Sustainability or Natural Capital Disinvestment? A Retrospective on Brazilian Economic Growth, 1965-1993

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ABSTRACT

This paper evaluates the consequences of the Brazilian 'economic miracle' of the 1960s and 70s on the country's natural environmental, with particular attention to two questions. First, to what extent did natural resource depletion - particularly Amazonian deforestation - after the economic miracle impact adversely on the opportunity for continued well-being improvements in Brazil? Second, was the government policy of targeting incentives toward investment in the Brazilian states in the North and Center-West economically sustainable in the long run? To address the first question, I use a 'green accounting' framework that corrects GDP growth for the value of depleted mineral, timber, and soil stocks, and apply it to Brazilian data from 1965 to 1993. For the second question, I base sustainability on whether gross capital formation exceeds the total value of resource depletion, and compare results under two alternative indicators for the same period. The results are generally inauspicious, especially in years subsequent to 1980, and cast considerable doubt on the efficacy of earlier government policies.

KEY WORDS

national income accounting, natural resource depletion, sustainability

RESUMO

Este trabalho avalia as conseqüências do 'milagre econômico' dos anos sessenta e setenta sobre o meio ambiente, com particular atenção a duas questões. Primeiro, em que medida o esgotamento dos recursos naturais depois do milagre - especialmente o desflorestamento no interior do País - afetou adversamente a possibilidade de melhoria continuada no bem-estar social brasileiro? Segundo, teria sido sustentável, no longo prazo, a política de dirigir os incentivos econômicos para investimentos nas regiões Norte e Centro-Oeste? Para responder à primeira pergunta, utilizo um método de 'contabilidade verde', que corrige o crescimento de PIB pelo valor dos recursos naturais exauridos - minerais, madeira, e solo, neste caso - e o aplico a dados das contas nacionais de 1965 a 1993. Quanto à segunda pergunta, baseio a noção de sustentabilidade na possibilidade de a formação bruta de capital fixo exceder o valor total dos recursos exauridos, e comparo os resultados para o mesmo período com dois indicadores alternativos. Os resultados finais são geralmente desfavoráveis, especialmente após 1980, e lançam considerável dúvida sobre a eficácia da política dos anos anteriores.

PALAVRAS-CHAVE

contabilidade da renda nacional, esgotamento de recursos naturais, sustentabilidade

JEL classification

O13, O54

INTRODUCTION

Many refer to the period in Brazilian history spanning the mid-1960s and the mid- to late-1970s as the 'economic miracle.' Aggressive government policy after 1965, particularly economic incentives to promote economic activity in the country's interior, stimulated rapid economic growth nationwide. GDP grew at 8.6% per annum from 1965 to 1973, and per capita GDP at 5.9%. During this time Brazil also made important strides in its transition from a predominantly agrarian to a 'mixed manufacturing' economy. Consequently, some (e.g., ALMEIDA, 1998) still consider Brazil to be among the leading developing countries in the quest for industrialized country status. Brazil's economic successes have not, however, been without costs.

One negative consequence of the miracle - its regressive distributional effects - is well documented (see, e.g., BUNKER, 1981, 1984; DAVIS, 1977; HOFFMAN, 1989) and is therefore not discussed here. The primary concern of this paper is the steady and irreversible natural resource depletion that Brazil suffered from the late 1970s to the early 1990s, a process that continues unabated. Although not visible in its GDP growth statistics, Brazil sacrificed much of its natural resource base (particularly tracts of forest) to finance short-term consumption. Despite the relatively minimal magnitude of resource depletion during the actual 'miracle years' (1965-73), this earlier period was an important catalyst in subsequent events. The apparent prosperity realized during the economic miracle served to reinforce the widespread precept that the Amazon rain forest was 'not really Brazilian' (i.e., it was a remote backwater) and that continued economic success required that it be developed or 'colonized'. (HECHT, 1985; KATZMAN, 1976)

It is in this context that I consider the question of economic sustainability, an issue explored by many authors in recent years (see, e.g., VEIGA, 1994; LÉLÉ, 1991; MUELLER, 1998; VIEDERMAN, 1995). Although no consensus exists on a precise definition, most associate sustainability with well-being provisions for future generations, often referred to as intergenerational equity. Brazil's consumption of its natural resources - or, if you will, 'natural capital' - may have, despite the short-term benefits, left an ominous legacy for future generations of its citizens. If so, the accepted method for calculating national accounts should be revised to reflect this other form of capital depletion. Doing so would provide us with an indicator - 'green' GDP - that measures sustainability as well as social progress.

