Is Mozambican Growth Sustainable? A Comprehensive Wealth Accounting Prospect

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Abstract

We estimate the wealth of Mozambique in 2000 and 2005 in order to assess the sustainability of its development path. Our methodology builds on Arrow et al. (2007). We show that Mozambican growth is driven mainly by human and physical capital accumulation, while the pressure on natural capital remains low. Moreover, changes in knowledge and institutions significantly enhance the outcome of the different capital assets while population growth has a strong downward effect on wealth per capita. In the end, we conclude that Mozambique, unlike many other sub-Saharan countries, followed a sustainable growth path in recent times.

Keywords: natural capital, sustainable development, Mozambique, comprehensive wealth accounting

1 Introduction

There is a growing literature on how to measure development, and how to assess the sustainability of this development. The limitations of the gross domestic product (GDP) as a welfare indicator have been pointed out long years ago by welfare economists. There is now a 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 in 2009. We focus in this paper on the sustainability issue. IF one tries to assess whether the development path of a country is sustainable or not, it has to adopt a definition of sustainability. The definition we consider is derived from Dasgupta and Mäler (2000): "each generation should bequeath to its successor at least as large a productive base as it inherited from its predecessor". They define the productive base (or wealth) as the set of the different capital stocks of the economy. Not only produced capital, but also human (education level, knowledge, health, etc.), social (institutions, level of trust, etc.) and natural (mineral resources, soil resources, forests, fish resources, etc.).[1] A development path is then said to be sustainable as long as the society's productive base (per capita) does not shrink.

David Pearce, among others, laid the theoretical foundations of wealth accounting exercises (Pearce and Atkinson, 1993). Other contributions were Asheim (1994), Hamilton and Atkinson (1996), Hamilton and Clemens (1999) and several others after. Kirk Hamilton and his team at the World Bank made also an impressive work on the issue, theoretical as well as empirical. Their contributions are summed up in the book *Where is the Wealth of Nations?* published in 2006. They provide natural capital, total wealth and adjusted net saving estimates for 210 countries. More recently, Arrow et al. (2004) and Arrow et al. (2007) made significant improvements, broadening the scope in terms of assets considered.

This paper is in line with those contributions. It is a detailed empirical application of the above-mentioned framework, with several methodological improvements, in the case of Mozambique between 2000 and 2005. Our focus is not only on physical and natural capital as in most of the green accounting literature. Human capital is a central asset in our analysis. Building on Arrow et al. (2007), we improve the treatment of the health dimension of human capital. We also investigate how institutions, knowledge capital and other intangible assets affect the sustainability of Mozambique's growth path.

[1] Institutions are not always considered as capital. Dasgupta (2009), for example, considers them as a social infrastructure guiding the allocation of resources.

Before entering the thick of things, it might be useful to draw a brief overview of the situation in Mozambique. Since peace came in 1992, Mozambique has been one of the world's fastest growing economies with an average growth rate of 8% over the past decade. It is often presented as an African "success story". Nevertheless poverty remains widespread and the country is still heavily dependent on donor aid. GDP per capita was $397 in 2007, among the lowest in the world. Economic growth is driven mainly by foreign financed "mega-projects" and large aid inflows. It is also very dependent on its natural capital, for at least two reasons. On the one hand, most current mega-projects involve exhaustible natural resources (mainly gas, coal and heavy sands). On the other hand, the population strongly relies on its renewable natural resources, since 75% of the population works in the agricultural sector, which contributed 26% of GDP in 2005. Social indicators have been on an upward trend in Mozambique with, for example, a significant increase in the number of children in lower primary grade. As regards to health, most indicators – infant mortality rate, maternal mortality rate, malnutrition – have improved significantly. However, mortality rates are still high, and AIDS is a critical problem, having a significant adverse impact on life expectancy.

In order to assess the sustainability of Mozambique's development path, we collected extended datasets and numerous studies from international organizations (World Bank, Food and Agricultural Organization, French Agency for Development, etc.), national ministries (agriculture, fisheries, environment and forestry, national institute of statistics, health, finance, etc.), non-governmental organizations (World Wide Fund for Nature, Justice Ambiental) and Eduardo Mondlane University. We have also had in-depth discussions with experts on the reliability of the data collected. This work thus relies on a comprehensive compilation of almost all existing studies and databases on Mozambican natural, human and physical capital.

The paper is organized as follows. Section 2 recalls the theory of wealth accounting and the importance it has for sustainability issues. In Section 3 we present the details of the methodology used to estimate the different assets, and how we introduce technological progress and population growth into the accounting. The results are presented and discussed in Section 4.

2 Theoretical framework

We present in this section the overall theoretical framework and the assumptions used in this work. We start with a precise definition of the sustainability criterion used (2.1). Then we present how intertemporal social welfare variations are assessed, and the link with capital assets variations (2.2).

