, but since 2002 is on a weakly sustainable development path. As shown in Figure 1, the upward trend is mainly driven by an increase of physical capital. Education expenditures are an important positive contributor to the human capital stock increase. The other components (pollution costs and natural capital depletion) are depleting total wealth. Physical capital depreciation, soil degradation, and indoor pollution have a strong downward effect on the ANS.

Table 3. Adjusted Net Saving Components for the Year 2005 (% of Gross National Income)

Items	%
Gross national saving	+9.56
Consumption fixed capital	–8.11
Education expenditure	+1.80
Net forest depletion	0
Soil depletion	–2.36
CO_2 damage	–1.0
PM_{10} urban pollution	–0.41
Rural Indoor pollution (morbidity + mortality)	–2.8 (1.1 + 1.7)
Adjusted net savings	–3.3

The main policy recommendations that can be derived for each type of capital are presented in Table 4.

One can see that these are questions and not already well-defined policies, since the ANS merely describes the current development path. However, its interpretation yields several messages about Madagascar. First, to some extent, the ANS can be used as a tool to prioritize environmental issues and balance investments between natural, reproducible, and human capital. But it is important to bear in mind that the ANS computation has to be completed with cost–benefit analysis to lead to policy recommendations and answer the issues it raises. There is no direct link between the relative importance of one specific capital depletion and the need to invest in the restoration or protection of that capital. Second, the ANS can be interpreted as an extended Hartwick rule (this rule defines the amount of investment in physical or other capital assets that is needed to exactly offset declining stocks of nonrenewable resources). A possible implication of a negative ANS is that actual consumption is too high compared to the actual level of investments needed to maintain the productive base. This raises ethical debates for a country such as Madagascar where consumption levels are particularly low. The ANS moreover focuses attention on intergenerational equity, dealing with average consumption levels, whereas intragenerational issues are also critical. Third, the portfolio of assets considered here is not exhaustive, as investments in health or knowledge capital, for example, are not considered. The inclusion of these could enhance the productivity of the existing assets (through technological progress) and thus would counteract a part of the wealth depletion. However, as noted earlier, the ANS can be used even at this imperfect stage as a sustainability indicator. Thus, policy recommendations based on this indicator remain valid.

Genuine Process Indicator (GPI)

Methodologies to calculate the GPI are widely diverse. In this section we apply the methodology developed in Talberth et al. (2007) although, due to data limitations, we

Table 4. Main Policies Implications Derived From the Adjusted Net Saving Interpretation

Asset considered		Main results	Policies involved—how to boost investment in this asset?
Physical capital		• Low national gross saving • High depreciation	• What monetary and fiscal policies boost gross saving rates and limit physical capital depreciation?
Natural capital	Nonrenewable	• Important exhaustible resources depletion	• Do fiscal policies capture well the rent? • What about the reinvestment of the rent? • (Hartwick rule)
	Renewable	• Low renewable capital depletion	• Do existing natural resource policies encourage overexploitation? • How to boost the productivity of these assets?
Human capital	Education	• Important investments in education	• Are enough resources reinvested into education? • Are these expenditures effective?
	Health	• High human capital depletion because of air pollution/ unsafe water supply	• Are pollutant emissions beyond the socially optimal levels? (level where marginal damages = marginal abatement costs) • What are the most cost-effective policies to reach this level?

could not be as exhaustive for Madagascar. Talberth et al. is one of the most recent and exhaustive methodology we've found. We adjust consumption for inequalities (by means of Gini coefficients), domestic, informal and volunteer works, nondefensive public expenditures (health and education), services from the road network, indoor air and water pollution, loss of primary forest, commuting time lost, net capital investment, and net change in foreign position (mainly external debt).

In the end, we have GPI = final consumption (adjusted for inequalities) + domestic and volunteer work value + public nondefense expenditures (health and education) – indoor air pollution cost – water pollution cost – loss of primary forest – commuting cost – CO_2 damages + net capital investment + net change in foreign position. The detailed assumptions and calculations are presented in Appendix B.

The evolution of the per capita GPI between 1982 and 2004 is presented in Figure 2. Figure 3 shows the relative importance of the main contributors of the GPI.

