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The usefulness of aggregate sustainability indicators for policy making: What do they say for Madagascar?

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Abstract

In this paper we compare the practical policy implications that can be derived from the calculation of three aggregate sustainability indicators for Madagascar. The chosen indicators are: the Adjusted Net Saving, the Genuine Progress Indicator, and the Ecological Footprint. Our 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 which we do not see as complementary. The Ecological Footprint provides policy recommendations that are too general for poor countries rich in natural resources, such as Madagascar. The Genuine Progress Indicator 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, we consider that the Adjusted Net Saving provides the most consistent information to decision makers regarding the sustainability of Madagascar's recent development path.

Keywords: Sustainable Development, Madagascar, Ecological Footprint, Adjusted Net Saving, Genuine Progress Indicator

1 Introduction

There is a growing literature on how to measure development, and how to assess the sustainability of that development. The limitations of the gross domestic product (GDP) as a welfare indicator were pointed out many years ago by welfare economists, and there is now consensus in the political sphere on the need to develop other indicators to measure the evolution of present welfare and the sustainability of the actual development paths. The most recent example is the 'Sen-Stilgitz' Commission set up by the French President Nicolas Sarkozy, whose report is expected in 2009.

The existing literature on aggregate sustainability indicators tends either to calculate, improve or criticize one specific indicator (see for example (Talberth et al, 2007) for the Genuine Progress Indicator or (Fiala, 2008) for the Ecological Footprint), or else concentrates on comparing the validation (or not) of a specific sustainability criterion (see for example (Nourry, 2008; Siche et al, 2008; Hanley, 1999)). The issue is however rarely policy recommendations and how to translate the information provided by these indicators into political action. This is the focus and key insight of our work.

Our work has been driven by one pragmatic question: what is the use of these aggregate indicators in terms of policy recommendations? We focus more specifically on aggregate indicators on a country scale. The chosen indicators are: the Adjusted Net Saving (ANS), the Genuine Progress Indicator (GPI) and the Ecological Footprint (EF). Although we are aware of many limitations of the chosen indicators, the idea is to test their usefulness in policy debates by trying to derive and compare the main messages that they deliver. 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? Although our main question is practical, our work contains some discussions on the theoretical and methodological limitations of the three chosen indicators.

We propose a case study on a specific country: Madagascar. It is an interesting case for several reasons. First, it is heavily dependent on its natural capital, and the population strongly relies on its renewable natural resources. 75% of the population works in the agricultural sector, which contributed to 25% of the GDP in 2005. Environmental degradation of the island is however severe. Deforestation rates are high in some parts of the island, soils are being eroded, and many ecosystems have been damaged. Second, most of the detailed empirical studies on aggregate sustainability indicators have been undertaken primarily in rich or emerging countries and there has been very little focus on African countries.

In Section 2 we analyse the three indicators through an identical analytical grid: first, we present the definition of the sustainability that the indicator claims to measure, and the indicator itself with its theoretical framework; second, we briefly review the main criticisms in the existing literature; and finally, we present the kind of information that the indicator can ideally provide to policy makers when applied to a specific country. In Section 3 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. Section 4 concludes on the usefulness of these indicators for policymakers in the context of Madagascar.

2 Analysis of the three indicators

2.1 Adjusted Net Saving (ANS)

An economy's productive base is the set of four different capital stocks: produced capital, 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 ANS are built on this framework. The definitions of sustainable development that these indicators are supposed to asses are economic transcriptions of the Brundtland Commission's definition. Two variants exist. On the one hand, the sustainability dimension is introduced through a constraint on the utility of consumption over time. A development path will be considered sustainable as long as the utility of consumption is not declining over time. This variant draws on the philosophical theory of justice developed by Rawls. In the other one, the constraint is on changes in opportunities, rather than change in outcomes. The development path will be sustainable as long as total wealth or aggregate capital, defined as the monetary sum of the four types of capital, is non-declining. The two approaches are linked but not equivalent (Pezzey, 2006). In this section we present a capital-based indicator: the ANS.