2.1 Which sustainability criterion?

Let us define intertemporal social welfare V_t at t as:

$$Vt = \int_t^{\infty} u(c(s))e^{-\delta(s-t)}ds$$

where u is a utility function, t is time, c is a vector including marketed goods consumption flow, but also non-marketed goods or services consumption such as ecosystem services, and δ is the discount rate. Economic growth will be considered sustainable at time t as long as $dV_t/dt \geq 0$. In other words, to be sustainable, the productive base transmitted to the next generation should be able to generate at least the same intertemporal welfare. To assess the sustainability of a country's development, one has thus to estimate dV_t/dt. This is what we do for Mozambique between 2000 and 2005.

2.2 How is calculated intertemporal social welfare variation?

To assess V_t and its variation over time, we need to know the state of the productive base of the economy at time t, and to assume a resource allocation mechanism to forecast the evolution of these stocks. We describe the economy's productive base by distinguishing three different capital assets: produced capital K (buildings, machines, roads, etc.), human capital H (education, health, etc.) and natural capital N (exhaustible and renewable natural resources, ecological services). The consumption path, and thus intertemporal welfare, is determined by the evolution of the economy's productive base. At any given time, the output generated by this productive base is allocated between consumption and investment in the different capital stocks. The rules governing the allocation of the different resources are what we defined previously as the resource allocation mechanism. It can be governed by optimizing behaviours or by exogenous rules that make it non-autonomous. If we assume that the resource allocation mechanism is non-autonomous, it means that V_t is an explicit function of time. Thus we have:

$$Vt = V[K(t), N(t), H(t), t] \qquad (1)$$

The allocation rules can be non-autonomous for several reasons. Dasgupta (2009) gives five examples: an exogenous technological or institutional change, global public goods, capital gains, population change, and uncertainty. If we differentiate (1) with respect to time, we obtain:

$$\frac{dV_t}{dt} = \frac{\partial V}{\partial t} + \frac{\partial V}{\partial K}\frac{dK}{dt} + \frac{\partial V}{\partial N}\frac{dN}{dt} + \frac{\partial V}{\partial H}\frac{dH}{dt}$$

$\frac{\partial V}{\partial K_i}$ is the marginal increase in intertemporal welfare from one unit increase of the capital stock, and can thus be interpreted as the shadow price of the capital stock. Intertemporal welfare V_t variation results from the evolution of the three capital stocks defined previously – we will call them 'comprehensive wealth', a term coined by (Arrow et al., 2007) – and exogenous factors described by $\frac{\partial V}{\partial t}$. For the latter, in this study, we consider technological change, population growth and climate as a public good. We are not able to consider capital gains because of data limitations.

The first step is to assess the variation of the different capital stocks: human, physical and natural. This is a way to measure the net investment in these different assets[2]. The second step is to include the impact of exogenous factors. Here, we rely on Arrow et al. (2004) and Arrow et al. (2007) who propose a framework to introduce technological and institutional change through the growth of the total factor productivity (TFP). We add the impact of climate change on the Mozambican economy. Finally, we make an adjustment to account for demographic change in order to obtain an estimate of the change of the productive base relative to population. At this stage, unlike most green accounting literature, we did not make any assumptions regarding the optimality of the economy.

3 Methodology

On this section we present the methodology used to evaluate the physical (3.1), human (3.2), and natural capital (3.3). The last section deals with the calculation of the exogenous factors (3.4).

[2] Some authors refer to it as genuine (adjusted net) saving, genuine investment or inclusive investment

3.1 Physical capital (and urban land)

We use the perpetual inventory method, which derives capital stocks from the accumulation of investment series. The aggregate capital stock value in period t is given by:

$$\sum_{i=0}^{25} I_{t-i}(1-\alpha_i)^i$$

where I is the value of past investment at constant prices (gross capital formation from (World Bank, 2005)) and α_i the depreciation rate. We derive depreciation rates over time from Jones (2006). As in World Bank (2006), we assume that urban land value represents 24% of produced capital (Kunte, 1998). Moreover, we are interested in produced capital owned by Mozambicans, and not the stock owned by foreign investors outside the country. In the same way, Mozambican residents own some physical capital outside the country. As in Arrow et al. (2007), our notion of sustainability focuses on the changes in the productive base owned by a given country's residents. We use Lane (2006), which constructs net holdings of international assets. We can then calculate the physical capital adjusted for international holdings in 2000 and 2005.

3.2 Human capital

The OECD (Organization for Economic Cooperation and Development) (1998) defines human capital as "the knowledge, skills, competences, and other attributes embodied in individuals that are relevant to economic activity". In this study, we focus mainly on the educational and health dimension of human capital. During the colonial era, education of the indigenous population in Mozambique was neglected, with resulting low literacy rates. Even after the abolition of the *indigenato* in 1961, education was limited to primary schooling, so as not to produce educated opponents of the colonial power. After independence, education became a priority for FRELIMO (Frente de Libertaçao de Moçambique) (Jones 2006). Basic education indicators have only recently begun improving. For example, the number of children in lower primary grades rose from 1.7 million in 1997 to 2.8 million in 2003. The number of schools has been increasing, and the net enrolment rates for lower primary grades reached 69% in 2003 compared to 44% in 1997. Nevertheless the quality of education remains low. Completion of primary schooling remains low, and the number and qualifications of teachers have not increased proportionally.