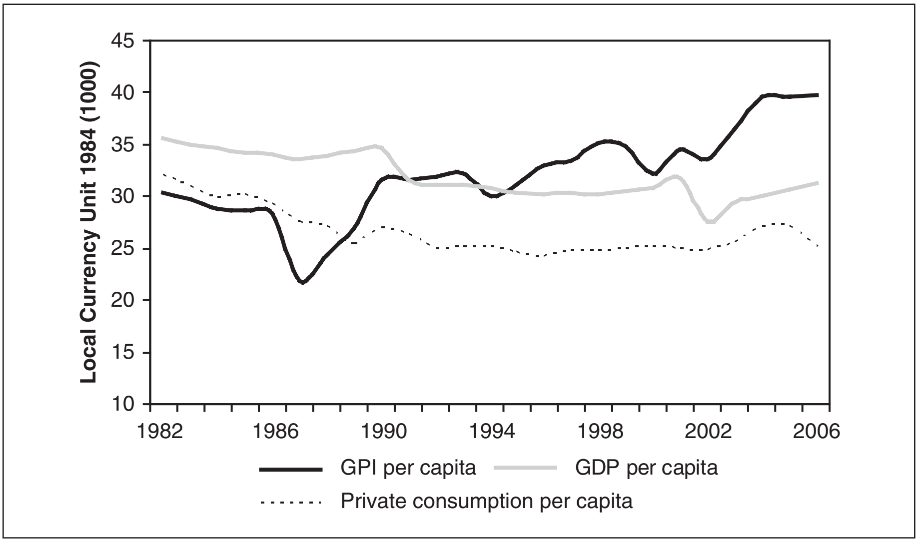

Figure 2. Per capita genuine progress indicator, private consumption, and gross domestic product between 1982 and 2000

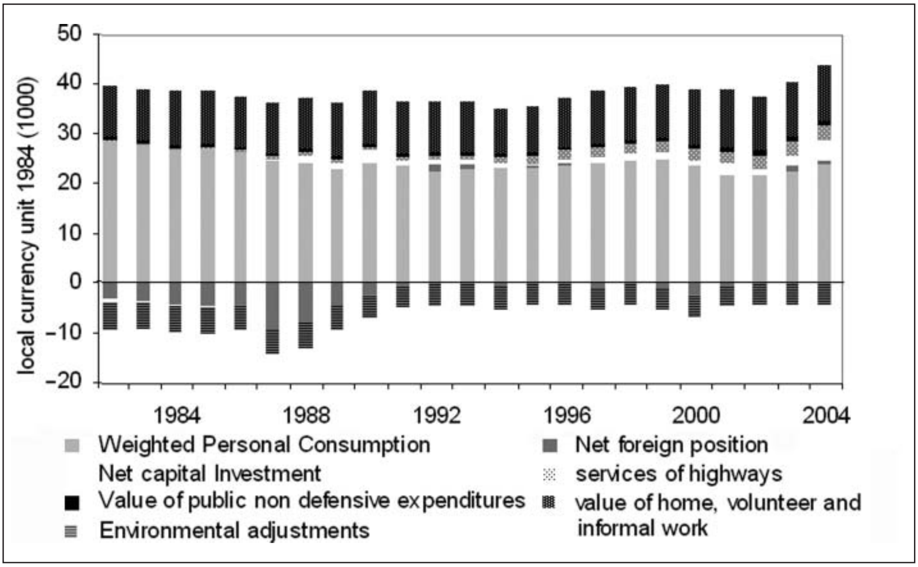

Figure 3. Decomposition of economic, social, and environmental adjustments of the genuine progress indicator between 1980 and 2004

One can see that, per capita GDP, private consumption and the GPI have different trends. The introduction of social and environmental adjustments thus gives quite a different picture of Madagascar's development path. We can distinguish two different periods. Before 1987, the GPI decreased sharply, mainly because of the country's debt that increased threefold during the 1980s, and a decrease of per capita private consumption. From 1987 to 2004 the GPI increased steadily for several reasons. The debt burden was decreasing, large investments were made in reproducible capital (net capital investment), and inequalities decreased in the 1990s (although they increased again after 2000). Social adjustments are also significant. Domestic work and time spent on transportation account for a large share of the GPI. On the other hand, environmental adjustments are quite low. These are mainly air and water pollution costs.