This paper seeks an answer to two distinct questions. First, did Brazilian per capita "green GDP" improve from 1965 to 1993, despite the country's widespread natural capital consumption, especially in years following the economic miracle?[1] Second, if so, were the policies that brought about the dramatic changes both in GDP and in resource depletion economically sustainable? To answer the first question, I adopt the revised accounting framework employed in Repetto *et al*. (1989) and Solórzano *et al*. (1991), which corrects national income for the total value of depleted natural resources. The resources I consider here are mineral ore, timber, and soil. To address the second question, I probe beyond green GDP and refer to Brazil's capital accounts, specifically comparing capital formation and depletion of natural capital. As noted by Castaneda (1997), Jackson and Marks (1999), Pearce and Atkinson (1993), and many others, findings of national net disinvestment are generally suggestive of lack of sustainability.

The paper proceeds as follows. The next section lays out the framework for measuring green income and sustainability, and reviews some of the pertinent studies on these questions. Section 2 discusses the methodology and data to be employed in estimating the value of each of the natural resources, and displays results for each of the individual resource accounts. Section 3 presents the findings of the study, and the final section offers a few concluding thoughts.

1. *INCOME GROWTH, SUSTAINABILITY, AND GREEN NATIONAL ACCOUNTING*

Centuries or even decades ago, most humans pursued their economic objectives without great concern for the long-term consequences of their activities on the natural environment. Not only was the global population relatively small, making the abundance of available natural resources appear almost infinite, but the majority of the world's peoples and cultures pursued simple or subsistence lifestyles that had imperceptible impacts on the environment. In such a context, economists might not have been remiss in treating natural resources as 'free gifts,' and prescribing economic development policy predicated on the consumption of these gifts.

Matters are different today, however. Although most would argue that mankind has in many ways progressed remarkably over the years, human stress on the natu-

1 I avoid the more complex notion of whether Brazil developed economically. Even though GDP growth may, for some, be necessary and sufficient for development, many would not accept such a claim. SACHS (1994), for example, has argued that development involves at least five dimensions: the social, economic, ecological, spatial (i.e., optimal territorial allocation of economic activity and optimal urban-rural mix), and cultural. Many others have attributed specific variables such as literacy, longevity, or political rights to the notion of development.

ral environment has grown almost immeasurably during the twentieth century. The world population has quadrupled, lifestyles are increasingly characterized by high consumption, productive technologies are more capital-intensive than ever before, and specialization has, in many developing countries, led to agricultural development based on one or at most a few crops. The environmental consequences of all these changes have spurred recent interest in the issue of sustainability among economists.

Brazil in many ways typifies these changes, and seems an ideal subject for a sustainability assessment. For instance, the country's Amazon basin has been shrinking, especially over the past thirty years, as Brazil's interior is increasingly used to support cash-crops or cattle and to resettle migrants from further east (particularly those from the impoverished Northeast). These activities have necessitated considerable deforestation; in the 15 years spanning 1978 and 1993, 7.5% of the Amazon forest disappeared (INPE, 1995). This may in part have been due to Brazil's need, intensified by the debt crisis, to export its way out of its economic problems at the time.[2] But massive resource depletion has outlasted the worst years of the debt crisis, and is likely to continue until an adequate means of internalizing its attendant social costs into the market system is developed.

One means of internalizing these costs would be to have the national income accounts reflect them. The lack of sustainability that many (e.g., COSTANZA & DALY, 1992; HARRISON, 1989; TORRAS, 1999) attribute to GDP growth results less from the pursuit of growth *per se* than from the manner in which GDP growth is measured. After all, income, at a fundamental definitional level, encompasses sustainability. As noted by Hicks (1946, p. 172), '*Income is the maximum value that a person can consume during a time period and still expect to be as well off at the end of the period as at the beginning*.' In other words, cash flows that make one worse off over time (less wealthy) should not count as income; they should instead be regarded as capital consumption.