The method used to assess human capital is similar to Arrow et al. (2007), which itself built on the seminal work of Mincer (1974). The idea is that a human being, like other kinds of capital asset, generates a stream of income over time. A person's human capital stock depends on the average educational attainment and the return to education. We assume here a perfect labour market, so the marginal productivity of human capital equals wages. The value of human capital is estimated through the formula p_H*H in which:

- the stock of human capital H equals $P.e^{\delta A}$, where P is the working population, δ the rate of return on education and A the average educational attainment of the working population
- the shadow price p_H of one unit of human capital equals $\int_t^{t+m} w.e^{rt}dt$, where: w is the annual rental value of one unit of human capital (equals total wages divided by the total stock of human capital), r the discount rate, and m the average remaining working years until retirement or death

The annual rental value of human capital is assumed to be constant between 2000 and 2005. The evolution of human capital value will then result from the evolution of the stock (thus the evolution of the educational attainment of the population) and the evolution of the shadow price of human capital (not the rental value, because this is assumed to be constant, but through the average remaining working years, which is closely linked to life expectancy in Mozambique).

3.3 Natural capital

Natural capital includes exhaustible resources, renewable resources (forests, land resources) and environmental services produced by ecosystems (water filtration, waste assimilation, etc.). Market prices for natural assets are often missing. Thus, the different natural resources are valued as the present value of resource rents during the asset's lifetime:

$$\sum_{i=t}^{T} \frac{p_i q_i - C(q_i)}{(1+r)^i}$$

where p_i is the price at time i, q_i is production, C the production costs and r the discount rate. For each natural resource, we apply the following assumptions: a constant rental rate over time[3], a 25-year accounting period (2005-2030), the value of the resource at the end of the discounting period is zero, a 4% discount rate. The methodology we use for natural capital calculation is thus very similar to that of the World Bank (2006). We consider the following

[3] Rental rate = economic rent / output *100

resources: cropland, pastureland, forests (timber, non timber forest resources NTFR), protected areas, fish and mineral resources. The detailed calculations, data (on prices, production costs, production quantities) and sources are reported in the Appendix A.

3.4 Exogenous factors

Having presented how to assess the value of natural, physical and human capital stocks, we now describe successively three exogenous factors: technological progress which enhances the overall productivity (3.5.1), the growth of population to obtain per capita figures (3.5.2) and damages from carbon emissions (3.5.3).

3.4.1 Technological and institutional progress

Technological change has to be understood in a broad sense. It concerns every change which enhances the productivity of the different production factors. It can involve new technologies as well as better performing institutions. It may be understood as the result of the accumulation of production factors usually considered as residual in growth accounting studies. We assume technological change to be exogenous and costless, through the growth of total factor productivity (TFP). The costless hypothesis seems reasonable for Mozambique, since we can assume that most technological progress in Mozambique results from technology transfers from foreign direct investments. Arrow et al.. (2004) demonstrate under a set of assumptions (such as a Hicks neutral technology and an elasticity of output with respect to all forms of capital equal to one) that the growth rate of intertemporal social welfare V_t equals the growth rate of comprehensive wealth plus the TFP growth rate. We use TFP calculations from a recent growth accounting exercise (Jones, 2006), in which TFP growth rate is measured through a Cobb-Douglas production function that includes produced capital, labour force and human capital (measured through a human capital index based on the mean years of schooling). In this case, growth is explained by the accumulation of physical capital, the labour force and 'educational capital'. TFP captures the accumulation of others types of capital (the residual), mainly: natural, social (through institutions), and knowledge (technological progress). It is thus broad and heterogeneous. It should be kept in mind that this specification of the production function does not include natural capital, so that the TFP growth rate produced by Jones (2006) may provide a biased estimate of the growth of intangible capital. As a consequence, we propose in Appendix B a correction of the TFP growth rate.

3.4.2 Population growth rate

We assume that population growth is exogenous. In our study, we are interested in the growth of real wealth per capita V/P (P is the population and V the total wealth). Under several hypotheses (the growth rate is assumed to be constant, per capita consumption is independent of population size, and transformation possibilities among goods and services exhibit constant returns to scale), we can write:

$$\frac{d(V/P)}{dt} = \frac{\dot{V}}{P} - \frac{V}{P^2}\dot{P} = \frac{\dot{V}}{V} - \frac{\dot{P}}{P}$$

To obtain the per capita wealth growth rate, the wealth growth rate has to be adjusted downward by subtracting population growth rate. The assumptions are somewhat unrealistic, although widely used. It is not however within the scope of this paper to refine the introduction of population growth in wealth accounting exercises, a far from easy task (see (Arrow et al., 2003; Asheim et al., 2007; Ferreira et al., 2008)).