Any interpretation of the GPI would tend to focus policy debates on recent rising inequalities, the high cost of water and air pollutions, and the need to be cautious about the net foreign position (mainly the external debt). Naturally, interpretation stresses the importance of increasing final consumption, which is the main contributor of the GPI.

The policy-guiding value of the GPI in terms of sustainability is very disputable, as explained previously. Nevertheless, it is an attempt to obtain a comprehensive measure of current welfare. As such, it provides some information on the evolution of social, environmental, and economic contributors to present welfare. Like with the ANS, there is no direct relationship between the relative importance of a specific item (or its evolution over time) and the social profitability of investing in it. It would be necessary to complete the investigation with a cost–benefit analysis in order to compute the most socially profitable trajectory of the different components. The GPI stresses social or environmental problems usually not considered in traditional indicators. The adjustments made to account for these problems are, however, sometimes quite disputable and normative, reflecting mainly what an idealistic society should be. The indicator, therefore, becomes highly sensitive to political objectives. The evolution of the GPI contradicts to some extent the recurrent negative indications of the ANS, which means that consumption should decrease over time. The evolution of per capita consumption over time is indeed decreasing, whereas the GPI per capita is increasing.

The Ecological Footprint (EF)

We have not made any new calculations or adjustments for the EF. We used data from the *Africa Factbook* (Global Footprint Network, 2006). The evolution of the EF between 1980 and 2004 is presented in Figure 4. First, the EF of Madagascar, like the one of many African countries, is very small. The biocapacity of the country, although shrinking because of population growth, remains much larger than its actual use. In 2000 the supply of biologically productive land per capita was 3.15 global hectares, which is fairly substantial. This has to be balanced with the average demand for ecological services of 0.7 global hectares, which is very low and is consistent with the low

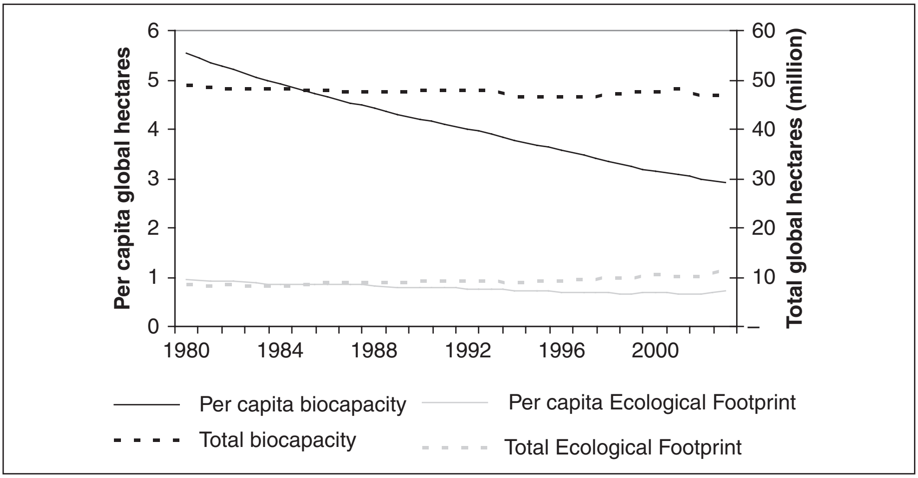

Figure 4. Biocapacity versus ecological footprint (total and per capita) between 1980 and 2004 for Madagascar

consumption level. Agricultural activities (0.29 for crops and 0.15 for pastures) and fuel-wood collection (0.12) account for the largest share of the EF. This means that the country could be currently on a sustainable development path. However, if the current trend continues, it could become unsustainable. If we look at per capita results, the EF was slightly lower in 2004 than it was in 1960.