Hicks' logic, however, is contrary to the manner in which the United Nations System of National Accounts (SNA) treats natural resources. Although the SNA correctly counts depreciation of fixed or 'man-made' capital (machines, factories, etc., hereafter K_M) as a balancing negative item in the determination of national

2 Brazil's external debt was compounded by what MARTÍNEZ-ALIER (1997) refers to as Brazil's 'ecological debt.' By the latter he means the extent to which the economic loss associated with the country's resource depletion is not reflected in world market prices - specifically, the price of Brazil's export commodities. If institutions designed to reduce ecological debt (by accurately reflecting the economic losses) had been in place at the time, Brazil's export revenues would undoubtedly have been greater, and its external debt consequently lower.

income, it fails to account for depletion of 'natural capital' (trees, minerals, soil, water, etc., hereafter K_N). Consumption of these assets is treated as income, and the SNA consequently overstates true national income.

Hicks, of course, does not mention natural resources in his definition of income. Is this because K_N and K_M are not truly accounting equivalents? The omission is more likely because natural resources were still generally regarded as 'free gifts' at the time of Hicks' writing. After all, capital literally means wealth. Insofar as natural resources possess some economic value (an incontestable point), they are a form of capital **by definition**, despite not being produced, as is K_M, by human hand or machine. Sustainable income (or green GDP) should therefore be defined as the maximum flow that will still allow the aggregate value of K_M and K_N stocks to be preserved.[3]

There have been a number of 'green accounting' country case studies which calculate sustainable income, usually over a range of years, in order to assess the long-term viability of earlier economic policies. Perhaps most well-recognized are studies by the World Resources Institute (WRI) on Indonesia (REPETTO *et al*., 1989) and Costa Rica (SOLÓRZANO *et al*., 1991). The World Bank has also produced similar studies, albeit following a somewhat different methodology (discussed in the next section), for Mexico (MARGULIS, 1992) and Papua New Guinea (BARTELMUS *et al*., 1992). Related studies have also been conducted on Brazil (e.g., BASTOS, 1995; CAVALCANTI, 1995; SERÔA DA MOTTA & MAY, 1992; YOUNG & SERÔA DA MOTTA, 1995), although these either do not calculate sustainable income or 'green GDP' or, where they do, the analysis is only partial (i.e., focusing on only one type of natural resource).

While growth in green or sustainable income may be superior to conventional GDP growth as an indicator of economic progress, it is not without its problems. As suggested by Pearce *et al*. (1996), sustainable income will always be positive (barring heretofore unseen levels of resource depletion) implying, by definition,

3 The implied claim is that K_M and K_N are relatively substitutable in the sense that income is sustainable even in the face of severe loss of K_N, as long as this loss is accompanied by a corresponding gain of K_M (of at least the same amount). While accepted by many, this premise remains controversial. PEARCE *et al*. (1990), for example, argue that the ability of K_M to compensate for, say, lost ecosystem functions in the future is uncertain and that irreversible depletion of K_N might be far more costly than presently anticipated. Others argue that if K_M and K_N were indeed reasonable substitutes for each other, humans would not require nearly as much K_M as presently exists. Moreover, if K_N stocks were exhausted, continued production of K_M would be jeopardized, since many forms of the latter require K_N inputs (for more on this, see PRUGH, 1995). Dissenters from the 'substitutability thesis' distinguish between **weak** sustainability, which requires preservation of a nation's total capital stock (i.e., $K_M + K_N$), and **strong** sustainability, which additionally entails independent preservation of the K_N stock.

that the economy in question is sustainable. As for the green GDP growth rates, they are not always smaller than conventional GDP growth rates (whether they are will depend on whether the ratio of resource depletion to GDP increases over time), and the policy implications are therefore often ambiguous. For this reason, a nation's capital accounts grant us greater insight into the sustainability question than its income accounts. This paper therefore evaluates the consequences of Brazilian resource depletion by adjusting both the country's income and capital accounts.