3.4.3 Carbon damages

We use the methodology developed in Arrow et al. (2007). Their idea is to index the climate change cost of one particular country on global emissions. Nordhaus and Boyer (2000) estimate that global warming will cost 1.5% of World GDP, and 3.5% of the GDP for African countries (we use the most conservative IPCC[4] scenario, corresponding to a doubling of CO_2 emissions). We use this approximation for Mozambique. Thus we can conclude that the climate change cost for Mozambique will represent 0.027% of the world cost. Then, if we assume CO_2 emissions in the world from 2000 to 2005 to be equal to 6.6 billion tons (WDI, 2005) and a marginal damage cost of $50 per ton of carbon dioxide (Tol, 2005), this gives a global damage of $545 billion for the period 2000-2005 The climate change cost for Mozambique is thus $41 million.

[4] Intergovernmental Panel on Climate Change

4 Results

4.1 Physical capital

Table 1 shows the results for the evolution of physical capital between 2000 and 2005.

	All physical capital ($ million)	Mozambican owned physical capital ($ million)
2000	15,245	7,425
2005	24,584	17,082

Table 1: Physical capital in 2000 and 2005

We see a large increase in physical capital in Mozambique between 2000 and 2005. Another significant characteristic is the relatively high share of foreign capital, linked to the large number of megaprojects (especially in the mining sector) in the country.

4.2 Human capital

The first step is to asses the total stock of human capital. Because of data limitations, we were obliged to focus on the population aged over 15 in constructing the working population. From Jones (2006) we obtain a distribution of the average educational level for the working population into four categories: skilled workers subdivided into those with primary, secondary or higher education as against unskilled workers[5]. From the data on consumption (not wages) and educational level in the Mozambican population (given in (Jones, 2006)), we derive a 12.5% rate of return on education. This figure is consistent with other regional studies such as (Psacharopoulos, 2004). Results are shown in Table 2.

	Average educational level	Average per capita human capital	Active population (over 15)	Human capital stock
2000	2.2	1.20	8,790,000	10,596,429
2005	2.6	1.24	9.288,000	11,556,343

Table 2: Human capital stock in 2000 and 2005

[5] We assume that primary education correspond to 7 years of schooling and secondary or higher education to a minimum of 11 years of schooling at least

The second stage is to assess the value of one unit of human capital. One major problem is that people in Mozambique are mostly self-employed, so that it is difficult to obtain an average annual wage or the total wage bill for the country as a whole. We therefore take the labour share from the growth accounting framework of Jones (2006). One of the baseline cases involves a simple Cobb-Douglas production function with constant returns to scale. The labour share is assumed to be 60% of total output. From the Cobb-Douglas properties and assuming that wages reflect the marginal product of labour, we can conclude that the total wage bill amounts to 60% of GDP. This is rather crude, but more consistent than any of the surveys on incomes that we found. We derive average remaining working years for the age 30-35 population segment – which corresponds to the average age of the working population both in 2000 and 2005 – from WHO life tables and population pyramids (US Census Bureau database). Data used and results are shown in Table 3.

	2000	2005
Rental value of one unit of human capital ($2005)	367	345
Remaining working years	34.1	31.9
Shadow price of one unit of human capital ($2005)	6,837	6,651

Table 3: Computation steps of the shadow price of human capital

Results from Table 2 and Table 3 are then used to assess human capital value and compiled in Table 7. It reveals a significant increase in human capital between 2000 and 2005. This evolution is driven by two opposing factors. On the one hand, there was a significant increase in the overall educational level. Indeed, investments in the education sector have been important during the nineties in Mozambique. On the other hand, the shadow price of human capital decreased, mainly a result of a fall in life expectancy, probably due to AIDS (the prevalence rate is around 16% for adults) and tuberculosis.

4.3 Natural capital

4.3.1. Value of natural capital for 2005

Table 4 presents the composition of natural capital for the year 2005 (as a comparison we also include World Bank's figures6).

[6] Care should be taken in comparing since our figures are for 2005 and those of the World Bank for 2000.

		Net present value		
		Present study per capita ($2005)	World Bank per capita ($2000)	Present study ($2005 million)
Mineral resources		940	---	17,860
Forest land	Timber	347	340	6,593
	NTFR	133	392	2,527
	Protected area	30	9	570
Agricultural land	Cropland	694	261	13,186
	Pastureland	109	57	2,070
Marine resources	Fisheries	19	---	361
Total		2,272	1,059	43,168

Table 4: Breakdown of natural capital

Land resources are the most important part of Madagascar's natural wealth, with cropland constituting around a third of its total natural capital value. Mineral resources (especially through gas, coal and heavy sands) represent also an important share, accounting for more than 40% of the natural capital. The importance of forest is understandable, given its share in the GDP, but the relatively weak importance of NTFR is more surprising. Fisheries are also a small part of the natural wealth, mainly because rents are low.

4.3.2. Value of changes in natural capital between 2000 and 2005

Having calculated the value of Mozambique's natural capital for 2005, it is possible to derive the value of the different natural capital stocks in 2000 by tracing back the evolution of these stocks. We focus on subsoil assets (mainly natural gas), cropland and forest resources.