Thus, Madagascar's biocapacity is still much greater than its footprint. The country's population growth and age distribution suggest that its total EF is going to increase rapidly, but it still has large ecological reserves. There is currently no constraint on natural resources to meet the population's demand of environmental goods and services. As emphasized in the *Africa Factbook*,

> Poverty and unmet needs can exist even with an ecological reserve, particularly if a county's biocapacity is not well managed. . . . If local overharvesting leads to liquidation and collapse of productive ecosystems, revenue streams that might have come from the renewable resources produced by these ecosystems may be permanently lost.

If we use the analytical grid provided in Table 1, the need to improve the management of ecological assets seems to be the main policy implication for poor countries such as Madagascar. Rapid population growth, which is the major driver of the EF increase, is of course also a concern.

The implications for policy derived from the EF interpretation for Madagascar are, therefore, very broad and general: The country's bioproductivity needs to be managed and its population growth controlled. This is somewhat disappointing and not particularly informative for the policy debate. The application of the EF indicator for Madagascar, and more generally for poor countries rich in natural resources, may not be very appropriate. Moreover, these countries' priority is to increase their consumption level, rather than promoting a consumption pattern that uses very little biocapacity (although these objectives are not necessarily in conflict), and indeed, we are far from the "overshoot" in Madagascar. Another major concern for policy is that natural capital is analyzed independently of other types of capital, which can be misleading. For example, there is a large quantity of land available in Madagascar, but farmers need to invest in human and physical capital to use this natural capital. Since farmers in Madagascar have very little access to physical (or financial) capital, and since their human capital is very low, natural capital, which is a complementary asset, has a very low value. The huge amount of natural capital suggested by the amount of biocapacity is thus misleading. Moreover, as for the other indicators, there is no direct relationship between the relative importance of the share of one specific consumption or biocapacity and the social profitability of policies focusing on this item.

Conclusions

In this article we have presented a comparative analysis of three aggregate sustainability indicators: the ANS, the EF, and the GPI. After having described and criticized their theoretical foundations, we have insisted on the policy messages that can be derived from their calculation as applied specifically to Madagascar.

Sustainability indications. In Table 5, we present a synthesis of the main sustainability messages that can be drawn from the three indicators. The most striking message is that the three indicators give very different results. The negative ANS during the 1980s and 1990s indicates that the growth rate of consumption should become negative in the future. Thus, development can be considered over this period as unsustainable, whereas the EF does not indicate any cause for alarm. Finally, the GPI can hardly be considered as a sustainability indicator and should be considered instead as an extended present welfare indicator.

Policy recommendations for sustainable development. The three indicators provide a very broad range of policy implications. The ANS highlights air pollution, soil degradation, and low net savings (because of low gross savings and a high physical capital depreciation), whereas the EF reveals a need to improve the management of ecological assets, and the GPI uncovers issues of rising inequalities, water and air pollution costs, and the need to control the external debt. With such a broad range, the three indicators together are complementary, as they highlight different issues with different perspectives. Although we consider the GPI to be interesting, as it addresses the social dimension of development, it cannot be considered strictly as a sustainability indicator. It does nevertheless enrich the description of current welfare, and focuses attention on issues that are rarely treated, such as inequalities. In the context of this study, it reveals

Table 5. Main Information on the Sustainability of Madagascar's Growth Derived From the Interpretation of the Three Indicators

	Adjusted net saving	Ecological footprint	Genuine progress indicator
Physical capital	• Low gross saving • High physical capital depreciation	• No information	It provides information on the evolution of present welfare but nothing on the sustainability of the level of it.
Natural capital	• High cost of soil degradation • Low forest depletion	• Small footprint • Biocapacity much higher than actual use	
Human capital	• High indoor air pollution impact • Important investments in education	• No information	
Social capital	• No information	• No information	
Development path sustainable?	• Not sustainable except after 2000	• It could be, as the biocapacity is much higher than actual use (minimum requirement)	

the need to broaden first the description of current welfare, before we begin to wonder whether this level of welfare can be sustained or not. This is particularly true for a country such as Madagascar with limited monetization, which makes monetary consumption a particularly inadequate present welfare indicator.