I have thus far said nothing about how the depleted natural resources are to be valued. The issue is very complex. Ideally, a resource's monetary value would reflect not only its marketable potential (i.e., the profits that a unit of the resource would fetch in the market), but also other benefits associated with its use, many of which may not yet be recognized.[4] Given limited available information on these other benefits, however, most studies limit themselves to the market capitalization value of the resources.[5] It is therefore likely that the extent of resource depletion reported in these studies has been, to a greater or lesser degree, understated. The same can be said of the results reported in the present study which, caveats notwithstanding, also limits its scope to the marketable resource values.

Following the WRI and World Bank - and unlike earlier Brazilian studies - I calculate per capita sustainable income growth and compare it to per capita GDP growth from 1965 to 1993. To address the sustainability question, I compare gross capital formation, or investment, to investment net of estimated resource depletion value, as done in other earlier studies (e.g., MUNASINGHE, 1999). Finally, I employ a variation on this approach, the Pearce and Atkinson (1993) index, applying it to the Brazilian data for each of the years in the period studied. The methodologies employed to estimate the values of the different resources - minerals, timber, and soil - are described in the following section.

4 The ability of trees in the Brazilian Amazon to regulate global climate, for instance, is not yet fully understood; much less is the **value** of such a benefit. Also, yet-undiscovered medicinal benefits associated with certain species of flora or fauna potentially confer great 'option values' on these resources (for more on this, see ADGER *et al*., 1995; AGUIRRE & FARIA, 1996; TORRAS, 2000).

5 Even those that consider some of the non-market benefits (e.g., ADGER *et al*., 1995; COSTANZA *et al*., 1997) base their calculations, for the most part, on rather crude assumptions.

2. THE NATURAL RESOURCE ACCOUNTS

2.1 Methodology and Data

2.1.1 Mineral and Timber Accounts

The value of a mineral or timber stock can be deduced from its net present value (NPV), or the sum of all future profits derived from it. In theory, proper estimation of the NPV should always include information on the size of the resource stock in question, time (e.g., years) until exhaustion, future prices, and future interest rates. In reality, the calculated values in large part depend on the valuation method employed.

There are two recognized methods for estimating the NPV of a resource stock. The first, the net price method (hereafter NP), is the one employed in the WRI case studies, and the other, the user-cost approach (UC), tends to be favored by World Bank economists (see, e.g., EL SERAFY, 1989). There are two main conceptual differences between these two approaches. First, NP treats natural resource depletion as if it were capital depreciation, and thus deducts from gross income the total value of the extracted resource. UC, in contrast, views natural resources as saleable assets and, as such, deducts only a fraction of the value, regarding the remainder as 'true' income.[6] Second, while NP assumes that resource extraction follows the Hotelling efficiency rule whereby net price, or rent, rises over time at the prevailing rate of interest on alternative investments, UC assumes a constant rent.[7] In comparing the two methodologies, one often finds that the estimated values vary considerably (see, e.g., YOUNG & SERÔA DA MOTTA, 1995).

Although not clear from the above which approach is superior, this study adopts NP because its data requirements are less onerous. The UC calculation requires

6 The rationale behind a partial deduction is that consumption of the resource today imposes a 'user cost' on future generations - their inability to consume the resource tomorrow. The fraction representing income depends on the interest rate and the time period over which the resource is to be exhausted:

$$\frac{x_t}{Rq} = 1 - \frac{1}{(1+i)^{n_t+1}},$$

where x_t is true income at time t, R is (constant) unit rent or net price, q is fixed extraction level, i is the interest rate, and n_t equals the number of periods until exhaustion.

7 UC adherents are critical of the NP assumption about a resource's rent because it implies that marginal extraction cost does not increase over time. While admittedly unrealistic, especially in the case of minerals, the UC assumption implies that marginal cost rises at precisely the prevailing interest rate, which seems a rather arbitrary claim.

the size of the resource stock (in terms of tons, cubic meters, what have you), information which is often quite sketchy for both mineral reserves and forest inventories.[8] NP, in contrast, only requires annual extraction levels. The NP formula is as follows:

$$V_t = \sum_{\tau=0}^{n_t-1} \frac{1}{(1+i)^\tau} [(1+i)^\tau p_t] q_\tau = S_t p_t \qquad (1)$$

where V_t is the value of the resource stock at some initial time t, n_t is the expected period to exhaustion at time t, p_t equals the net price at time t, q_τ is the expected amount to be extracted at future time τ, and S_t is the size of the resource stock at time t.