Subsoil asset depletion - we rely on World Bank estimates of resource extraction for a range of fossil fuels and minerals. Depreciation of these resources is computed as the product of price minus the average cost of extraction multiplied by the volume extracted: (P-AC)R where P is the resource price, AC is average cost and R is the volume extracted. For exhaustible resources (mainly natural gas at the moment for Mozambique), we use World Bank datasheets (compiled for the calculation of genuine savings and available on the World Bank website). Post-2005, the exploitation of coal and heavy sands is likely to increase the depletion of exhaustible natural capital.

Cropland degradation - To estimate the cost of soil degradation on cultivated areas, we use the net nutrient replacement cost method. Folmer (1998) provides figures on nutrients (nitrogen, phosphorus, potassium) depletion on a national scale. These are converted into fertilizers bags (see Table 5)[7].

N (kg/ha)	P (kg/ha)	K (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	NPK (kg/ha)	Fertilizers (kg/ha)	Cost ($/ ha)
33	6.4	25	15	30	77	172	72

Table 5: Nutrient balance for cultivated fields and associated per hectare cost

Some important limitations drove us to consider only the relatively small permanent crop area of around 235.000 hectares[8]. Assuming a $0.42 per kg fertilizer price, we obtain in the end a low annual cropland capital depletion of around $17 million per year.

Forest stock depletion – We distinguish two different stocks: the roundwood stock (of commercial value) and the woody biomass stock (mainly for fuelwood). We assess the evolution of each stock, balancing annual wood harvest against annual regeneration. On a national scale, there is no depletion of these two stocks. For roundwood stock, quantities harvested each year (135000 m^3), even if we assume high rates of illegal logging, are below annual regeneration (500000 m^3) as reported in the last National Forest Inventory (Marzoli, 2008). For the woody biomass stock, the annual potential biomass productivity on a national scale (46921000 tons) remains much higher than current fuelwood consumption (14003000 tons) (Wisdom report). As a consequence, we do not consider any depletion of these two stocks[9.]

The aggregate results for natural capital depletion (mineral and cropland resources) are compiled on Table 6.

[7] The coefficients used to convert the nutrient content of the soil into forms in which they exist as fertilizers (N, P_20_5, K_20) are: kgP*2.29=kg P_2O_5, kg K*1.2=K_2O and a bag contains 15%N, 15% and 15%K

[8] First, the nutrient depletion assessed is on a yearly basis although there may not be any depletion of nutrient stocks on a longer time scale (because of fallows and rotations), but only for cultivated fields. Second, chemical fertilizers may not be the cheapest substitute (organic fertilizer or new lands would be certainly more appropriate).

[9] For the roundwood stock, there may not be a significant depletion of the overall stock (including all commercial species), but many local observers point to a rapid degradation of the quality of the forest. There would be a depletion of the most valuable roundwood species.

	Depletion value ($2005 million)
Subsoil assets	-520
Wood capital	0
Soil degradation	-85
Natural capital	-605

Table 6: Natural capital depletion between 2000 and 2005

4.4 Compilation of the results

First, we present the evolution of natural, physical and human capital assets (previously named 'comprehensive wealth')(4.4.1). Damages from global carbon emissions are also included in this section. Second, we account for population growth and technological change to obtain the change of per capita total wealth including the effect of technological progress (4.4.2).

4.4.1 Evolution of comprehensive wealth

	2000 ($2005 million)	2005 ($2005 million)	Variation ($2005 million)
Human capital	72,448	76,857	+4,409
Natural capital	43,773	43,168	- 605
Physical capital	7,425	17,082	+9,658
Carbon damage	---	---	-41
Comprehensive wealth	123,646	137,107	13,421

Table 7: Change in comprehensive wealth

We can observe from Table 7 that there has been an important increase of both human and physical capital stocks. Human capital increased because of the increase of the average educational level, physical capital certainly because of large scale projects. Gas stocks depletion accounts for most of natural capital depletion which appears to be relatively low[10]. In the end, the stock of natural, human and physical capital has been significantly increasing.

[10] The exploitation of gas started only in 2004, so that its contribution to natural capital depletion should increase significantly in the future. Coal and heavy sands extraction has also not started.

4.4.2 Accounting for population growth and technological change

As indicated before, we correct the TFP growth rate estimate from Jones (2006). Following the formula obtained in Appendix B, we get to a much larger growth rate of 4.8%. This can be explained by the fact that physical capital accumulation in Mozambique is substantial. Indeed, as we introduce natural capital into the production function, it reduces the relative contribution of physical capital in the output (as we assume constant return to scale). Thus, TFP growth has to be higher, reflecting higher positive externalities of the fast growing physical capital. Results are compiled on Table 8.

	Growth rate (%)
Comprehensive wealth growth rate	+2.2
TFP growth rate	+4.8
Population growth rate	-2.4
Per capita comprehensive wealth growth rate accounting for TFP	+4.6

Table 8: Growth rate of comprehensive wealth per capita adjusted for residual growth

The comprehensive wealth growth rate hardly covers the population growth rate. The increase in total wealth per capita therefore relies mainly on the TFP growth rate. In our calculations, it reflects both an increased productivity of physical and human capital, consistent with the large amount of foreign direct investment in the country and an increase of the social capital.