The ANS can be understood as a measure of the variation of the wealth (or aggregate capital) of a country, as indicated in equation 1.

$$ANS = \dot{K}_p + \dot{K}_N + \dot{K}_H + \dot{K}_S \qquad (1)$$

where K_P is physical capital, K_N is natural capital, K_H is human capital and K_S is social capital. ANS is rooted in an optimal growth model. It is quite straightforward that a positive (negative) ANS ensures sustainability (unsustainability) as defined as non-declining wealth (which corresponds to the second variant). However, this does not necessarily ensure that utility will not decline (first variant). Hamilton and Clemens (1999) show that a negative ANS implies that future levels of utility over some period of time will be lower than current levels, which means unsustainability regarding the first variant. A positive ANS signals sustainability (defined through a non-declining utility), provided that the growth rate of ANS does not exceed the interest rate (Hamilton and Withagen, 2007). Thus, the interpretation of ANS depends on the sustainability definition used, the non-declining utility definition being a bit more restrictive than the non-declining wealth one.

The main criticisms levelled at capital-based indicators are the following. The first is theoretical. It claims that most of the green accounting literature relies on a set of critical assumptions such as: constant population, no technological change, closed economy, economy at a full optimum, and convex commodity transformation possibility (Dasgupta, 2008). These may seem unrealistic and very crude, but there is continuous progress towards relaxing these assumptions. The second criticism is also theoretical. ANS is said to be a weak-sustainability indicator since it relies on the assumption of perfect substitutability between the different assets. It is just a first step towards assessing sustainability. A country which is not weakly sustainable will not be strongly sustainable, as this requires a non-declining natural capital (or at least a 'critical natural capital'). However, many of the concerns voiced by strong sustainability proponents can be introduced theoretically into a weak sustainability framework. Shadow prices should reflect the possibility of crossing a threshold or the rates of substitution between the different forms of capital. In the real world, ecosystems have highly complicated dynamics, often non-linear 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 there is a fragmentation of the forest area, this could induce a rapidly reduced connectivity between the forest patches, with consequences on pollination and thus on crop production (Bodin, 2006). The determination of these shadow prices is a difficult exercise and there is room for collaborative work between ecologists and economists. Thirdly, and these are empirical criticisms, some critics claim that there is reason to be 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 is poorly integrated into the ANS calculation as only education expenditures and air pollution damage to health are considered. Health expenditures should be considered as investments, increasing life expectancy and workers' productivity in the long term, like research and development expenditures which 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 pollution in the accounting framework (Hamilton, 1996) or on how to value natural capital depletion as several competing methods exist (Atkinson and Hamilton, 2007). In the end, one wonders if the ANS is still useful as a sustainable development indicator, considering the theoretical restrictive framework and the poor treatment of some of the capital assets, like intangible capital. But one considerable strength of the ANS compared to many other indicators is that it can be empirically tested. Several authors have been testing the empirical relationship between ANS and trends in future consumption or welfare (Hamilton, 2005; Ferreira et al, 2008; Gnegne, 2009). Results show that, even with all the imperfections stressed above, the ANS can be used as a proxy of future welfare change, particularly in developing countries.

What is the use of the ANS indicator in the policy debate on sustainability?

If the development process is conceived of as the management of a portfolio of assets, and growth occurs through the accumulation of the different forms of capital, it is possible to identify different policy levers which can be inferred from the components of ANS (which correspond to the variations of the different capital assets). To give valuable information to policy makers, these different policy options should be prioritized by means of social cost benefit analysis. It would give a framework on how to balance investments between the different capital assets (through macro or more sectoral policies) so as to achieve sustainable growth. Therefore, the ANS is thus a tool which 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.