While deriving V_t does require information on S_t, the value of stock depletion **over a given time period** (or ΔV_t) does not. The fact that the interest rate and the rate of increase of the net price cancel (making the present value of the resource rent remain constant, in contrast to the UC case, where the undiscounted rate is constant) is critical in the relatively simple outcome in the K_N depreciation assessment:

$$DEP_t = -\Delta V_t = S_{t-1}\, p_{t-1} - S_t\, p_t \qquad (2)$$

where DEP_t equals this depreciation. In applying this formula to the present study, we can let this figure equal the extraction level for the period in question times the average net price over the period, or $-\Delta V_t = 0.5 q_t (p_{t-1} + p_t)$.

Although Brazilian mines contain nearly fifty different types of ore, this study focuses on a subset of these, specifically aluminum, chromium, coal, copper, gold, iron, lead, magnesium, manganese, nickel, silver, tin, tungsten, and zinc. Data for annual volume of extraction of these minerals from 1965 to 1993 are obtained from the *Anuário Estatístico do Brasil*, published by the Brazilian Institute for Geography and Statistics (IBGE), for several years. Annual market prices are taken from the *Commodity Trade and Price Trends* report, the U.S. Bureau of Mines *Sta-*

8 The UC formula for valuing a resource stock is:

$$V_t = Rq \sum_{\tau=0}^{n_t-1} \frac{1}{(1+i)^\tau},$$

where V_t is the stock value at time t, and R, q, i, and n_t are as in footnote 4. Since n_t must be known to obtain V_t, this implies, given q, that the stock size is known as well.

tistical Compendium, the Commodity Research Bureau's *Commodity Yearbook*, and, in the case of silver, the Silver Institute's *World Silver Survey 1950-1990*. Most prices are in U.S. dollars, so they are converted to Brazilian reais (R$) according to the exchange rate reported by the International Monetary Fund. Estimates of unit extraction and transport cost are based on figures from several years of the IBGE's *Pesquisa Industrial*.

Timber stock depletion is estimated from the change in forest cover for each Brazilian state, which is in turn inferred from the annual increase in agricultural area. The latter data are taken from the IBGE's *Censo Agropecuário*. Once the deforestation area approximations are obtained, estimates of the average forest 'density' (i.e., timber volume per hectare) are used in calculation of the physical depletion amounts. The forest density numbers are from Serôa da Motta and May (1992). World market prices for timber are from *Commodity Trade and Price Trends*. Estimates for economic rent are based on Repetto *et al*. (1989). As with the mineral data, extrapolation was necessary for years for which data are lacking.

2.1.2 Soil Accounts

Erosion of fertile, nutrient-rich soil detracts from the land's ability to sustain agricultural production. The extent of soil erosion can be measured directly, by measuring agricultural productivity loss, or indirectly, by estimating the value of the physical and biological soil properties lost as a consequence of the erosion. Although the direct method, or the productivity loss approach, is probably more accurate than the indirect approach, its data requirements are daunting. Information is required on a host of variables such as physical and biological soil loss and the relationship between erosion and productivity for each type of soil. Moreover, estimation of erosion by this approach demands data on labor and machinery requirements and costs, as well as production levels and prices over time for a variety of crops. (SOLÓRZANO *et al*., 1991)

The indirect method, known as replacement cost, is less complicated empirically. This approach emphasizes the nutrients (e.g., nitrogen, phosphorous, potassium) that contribute to crop growth which are lost as a result of erosion. The value loss associated with soil erosion is inferred from the necessary expense on chemical fertilizers required to replenish the soil with nutrients. Because of its relative simplicity, the replacement-cost method is employed in this study.[9]

9 Other soil erosion valuation studies opt, on the same grounds, for the replacement-cost method (see, e.g., BASTOS, 1995, and SOLÓRZANO *et al*., 1991).

The economic loss attributable to soil erosion is estimated as follows:

$$VSE = (QN_{tot}) \cdot e(P_f),^{10} \quad (3)$$

where QN_{tot} equals the quantity lost of a given type of nutrient, P_f represents the unit price of the corresponding replacement fertilizer, and e (>0) is an 'efficiency' factor to account for the fact that a ton of, say, nitrogen fertilizer does not fully compensate for a lost ton of nitrogen.