The usefulness of the EF for policy recommendations, in turn, is very limited for a country such as Madagascar. It yields implications that are too broad and general to be really useful to policy makers and does not seem to be appropriate for poor countries with low consumption levels and an abundance of largely untapped natural resources. Nevertheless, it remains an instructive indicator for raising the awareness of people not involved in environmental management.

In the end, the ANS is, in our opinion, the only indicator that can help policy makers to actually build sustainability policies. It provides a valuable framework for monitoring the evolution of a country's wealth and for balancing investments between the different forms of capital. The ANS indicator is of course still evolving and can be improved by adding other capital assets or relaxing some of the simplifying assumptions used. The recent work on the inclusion of technological progress (Arrow et al., 2007) is particularly promising. Moreover, the aggregation of the different components of the indicator can be questioned, as we still do not have sufficient empirical estimates on the substitutability between the different assets. But this is a common shortcoming of every aggregate sustainability indicator.

As a consequence of the shortcomings of the ANS we have presented, this approach should be supplemented with physical measurements of the evolution of capital assets not at all or poorly covered by this monetary indicator. Moreover, the shadow prices used rely on strong assumptions and, for example, do not yet include the risk of collapse of the assets. Various physical indicators can be proposed such as the quality of water and air (the concentration of ozone or particles), climate (the temperature deviation from the historical norm), biodiversity (fragmentation of natural habitats), and social capital (volunteering in local associations, level of trust, level of adherence to group norms). These would complement a framework using the ANS indicator to assess sustainability.

Finally, if the ANS indicator gives information on the sustainability of the development path and the evolution of the wealth of the country, it does not establish causal relationships explaining the depletion of some of the assets. Policies cannot be directly derived from the interpretation of the indicator as the causal pathways that help or hinder sustainability have to be identified. However, it gives some hints on where to look at.

Appendix A

Detailed Methodology for the Adjusted Net Saving Computation

Adjustments	Methodology	Details and sources
+Gross national saving −Physical capital depreciation	Derived from national statistics	We use data already processed in World Bank (2005).
−Net forest depletion	Forest rent × net forest depletion (net price method)	Timber wealth depreciation equals the average unit rent multiplied by net wood depletion (quantity harvested – natural growth). However, Meyers, Ramamonjisoa, Sève, Rajafindramanga, and Burren (2006) report that there is no sign of roundwood stock depletion. The total wood consumption will nevertheless exceed total production in 2010, which means that wood capital stock should then decrease.

(continued)

Appendix A (continued)

Adjustments	Methodology	Details and sources
−Soil degradation cost	Nutrient loss replacement cost	We use Drechsel and Gyiele (1999), based on the national nutrient balance predictions for the year 2000 from Stoorvogel, Smaling, and Stoorvogel (1990). They obtain a range of US$90 to US$127 million for the replacement cost of annual nutrient depletion, which represents 6% to 9% of the agricultural gross domestic product (GDP).
−Human capital formation	Education expenditures	We use data already processed in World Bank (2005).
−Urban pollution damages (PM_{10})	WTP × disability adjusted to life year lost due to PM_{10} emissions	We use the results compiled by the World Bank (2005).
−Indoor pollution damages	Damages to humans in terms of mortality (human capital approach)	About 11,690 people die each year from indoor smoke because of the use of traditional fuels (1,420 adults older than 30 years, from acute respiratory illness, and 10,270 children younger than 5 years of age, from chronic obstructive pulmonary disease; WHO, 2007). We assume that 38% of children aged between 5 and 15 years are working . Their annual wage is approximately US$74. Beyond the age of 15 years, they are all working, earning an annual wage of US$233 (Institut National de la statistique [INSTAT], 2001). Their life expectancy at birth is around 54 years. We use a 4% discount rate and a 3% annual growth rate of wages.
−CO_2 damages	World CO_2 damages (carbon value × global emissions) × (% of the global cost carried by Madagascar)	We use the methodology developed in Arrow, Dasgupta, Goulder, Mumford, and Oleson (2007). Nordhaus and Boyer (2000) estimated that African countries (and thus Madagascar) will suffer losses of 3.5% of their GDP while the entire world will suffer 1.5% of global GDP. Thus, we can conclude that the climate change cost for Madagascar will be 0.026% of the total cost for the world. Then, if we consider that carbon emissions in the world in 2000 are 7 billion tons (World Bank, 2005), with a marginal damage cost of US$50 per ton of carbon (Tol, 2005), we have a global damage for 2000 of US$6,696 billion. The climate change cost for Madagascar is then US$92 million.