2.2 Genuine Progress Indicator (GPI)[1]

The GPI is an indicator which 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:

[1] We focus here on the GPI instead of the ISEW (Index of sustainable welfare) which belongs to the same family of indicators. The main differences are the exclusion of both public and private defensive expenditures on health and education, and the inclusion of deductions of cost estimates for loss of leisure time, underemployment, and loss of forests.

$$GPI = Cp + F + \Delta K \qquad (2)$$

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). It is completed to account for F, which is all the other flows of services (or disservices) contributing to present welfare: non-marketed services (derived from unpaid household labour value, 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 which affect present welfare (such as crimes, divorces, underemployment, etc.) and some environmental degradations which affect present welfare. Finally, several capital stock variations ΔK are added, such as natural capital depletion. Some additional adjustments are made to account for net capital growth and net foreign lending or borrowing[2].

The interpretation of the indicator in terms of sustainability is not straightforward, as the actual meaning of sustainability is not very clear. Hanley et al. (1999) consider that "a rising path of ISEW over time would indicate that an economy was becoming more sustainable". We see this as reflecting the vision of sustainability as an equilibrium between economic, social and environmental factors. But it gives no information on the ability of the society to maintain this level of present welfare. Lawn (2003) proposes a theoretical framework based on the Fisherian income concept, which can be described as the services or 'psychic income' enjoyed by the ultimate consumers of human-made goods. This would be some form of utility-based measure of income, as opposed to a production-based measure which would correspond to the Hicksian income previously introduced. There is much confusion regarding the terminology used and the difference between Hicksian and Fisherian income. In the end, the link with sustainability remains unclear.

The GPI has been criticized for its lack of theoretical foundations, particularly in terms of sustainability interpretation. First, Neumayer (2004) considers that it is a present welfare indicator and cannot be considered as a sustainability indicator. Harris (2007) likewise considers that "Fisher's concept says nothing at all about sustainability". The GPI is indeed a mix between a present welfare indicator (based on current flows of utility) and a sustainability indicator (based on stock variations, 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

[2] The theoretical ancestor of the GPI is the 'Measure of economic welfare' (MEW) developed by Nordhaus and Tobin (1972). The idea is to add (or deduct) every service flow providing utility (or disutility) to personal consumption. Daly (1989) and Cobb and Cobb (1984) upgraded it with several adjustments regarding environmental and social dimensions, as shown above.

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 the 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[3].

What is the use of the GPI in the policy debate?

"By defining development more widely than simply income, the value of the GPI 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, 2008). Daly and Cobb (1989) consider that the ISEW highlights policy areas which are usually poorly integrated, such as income inequality reduction or pollution. As indicated before, we consider that the GPI does not say anything in terms of sustainability and can be used mostly as a descriptor of the evolution of current welfare. However, 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. This should also be completed with cost-benefit analysis. From our point of view this is the best way to link the GPI with policy recommendations. As such, we consider that it is more valuable to compare the evolution of the GPI with private consumption, as the GPI is a broader descriptor of present welfare than of consumption (although it is usually compared with GDP, which is not a current welfare indicator).

2.3 The Ecological Footprint

In the most recent report of the Global Footprint Network on Africa (Global Footprint Network, 2008), sustainable development is presented as "a commitment to improving the quality of human life while living within the carrying capacity of supporting ecosystems" (quoted from (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 as an indicator of current welfare (quality of human life) on the x-axis versus the EF as a measure

[3] It is not within the scope of this paper to enter into a detailed criticism of these adjustments but some of them are questionable (see for example (Neumayer, 2004)).

of human demand on the biosphere on the y-axis. Specific thresholds regarding IDH (above 0.8) and the EF (below 1.8 per capita) characterize a sustainable development quadrant. We focus hereafter on the sustainability dimension, through the analysis of the EF.

The Ecological Footprint was introduced by Wackernagel and Rees (1996) as a simple 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 (it is called the ecological footprint, 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" (Kitsez et al, 2009).