Estimation of QN_{tot} is, in turn, based on a methodology used in other related studies, namely Bastos (1995), Cavalcanti (1995), and Solórzano *et al*. (1991). The equation is as follows:

$$QN_{tot} = \delta \bullet (K \bullet S \bullet R \bullet L \bullet C), \quad (4)$$

where δ represents the average concentration of nitrogen, phosphorous, and potassium in each of Brazil's 26 states, K is the soil erosiveness factor, S is the slope grade factor,[11] R is the rainfall runoff factor, L is the land use factor, and C is a factor which accounts for soil conservation practices. The product within the parentheses equals the soil loss per unit of area.

The soil erosiveness factor (K) for each state is inferred from the soil classification and map of agricultural potential found in the *Anuário Estatístico* 1994. The variable for each state depends on the approximate amount of each 'type' of soil quality found within it. The area weighted average of an ordinal scale of erosion susceptibility (ranging from 1 to 6) is then converted to K factors ranging from 0.08 to 0.38, following the range used in Solórzano *et al*. (1991).

The slope factors (S), ranging from 0.35 to 15.0, are also taken from Solórzano *et al*. (1991) Values for each Brazilian state are assigned based on regional topographical information, also in the *Anuário Estatístico* 1994, with mean slopes rang-

10 This is a simplified form of a formula employed in SOLÓRZANO *et al*. (1991), which substitutes (QN_{tot} - QN_{tol}) for QN_{tot} above, where QN_{tol} is the tolerable quantity of loss, equal to the soil's natural generative capacity (via decaying biological and geological material). The formula is simplified here because it is not clear whether adjustments for 'tolerable' levels of erosion would contribute much to the analysis. Any estimates would be exceedingly crude due to both limited data availability and enormous cross-regional variability in how much erosion is tolerable. Moreover, the prevailing soil conservation regime in each state, information which at present is also sketchy, would undoubtedly have an impact on how much erosion is tolerable.

11 Slope grade and slope length factor are, for simplicity, condensed into one figure.

ing from 4.25 to 39 degrees. The rainfall factor (***R***) in each state, ranging from 85 to 1,445, is based on the average annual precipitation in each of Brazil's states, with Pará the most moist and Ceará the driest.

The land use factor (***L***) depends on whether land was used for annual crops, perennial crops, or pasture (the erosion effect under forest cover was assumed to be negligible). The specific erosion factors are, respectively, 0.34, 0.086, and 0.04. The land use distribution in each state is from the IBGE's *Censo Agropecuário* for several years. Area amounts for missing years are extrapolated. The soil conservation factor (***C***) (theoretically between zero and one) was assumed to be equal to one, given insufficient information on conservation practices.[12]

Concerning specific nutrient types, this study employs estimates for loss of nitrogen, phosphorous, and potassium. The concentration of each nutrient per unit of soil ($\boldsymbol{\delta}$) in the different Brazilian states is based on numbers found in Bastos (1995), Cavalcanti (1995), and Solórzano *et al*. (1991).[13] The efficiency factor (***e***) for each nutrient is taken from Bastos. Finally, the world prices of urea, potassium muriate, and triple super-phosphate (fertilizers for the replacement of nitrogen, potassium, and phosphorous) are converted from dollars to 1993 reais using the deflators and exchange rates found in the IMF's *International Financial Statistics*.[14]

2.2 Resource Depletion Value Calculations

All told, over four billion tons of mineral ore were extracted from Brazilian mines from 1965 to 1993. For many minerals, annual quantity extracted tended to increase over this period. For some, such as aluminum, iron, and nickel, this growth in extraction level was steady and considerable. Discoveries in the late 1970s and early 1980s of new deposits of, for example, copper, gold, and iron, led to abrupt and pronounced increases in either their extraction or reserve levels.

Consequently, the aggregate annual value of Brazilian mineral extraction increased substantially in the 1965-93 period (Table 1). While extraction value amounted to R$75.5 million (1993 prices) in 1965, by 1993 the overall Brazilian mineral stock

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12 Doing so is not unreasonable, given the widespread practice in Brazil (often driven by government incentives) of further clearing of forest, as opposed to protecting or maintaining the viability of the used land, which would push *C* below unity.