4.5 Sensitivity of the results

Our results rely on a set of critical assumptions and the data used can be sometimes disputable. We should do systematic sensitivity analysis for every critical parameter. They are in fact so many that we prefer here to propose a qualitative overall assessment of the robustness of our results. For physical capital, the methodology used is standard and usual caveats apply. Our calculations are particularly sensitive to depreciation rates. We use rough figures from (Jones, 2006) but it is highly possible that our calculation overestimate physical capital stocks as shocks (economic or climatic such as the 2000 floods which have destroyed many infrastructures) are poorly accounted for. For human capital, one important assumption is the working population considered. Because of data constraints, we had to focus on workers above 15. However, children or youth under 15 should also be included as they are either working or building their human capital (with higher expected future incomes). If one could include the children under 15 in our results, this would certainly increase human capital accumulation as primary or secondary school enrolments are actually increasing. For natural capital, data are particularly constraining and our accounting is not exhaustive. For example, we could not consider groundwater, fisheries stock depletion or deforestation. These are however rarely considered as major environmental issues in the country so that we can believe that these would not be much significant. In the end, it seems to us that natural capital variation should not change significantly with better data and other assumptions. Finally, the TFP growth rate used as a proxy for technological and institutional progress is a core parameter in our work. TFP estimates from growth accounting exercises (as well as our adjustment method to account for natural capital) are highly sensitive to the underlying data and assumptions (on the factor shares for example). This issue clearly should be further investigated.

5 Conclusions and perspectives

This paper builds on the work carried out by Arrow et al. (2007). We add some methodological elements in regard to the health dimension of human capital, and refine the methodology developed by the World Bank for estimating natural capital. The paper offers interesting material for analyzing and characterizing Mozambique's current development path and assessing its sustainability. Despite the approximations made, we can conclude that Mozambique, unlike many other sub-Saharan countries, could be following a sustainable path at the start of this century. Its growth is driven mainly by human and physical capital accumulation, while the pressure on renewable natural capital remains relatively low. Compared to most sub-Saharan African countries in which TFP growth is often negative, TFP growth in Mozambique is relatively high, indicating that there is a significant accumulation of technological and social capital. Further work is needed to go deeper into the composition of this intangible capital or residual which is a key parameter in our analysis. Finally, although population growth is high, growth of per capita comprehensive wealth (accounting for technological progress) also remains high.

This study is, of course, not exhaustive. We had to neglect the depletion of several natural capital stocks, such as fisheries and pastureland, because of lack of data. Nor did we take into account water and air pollution, which could be important issues. The study could be improved in several key areas and further work is called for. However, we think it represents a first step toward a tool for accurately and comprehensively assessing the dynamics of Mozambique's growth path.

References

Asheim, G.B., Buchholtz, W., Hartwick, J.M., Mitra, T., Cees, W., 2007. Constant saving rates andquasi-arithmetic population growth under exhaustible resource constraints. Journal of Environmental Economics and Management 53, 2, 213-239.

Arrow, K.J., Dasgupta, P., Goulder, L.H., Daily, G., Ehrlich, P., Heal, G., Levin, S., Mäler, K.G., Schneider, S., Starrett, D., Walker, B., 2005. Are We Consuming Too Much?. Journal of Economic Perspectives, 18, 147-172.

Arrow, K.J., Dasgupta, P., Goulder, L.H., Mumford, K., Oleson, K., 2007. China, the U.S., and sustainability: Perspectives Based on Comprehensive Wealth. Stanford Working Paper.

Benfica, R., Zandamela, J., Zandamela, J., 2005. The economics of smallholder households in tobacco and cotton growing areas of the Zambezi valley of Mozambique. Research Report 59. Ministerio de Planificaçao e Desenvolvimento.

Bucuane, A., Mulder, P., 2007. Exploring natural resources in Mozambique: will it be a blessing or a curse? Discussion papers 54. Ministerio de Planificaçao e Desenvolvimento.

Coughlin, P.E., 2006. Agricultural intensification in Mozambique. Infrastructure, Policy and Institutional Framework – When Do problems Signal Problems Signal Opportunities?. Report commissioned by the African Food Crisis Study (Afrint).

Dasgupta, P., Mäler, K.-G., 2000. Net National Product, Wealth, and Social Well-Being. Environment and Development Economics, 5, 69-93.

Dasgupta, P., 2009. The Welfare Economic Theory of Green National Accounts. Environmental and Resource Economics, 42, 3-38.

DNTF (National Directorate of Land and Forest), 2008. Consolidation phase – Wood energy component WISDOM. Mozambique final report (AIFM).

Ferreira, S., Hamilton, K., Vincent, J.R., 2008. Comprehensive Wealth and Future Consumption: Accounting for Population Growth. The World Bank Economic Review, Vol. 22, 233-248.

Folmer, E.C.R., Geurts, P.M.H., Francisco, J.R., 1998. Assessment of soil fertility depletion in Mozambique. Agriculture, Ecosystems and Environment, 71, 159-167.

Gergely, N., 2005. Economic Analysis of comparative advantage for major agricultural cash crops in Mozambique. Background paper for World Bank.

Jones, S., 2006. Growth accounting for Mozambique (1980-2004). DNEAP discussion paper.