There are several criticisms of the indicator, presented below. In this respect we rely mainly on (Bergh and Verbrugen, 1999; Neumayer, 2003; Fiala, 2008). First, it is a static indicator. It does not consider long-term effects and the stock dimension of natural capital. It is based on flow accounts and not stock accounts, for the bioproductivity of land can increase at the expense of long-term impacts. For example, mechanized agriculture will increase land yields in present times, leading to a greater biocapacity. However, it can lead to soil degradation with impacts on long-term yields. Second, the EF neglects comparative advantages of countries rich in natural resources. Trade can spatially distribute the environmental burden. Many refer to an anti-trade bias of the indicator. This point can be taken further, to take into consideration the fact that the EF can be interpreted only at global level. At country level, the variations of the different parts of the footprint over time are the only useful information. Third, the EF cannot cover impacts for which no regenerative capacity exists (for example pollution in terms of waste generation, toxicity, etc.). Fourth, 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 included. 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 use of the Ecological Footprint in the policy debate?

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 (how to increase the biocapacity) and the demand side (how to decrease the EF).

<Insert Table 1>

2.4 Comparative synthesis of the different indicators

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

<Insert Table 2>

3 Results

3.1 ANS

To compute ANS, we adjust GDP with final consumption (to obtain gross saving), physical capital depreciation (gross saving minus physical capital depreciation), natural capital depletion (subsoil assets, forests and soils), pollution costs (indoor and outdoor air pollution) and human capital increase (education expenditures). Compared to previous World Bank calculations (World Bank, 2005), we improve on the data used, add soil degradation and indoor air pollution, and change the methodology to assess carbon dioxide damages. 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. Details are given in Appendix A.

The evolution of the ANS is presented in Figure 1, and its composition in Table 3 (for the year 2000). First, it shows that the ANS has been negative throughout most of the period, indicating an unsustainable growth trend. However, since the early nineties, it has been on an upward curve and even becomes positive after 2000 (except in 2002 because of political unrest). Madagascar can therefore be said to be on a sustainable growth path since 2000. This upward trend is mainly driven by an increase of the net savings (gross savings minus physical capital depreciation). As shown in Figure 1, the ANS is strongly dependent on gross saving rates. Education expenditures are an important positive contributor to the human capital stock increase. The other components are depleting total wealth. Physical capital depreciation, soil degradation and indoor pollution have a strong downward effect on the ANS.

<Insert Figure 1>
<Insert Table 3>

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

<Insert Table 4>

Limitations of ANS in terms of policy implications

The interpretation of the ANS indicators has several interesting messages regarding Madagascar's actual development path. First, to some extent, it is 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 be really useful in terms of policy recommendations. 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 resource. Second, the ANS can be interpreted as an extended Hartwick rule. 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 inter-generational equity, dealing with average consumption levels, whereas intra-generational issues are also critical. Third, the portfolio of assets considered here is not exhaustive, as health or knowledge capital for example are not considered. But, as noted above, the ANS can be used even at this imperfect stage as a sustainability indicator. Thus, policy recommendations remain valid.

3.2 Genuine Progress Indicator

Methodologies to calculate the GPI (or ISEW) are widely diverse. In this section we apply the methodology developed in (Talberth et al, 2007) although, due to data limitations, we could not be as exhaustive for Madagascar. We adjust for: inequalities (adjusting consumption by means of Gini coefficients), domestic, informal and volunteer works, non-defensive public expenditures (health and education), services from the road network, indoor air pollution, loss of primary forest, commuting time lost, and the net change in international position. In the end, we have: GPI = final consumption (adjusted for inequalities) + domestic and volunteer work value + public non-defence expenditures (health and education) – indoor air pollution cost – water pollution cost – loss of primary forest – commuting cost – CO_2 damages – net capital investment. The detailed assumptions and calculations are presented in Appendix B.

The evolution of the GPI between 1980 and 2004 is presented in Figure 2. Figure 3 shows the relative importance of the main contributors of the GPI for the year 2000.