13 The numbers in these studies are used to construct reasonable ranges of nutrient concentrations so as to reflect the vastly different Brazil soil types in the IBGE classification.

14 The exchange rate between the Brazilian and U.S. currencies in 1993 was 0.03216 reais per U.S. dollar. The real did not actually replace the cruzeiro real (CR) until 1994 (at a rate of 2,750 CRs per Real), so the 0.03216 figure reflects an actual 1993 exchange rate of 88.4 CRs per dollar.

was being extracted to the tune of R$981.8 million per year. Even relative to GDP the increase is significant, surging from two percent of GDP in 1965 to seven percent in 1993. The relative values peak in the mid- to late-1980s, reflecting the anomalously voluminous activity in the incipient years of the Brazilian 'growth pole' strategy of targeting Amazonian development in areas of considerable mineral wealth.

TABLE 1 - RESOURCE DEPLETION, BY SECTOR, 1965-93
(millions of reais, 1993 prices)

Year	Mineral Loss	As % of GDP	Timber Loss	As % of GDP	Soil Loss	As % of GDP
1965	75.5	2.0%	1,129.6	30.5%	189.0	5.1%
1966	66.8	1.7%	1,047.1	27.3%	191.1	5.0%
1967	64.6	1.6%	1,123.8	27.8%	193.3	4.8%
1968	79.8	1.8%	1,275.5	28.5%	195.7	4.4%
1969	104.0	2.1%	1,443.3	29.3%	198.2	4.0%
1970	153.7	3.0%	1,559.9	30.9%	200.5	4.0%
1971	162.2	2.9%	1,682.4	29.9%	188.0	3.3%
1972	159.3	2.5%	1,876.5	29.8%	197.3	3.1%
1973	163.8	2.3%	2,138.1	29.8%	206.0	2.9%
1974	185.2	2.4%	2,374.2	30.6%	323.6	4.2%
1975	185.6	2.3%	2,672.8	32.8%	295.8	3.6%
1976	240.4	2.7%	2,607.6	29.0%	240.6	2.7%
1977	226.4	2.4%	2,447.0	25.9%	237.8	2.5%
1978	189.6	1.9%	2,509.3	25.3%	214.5	2.2%
1979	302.4	2.9%	2,675.7	25.3%	267.1	2.5%
1980	644.9	5.6%	3,167.3	27.4%	284.6	2.5%
1981	566.4	5.1%	3,305.7	29.9%	266.9	2.4%
1982	601.4	5.4%	3,451.1	30.9%	293.7	2.6%
1983	1,043.5	9.6%	3,603.8	33.3%	263.4	2.4%
1984	1,336.5	11.6%	3,764.3	32.7%	277.9	2.4%
1985	1,286.5	10.4%	4,026.4	32.5%	311.3	2.5%
1986	921.8	7.0%	4,999.9	37.7%	244.3	1.8%
1987	987.7	7.2%	5,256.9	38.4%	229.3	1.7%
1988	1,448.4	10.6%	5,486.3	40.1%	276.1	2.0%
1989	1,160.2	8.1%	5,681.4	39.9%	294.5	2.1%
1990	990.3	7.3%	5,947.9	43.7%	299.7	2.2%
1991	989.2	7.3%	6,271.4	46.0%	305.0	2.2%
1992	1,089.7	8.1%	6,616.5	49.0%	309.2	2.3%
1993	981.8	7.0%	6,984.9	49.5%	313.7	2.2%

The aggregate value loss in the timber sector increased sixfold during the 1965-93 period, from R$1.1 billion in 1965 to R$6.9 billion in 1993. Relative to GDP, the increase is not nearly as dramatic. Only beginning in the late 1980s does the ratio of timber loss to GDP rise significantly, and this increase is due in large part to clear-cutting of secondary forest area, as clearing of virgin Amazon forest was considerably slower from the late 1980s to the early 1990s (although it has since risen again, to unprecedented levels).