WTP = willingness to pay

Appendix B

Detailed Methodology of the GPI Calculation

Adjustments	Methodology	Details and sources
+Final consumption	Private final consumption expenditure	Taken from the (World Development Indicators [WDI], 2005)
Weighted personal consumption	Personal consumption weighted by index of changing income distribution	We took Gini coefficients for the years 1980, 1993, 1997, 1999, and 2001 from WDI and UN School WIDER (World Institute for Development Economics Research). These were extrapolated linearly for the other years.
+Domestic and volunteer work value	Hours of household chores performed each year valued by the housekeeper replacement cost	Charmes (2005) has estimated the per capita amount of time used for domestic chores, water and fuel-wood collection, and volunteer work. Children older than 5 were included as they contribute to most of these chores. The adult agricultural wage was used for the economic valuation. It is considered that children's productivity is 30% of that of adults.
+Public expenditures (health and education) nondefensive	Value of nondefense government consumption spending	We consider 75% of public health and education expenditures. These were taken from the WDI.
−Indoor air pollution cost	Damage to humans from indoor air pollution	Same methodology as for the adjusted net saving (ANS).
−Water pollution cost	Damage to humans from water pollution (water-borne diseases)	Morbidity cost: Damages are valued on a yearly basis (long-term effects on morbidity and mortality are not considered) through revenue losses and defensive healthcare expenditures for an average rural household. We consider 88% of diarrheal illness cases are linked to unsafe water supply, sanitation, and hygiene (World Health Organization [WHO], 2002), a 12% 2-week prevalence rate, an average duration of a diarrheal episode of 4 days (2 hr per day lost to illness per diarrheal case). The treatment (oral rehydration salt) costs US$1. Mortality cost: We use the human capital approach to estimate the social cost of these premature deaths. From WHO (2002), 3.1% of deaths are due to unsafe water supply and sanitation in Sub-Saharan countries (children younger than 5).

(continued)

Appendix B (continued)

Adjustments	Methodology	Details and sources
−Loss of primary forest	Net present value of 1 hectare of forest multiplied by the deforested area	We use deforestation rates from the FAO (Forest Resource Assessment, 2005). The only values considered are the net present value of roundwood logging (assumed to be US$150 per hectare, based on Meyers et al., 2006) and nontimber forest products (assumed to be US$15 per hectare, based on Andrianjaka, 2001).
−Commuting cost	Time spent commuting valued at opportunity cost	Charmes (2005) provides information on daily time spent in transportation. The average wage is used for the economic valuation.
−Carbon damages	Damages from annual global emissions for the country	Same methodology as for ANS.
+Net capital investment	Annual capital growth minus the amount of investments necessary to compensate for capital depreciation and population growth	Physical capital value is assessed with the perpetual inventory method, using gross capital formation from WDI (World Bank, 2005)
+Net change in foreign position (lending-borrowing)	Mainly evolution of the external debt	We obtained data on external debt from WDI (World Bank, 2005).

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Notes

1. Atkinson and Hamilton (2007) discussed four alternative accounting methods: the marginal rent, the exhaustion, the simple present value, and the quasi-optimal approaches that are based on different assumptions regarding the evolution of extraction costs and prices. The authors conclude that the quasi-optimal approach is the most useful approach as it relies on more realistic assumptions and can be considered as a compromise between the net price and the simple present value approaches that yield polar estimates.
2. For example, Ferreira, Hamilton, and Vincent (2008) show that 1 percentage point change in adjusted net saving (ANS) translates into 1% change in the present value of changes in future consumption.
3. As mentioned earlier, the index of sustainable welfare is very similar to the genuine progress indicator.
4. The air pollution cost has been assessed for the year 2005 only and could not be extrapolated to other periods. As a consequence, the evolution of the ANS in Figure 1 does not include air pollution cost.

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