<Insert Figure 2>
<Insert Figure 3>

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 which 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 nineties (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. If we stick to the interpretation of the GPI in terms of sustainability made by its proponents, Madagascar can be considered to be on a sustainable development path as the GPI has been rising since 1987.

The interpretation of the GPI would tend to focus policy debates on recent rising inequalities, the high cost of water and air pollution, and the need to be cautious about the net foreign position (mainly the external debt). Naturally it stresses the importance of increasing final consumption, which is the main contributor of GPI. It would be necessary to complete the investigation with a cost-benefit analysis in order to obtain the most socially profitable trajectory and evolution of these different components.

Limitations of the GPI in terms of policy implications

The policy-guiding value of the GPI in terms of sustainability is disputable, as explained above. However, it can be considered as an attempt to obtain a comprehensive measure of current welfare. As such, it gives some information on the evolution of social, environmental and economic contributors to present welfare. We have already discussed several items driving the GPI trend. Like 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. The GPI stresses social or environmental problems usually not considered in traditional indicators. These adjustments are however sometimes quite disputable and normative, reflecting mainly what an idealistic society should be. The indicator therefore becomes highly sensitive to political objectives. An interesting fact is that the evolution of GPI is to some extent in contradiction with 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 GPI per capita is increasing. Here, we stress the need to have a good understanding of current welfare, not only based on marketed consumption, before investigating its sustainability.

3.3 The Ecological Footprint

We have not made any calculations or adjustments for the EF calculation and have used data from the 'Africa Factbook' (Global Footprint Network, 2006). The evolution of the Ecological Footprint between 1980 and 2004 is presented in Figure 4. First, the ecological footprint of Madagascar, like 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 consumption levels. Agricultural activities (0.29 for crops and 0.15 for pastures) and fuel-wood collection (0.12) account for the largest share of the ecological footprint. This means that the country could be on a sustainable development path. If we look at per capita results, the ecological footprint was slightly lower in 2004 than it was in 1960.

<Insert Figure 4>

Thus, Madagascar's biocapacity is still much greater than its footprint. The country's population growth and age distribution suggest that its total Ecological Footprint is going to increase rapidly, but it still has large ecological reserves. There is no constraint on natural resources to provide environmental goods and services to meet the population's demand. 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 EF increase, is of course also a major concern.

Limitations of EF in terms of policy implications

The policy implications derived from the EF interpretation for Madagascar are broad and general. They highlight the need to improve the management of its bioproductivity and to curb population growth. This is somewhat disappointing and not particularly informative for the policy debate. The use of the EF 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 which uses very little biocapacity, and we are far from the overshoot for Madagascar. Another major concern for policy implications is that natural capital is disconnected from other capital assets. It is analysed 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 human or physical capital to use this natural capital. Farmers in Madagascar have very little access to physical (or financial) capital, and their human capital is very low so that 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.

4 Conclusions

In this paper 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. This work has been undertaken for a specific country: Madagascar.

In terms of sustainability indication - In Table 5 we present a synthesis of the main messages that can be drawn from the three indicators in terms of sustainability. The most striking message is that the three indicators give very different results. The ANS indicates that Madagascar's development path was mostly unsustainable in the eighties and nineties, whereas the EF does not indicate any cause for alarmed. Finally, the GPI can hardly be considered as a sustainability indicator. We nevertheless note that the growth trend of the GPI is in contradiction with the negative ANS sign.