Kunte, A., Hamilton, K., Dixon, J., Clemens, M., 1998. Estimating National Wealth: Methodology and Results. Environment Department Paper 57, World Bank, Washington, DC.

Lane, P.R., Milesi-Ferretti, G.M., 2006. The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970–2004. IMF Working Paper 06/69.

Lizon, J.G., 2002. Rural livelihood dependence on wildlife resources in Gilé district, Mozambique and policy implications. Paper presented at an IFAD Workshop in Nairobi.

Mackenzie, C., 2006. Chinese Takeaway! Forest governance in Zambezia.

Marzoli, A., 2008. Avaliaçao integradas floresta de Moçambique. DNTF.

Mincer, J., 1974. Schooling, Experience, and Earnings. New York: Columbia University Press.

Nordhaus, W.D., Boyer, J., 2000. Warming the World: Economic Models of Global Warming. MIT Press, Cambridge, MA.

OECD (Organization for Economic Cooperation and Development), 2001. The Well-being of Nations: the role of human and social capital. Paris: OECD

Pearce, D.W., Atkinson, G., 1993. Capital theory and the Measurement of Sustainable Development. Ecological Economics, 8, 103-108.

Psacharopoulos, G, Patrinos, H.A., 2004. Returns to Investment in Education: A Further Update. Education Economics, 12, 111–134.
Tol, R.S.J., 2005. The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of Uncertainties. Energy Policy, 33, 2064-2074.
UICN, 2008. Assessment of economic benefits of Mozambique's protected areas.
Ogle, A., Nhantumbo, I., 2006. Improving the competitiveness of the timber and wood sector in Mozambique. Report prepared for the Confederation of Mozambican Business Associations under the Mozambique Trade and Investment project.
Vincent, J., 1996. Resource Depletion and Economic Sustainability in Malaysia. Development Discussion Paper 542, Harvard Institute for International Development, Cambridge.
Wilson, J., 2008. Financial flows in Mozambique's fisheries. Report for Norad-Marema-MdP.
World Bank, 2005. World Development Indicators 2005. The World Bank, Washington, D.C.
World Bank, 2006. Where is the wealth of nations? Measuring Capital for the 21st Century, The World Bank, Washington, D.C.
WWF (World Wildlife Fund), 2008. Pilot financial plan for conservation areas in Mozambique (2008-2017).

Appendix A: Details, data and sources for natural capital calculations

Cropland - Main crops in Mozambique are maize, cassava, mapira, various kinds of beans, peanuts, rice, cotton, cashew nuts, potatoes and tobacco. We consider crops covering more than 60,000 hectares. We assess rental rates on the basis of various production cost studies and local market prices (Gergely, 2005; FAO producer prices). Total rent in 2005 for each crop is estimated through the formula: *Total rent (crop i) = mean yield (crop i)*local market price*rental rate*crop i area.* To project total rents into the future, we use current production trends (over the last five years) for each crop.

crop	2005 area (Ha)	Yield (tons/Ha)	Producer price ($/tonne)	Production growth rate
Maize	1,749,534	1,004	153	0.0186
Cassava	1,038,851	7341	113	0.1603
Sorghum/mapira	364,370	637	146	0.0616
Beans (all types)	659,151	500	441	---
Peanuts (all types)	433,092	341	475	-0.0206
Pumpkin	103,413	1,831	164	0.0193
Rice	278,368	902	296	-0.0177
Cashew	54,616	1,193	238	0.0289
Potatoes	78,938	13,046	352	0.0043
Tobacco	85,234	1,388	1,671	0.0444
Sesame	65,027	661	129	0.0954

[Sources: TIA 2005, FAOSTAT, SIMA, Gergely (2005), Arlindo (2007), Coughlin (2006), Benfica (2005)]

Pastureland – Beef, goat meat and milk constitute the main output from pastureland in Mozambique. As we found no comprehensive data on production costs, we use the rental rate from the World Bank (2006) of 45%. Future rent projections are forecast using current production volume trends.

Output	Price ($/ton)	2005 production (tons)	Rental rate (%)	Total rent production growth trend (%)
Beef	4,052	38,100	45	0
Sheep meat	6,931	768		
Milk	518	68,765		

[Sources: FAOSTAT, (World Bank, 2006)]

Timber resources - We distinguish industrial roundwood from fuelwood production. For legal logging, we use national statistics from the forest ministry. We assume illegal logging is 40% of legal logging (MacKenzy, 2006). The sustainability of wood production is introduced through the lifetime of the resource. We evaluate the time to exhaustion with current production trends, annual regeneration, and total wood stock (from (DNTF, 2008) and (Marzoli, 2008)). Rental rates are assumed to be 40% for industrial roundwood (Bila, 2003) and 50% for fuelwood production.