<Insert Table 5>

In terms of policy recommendations to achieve 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 insists on the need to improve the management of ecological assets and GPI on the issues of rising inequalities, water and air pollution costs and the need to control the external debt. One could consider that the three are complementary, as they highlight different issues with different perspectives. This is usually the conclusion found in the literature on sustainable development indicators. However, this is not our conclusion here. First, although we consider the GPI to be interesting, as it contributes some elements on the social dimension of development, it cannot be considered strictly as a sustainability indicator. It does nevertheless expand on the description of current welfare, and focuses attention on issues that are rarely treated, such as inequalities. In the context of this study, it stresses the need to broaden the description of current welfare, before wondering if this level of welfare can be sustained or not. This is particularly true for a country such as Madagascar with limited monetization, which makes consumption a particularly inadequate present welfare indicator. Second, the usefulness of the EF calculation is very limited for a country such as Madagascar. It yields implications which are too broad and general in terms of policy recommendations 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. It is nevertheless a particularly instructive indicator for raising the awareness of people not involved in environmental management. In the final analysis, the ANS is in our opinion the only indicator that can help policy makers to build sustainable development policies. It provides a valuable framework for monitoring the evolution of a country's wealth and balancing investments between the different forms of capital. It is of course still evolving, and can be improved by adding other capital assets or relaxing some of the assumptions used. There is much left to be done, but the theoretical roots of this framework are strong, so that capital-based indicators may be less subject to change by successive governments than indicators closely linked to policy processes.

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Appendix A: detailed methodology for the ANS calculation

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 minus natural growth). However, (Meyers et al, 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.
- 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 (1990). They obtain a range of $US 90 to 127 million for the replacement cost of annual nutrient depletion, which represents 6 to 9% of the agricultural 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 (World Bank, 2005).
- Indoor pollution damages	Damages to humans in terms of mortality (human capital approach)	11,690 people die each year from indoor smoke because of the use of traditional fuels (1,420 adults over 30 years old, from acute respiratory illness and 10,270 children under 5 years old from chronic obstructive pulmonary disease) (WHO, 2007). We assume that 38% of children between 5 and 15 years old are working (INSTAT, 2001). Their annual wage is around $74. Above 15 years old they are all working, earning an annual wage of $233 (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, 2007). Nordhaus and Boyer (2000) estimate 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 $50 per ton of carbon (Tol, 2005), we have a global damage for 2000 of 6,696 billion dollars. The climate change cost for Madagascar is then 92 million dollars.

Appendix B: detailed methodology of the GPI calculation

Adjustments	Methodology	Details and sources
+ Final consumption	Private final consumption expenditure	Taken from the (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. 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 above 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) non-defensive	Value of non-defence 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 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 (WHO, 2002), a 12% 2-week prevalence rate, an average duration of a diarrheal episode of four days (2 hours per day lost to illness per diarrheal case). The treatment (oral re-hydration salt) costs \$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 under 5).
- Loss of primary forest	Net present value of one 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 \$150 per hectare, based on (USAID, 2001)) and non-timber forest products (assumed to be \$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 foreign lending/borrowing	Change in net foreign liabilities (mainly evolution of the external debt)	We obtained data on external debt from WDI (World Bank, 2005).

TABLES

	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: waste reduction and material and energy in production processes limitation

Table 1: policy implications derived from ecological footprint interpretation

	ANS	EF	GPI
Theoretical framework	Neoclassical growth models	(Rees, 1992) (Wackernagel, 1994)	Measure of economic welfare (Nordhaus, 1972) Fisherian income (Lawn, 2003)
Sustainability definition	non declining utility or non declining capital stock	Natural capital non declining	A development which increases present welfare
Unsustainability condition	ANS≤0	EF>Biocapacity	- decreasing GPI (for GPI proponents) - 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	- static - no technological change - externalities not considered	- Normative - Fuzzy theoretical foundations - not a sustainability indicator

Table 2: synthetic comparison of the different indicators

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
PM_{10} urban pollution	-0.41
Rural Indoor pollution (morbidity+mortality)	-2.8 (1.1+1.7)
ANS	**-3**

Table 3: ANS components for the year 2005
[% of gross national income]

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 produced capital depreciation?
Natural Capital	**Exhaustible**	- 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 over-exploitation? - 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?

Table 4: main policies implications derived from ANS interpretation

	ANS	EF	GPI
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)	

Table 5: Main information on the sustainability of Madagascar's growth derived from the interpretation of the three indicators

FIGURES

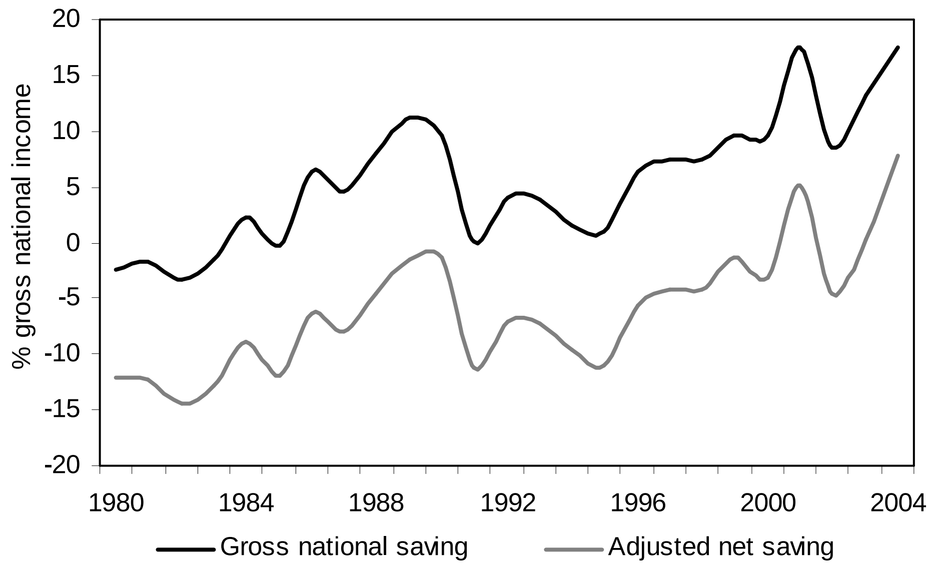

Figure 1: ANS and gross saving between 1980 and 2004 for Madagascar