Non-timber forest resources - We use two studies valuing NTFR: Suich (2006) in Bazaruto, Vilanculos and Chirendzene districts and Lizon (2002) in the Gilé district. These consider direct values only: fruit, wild animals, honey, raffia and bark, etc (first table thereafter). As we have no information on the time spent collecting these products (which is the main production cost), we use a 50% rental rate (based on figures from other southern African countries). We do not add indirect values (such as watershed protection) because it is already included in cropland (or other types of activity) downstream value (if we consider the environmental service 'protection against erosion'). To extrapolate from these household surveys to a country-wide scale is a risky task. We combine the average NTFR value consumed per household with an assessment of the importance of NTFR in the different provinces from the last national forest inventory (second Table thereafter).

	Lizon (2002)	WWF (2006)			Average
Unit: $/household/year		*Bazaruto*	*Chirindzene*	*Vilanculos*	
Food	58	27	20	0	30
Medicinal plants	---	---	---	---	---
Material and construction wood	11	46	173	91	65
Wood fuel	44	126	170	132	123

[Adapted from Lizon (2002) and WWF (2006)]

% use of NTFR for rural households	**North**	**Centre**	**South**
Food	21%	38%	52%
Fodder	2%	1%	4%
Medicinal plants	29%	20%	32%
fuel	19%	18%	1%
Construction wood and ustensils	25%	21%	8%

[Adapted from Marzoli (2008)]

Protected areas - In World Bank (2006), protected areas are valued at the lower end of per-hectare returns to pastureland and cropland - a quasi-opportunity cost. Instead, we propose a rough estimate of the net present value of the network of protected areas. IUCN (2008) suggests some of the principal benefits from the main protected areas are: ecotourism benefits (net revenues from the tourist industry amount to $45 million) and the existence value of the parks through environmental NGO investments (it reflect the willingness of people in rich countries to pay for the protection of biodiversity). WWF (2008) give an indication of the operating costs of the parks, around $5.3 per hectare per year. This figure is based on three national parks and thus does not reflect the heterogeneity of the parks (national parks, reserves and hunting reserves). To obtain the net present value of the protected areas, we assume that: their opportunity cost is low (mostly because of the quantity of land available), the return on capital invested is 15%, the growth rate of the rent is 5% per year (which is conservative in view of the projections for tourism by the Ministry for Tourism).

Fish resources - Production data are from Wilson (2008), based on statistics from the Instituto de Investigacao Pesqueira and Instituto Nacional de Desenvolvimento da Pesca de Pequeno Escala. We upwardly adjust catches by artisanal fisheries, since official statistics do not cover the whole coastal area. In accordance with local experts, we add 40,000 tons to recorded catches. We also use data on the value of fish harvested to derive prices (Wilson, 2008). From Wilson (2008) and consultation with local experts, we use a 10% rental rate for industrial fisheries and 5% for the artisanal ones.

Mineral resources - Bucuane (2007) has carried out subsoil assets valuation for Mozambique, following the methodology developed by the World Bank (based on (Vincent, 1996) which is a refinement of equation (5)). We use values from Bucuane's medium scenario.

Appendix B: Proof of the adjustment of the TPF estimate to account for natural capital omission in the production function

We use the TFP estimate derived in (Jones, 2006) which is the most recent work we could find. To fit our framework, we use the Cobb-Douglas production function case. The production technology is described through the following production function:

$$Y_t=A_tK_t^a(h_tL_t)^b \text{ with } a+b=1$$

where A is an Hicks-neutral technological change, K_t the physical capital, L_t the working population and h a human capital quality index. Let us define g(x) as the growth rate of x. The growth rate of the production Y_t is thus: $g(Y_t)=g(A_t)+a.g(K_t)+b.[g(h_t)+g(L_t)]$.

Let us add the flow from natural capital N_t, the production function becomes:

$$Y_t=A_tK_t^{a(1-r)}(h_tL_t)^{b(1-r)}N_t^r$$

where r is the share of natural resources in production. The growth rate of production becomes: $g(Y_t)=g_c(A_t)+a(1-r)g(K_t)+b(1-r)[g(h_t)+g(L_t)]+rg(N_t)$.

Equalizing the two expressions of $g(Y_t)$, we obtain an expression of the corrected TFP growth rate: $g_c=g+a.r.g(K_t)+b.r[g(h_t)+g(L_t)]-r.g(N_t)$

For the computation, we assume that: a=0.4, g(K)=0.45, g(L)=0.01, g(h)=0.018 (from (Jones, 2006)). For the flow from natural resources, we assume that r=0.2 and g(N)=0.033. 0.2 correspond to the share of agriculture in the GDP (thus it includes agricultural land (pastureland as well as cropland), fisheries and forests resources)[11]. 3.3% is the growth rate of cropland through extensification (according to data from Aviso Previo). We use it as a proxy for the rate of change of the flow derived from the renewable resources. Exhaustible resources are not included here as the exploitation (of gas) started only really in 2005 and the TFP growth rate estimate was assessed for the 1999-2005 period. The magnitude of the different terms is proposed on the table thereafter.

	Growth rate (%)
g	1.6
+a.r.g(K)	3.5
+b.r[g(h)+g(L)]	0.3
-r.g(N)	0.6
g_c	4.8

[11] The share of natural capital in comprehensive wealth in 2005 was around 30%, so that 20% might be an underestimate