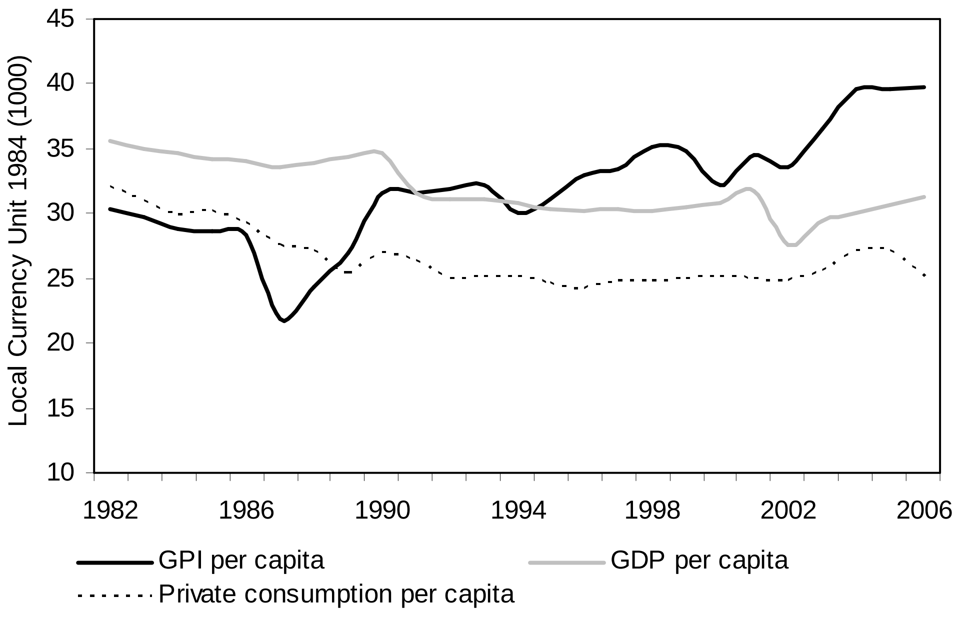

Figure 2: per capita GPI, private consumption and GDP between 1982 and 2000

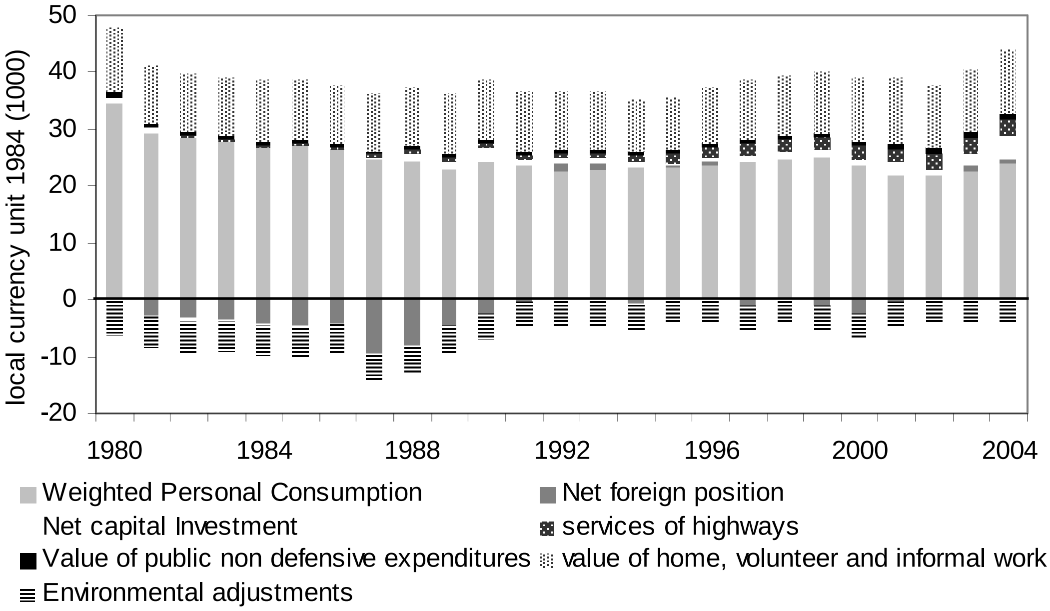

Figure 3: decomposition of economic, social and environmental adjustments of the GPI between 1980 and 2004

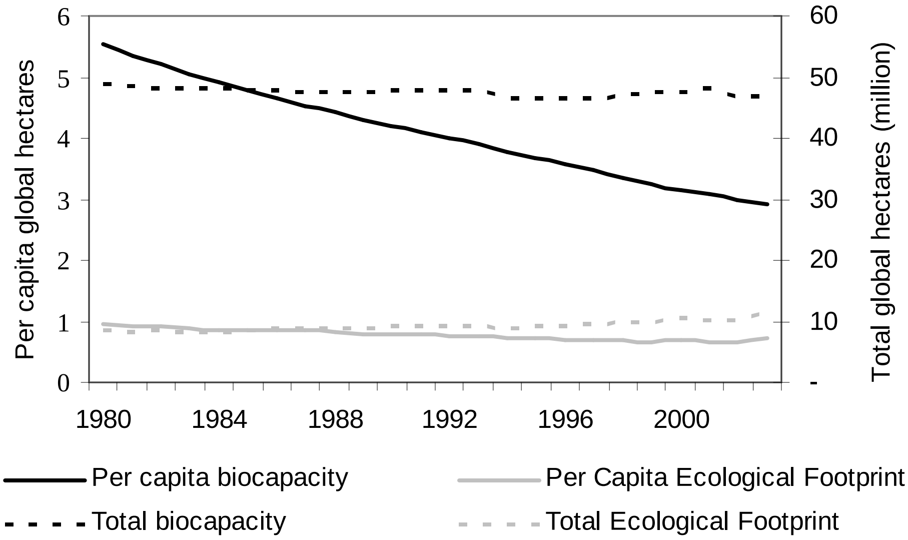

Figure 4: biocapacity versus ecological footprint (total and per capita) between 1980 and 2004 for Madagascar