The estimated value of soil erosion varied relatively little during the period, ranging from R$189 million in 1965 to R$313.7 million in 1993. Yet because deforestation predominantly took place in the North (i.e., in the states of Acre, Amapá, Amazonas, Pará, Rondônia, and Roraima), the loss resulting from erosion in this region was about seven times as great in 1993 as in 1965 (R$3.6 billion compared to R$561 million). Nevertheless, relative to GDP, the nationwide value of soil eroded exhibited a steady decline throughout the period, from about five percent of GDP at the beginning, to only a bit more than two percent at the end of the period.

We now apply the calculated mineral, timber, and soil losses to the Brazilian income and capital accounts for 1965-93. The next section presents the results, both for the question of how resource depletion impacted on income growth, and for the question of whether this growth was economically sustainable.

3. GROWTH AND SUSTAINABILITY: A LOOK AT THE EVIDENCE

3.1 WRI Approach

Brazil experienced a nearly fourfold increase in GDP from 1965 to 1993, but the story was quite different when we take natural resource depletion value into account (Table 2). Since resource depletion - especially mineral extraction and deforestation - accelerated beginning around 1980, the GDP gains in subsequent years are diminished considerably when adjusted for these losses. Sustainable income (SI) grew by only two and a half times over the 1965-93 period and, more important, SI was 26% lower in 1993 than in 1980.

The results are even more unsettling when we consider the per capita figures. While per capita GDP slightly more than doubled from 1965 to 1993, per capita SI increased by only one third (Figure 1). Notice also the difference in the trends. We see a sharp increase in per capita GDP prior to 1980, followed by minor fluctuation in subsequent years. While we observe the same sharp increase before 1980 for per capita SI (from R$25.2 in 1965 to R$57.8 in 1980), we see almost as pronounced a decline in subsequent years (to R$33.2 in 1993).

TABLE 2 - FIXED CAPITAL CONSUMPTION, RESOURCE DEPLETION, AND SUSTAINABLE INCOME, 1965-93 (million reais, 1993 prices)

Year	GDP	Fixed Capital Consumption	NDP	Total Resource Depletion Loss	Sustainable Income
1965	3,701.1	190.7	3,510.4	1,394.1	2,116.3
1966	3,839.8	165.8	3,674.0	1,305.0	2,369.0
1967	4,045.3	172.6	3,872.7	1,381.7	2,491.0
1968	4,482.4	192.4	4,290.0	1,551.0	2,739.1
1969	4,920.8	214.2	4,706.6	1,745.4	2,961.1
1970	5,049.6	268.1	4,781.4	1,914.1	2,867.3
1971	5,621.6	295.6	5,326.0	2,032.7	3,293.3
1972	6,294.0	326.6	5,967.5	2,233.1	3,734.3
1973	7,171.9	345.8	6,826.1	2,508.0	4,318.1
1974	7,755.1	371.0	7,384.1	2,883.0	4,501.2
1975	8,158.8	386.3	7,772.5	3,154.2	4,618.3
1976	8,994.6	422.5	8,572.1	3,088.5	5,483.6
1977	9,437.9	431.4	9,006.5	2,911.1	6,095.4
1978	9,907.2	457.8	9,449.4	2,913.4	6,536.0
1979	10,577.1	475.0	10,102.1	3,245.2	6,856.9
1980	11,552.8	457.5	11,095.3	4,096.8	6,998.6
1981	11,063.7	479.6	10,584.2	4,139.0	6,445.1
1982	11,154.1	610.0	10,544.1	4,346.2	6,197.9
1983	10,827.2	509.0	10,318.2	4,910.7	5,407.5
1984	11,515.7	541.4	10,974.3	5,378.8	5,595.5
1985	12,382.5	582.2	11,800.3	5,624.2	6,176.1
1986	13,249.2	622.9	12,626.3	6,166.1	6,460.3
1987	13,697.5	644.0	13,053.5	6,473.9	6,579.6
1988	13,688.8	643.6	13,045.2	7,210.8	5,834.5
1989	14,239.8	669.5	13,570.4	7,136.2	6,434.2
1990	13,620.7	640.4	12,980.3	7,237.9	5,742.5
1991	13,620.7	640.4	12,980.3	7,565.6	5,414.7
1992	13,496.9	634.5	12,862.3	8,015.4	4,846.9
1993	14,116.0	663.7	13,452.3	8,280.3	5,172.0

FIGURE 1 - TRENDS IN GDP AND SUSTAINABLE INCOME PER CAPITA

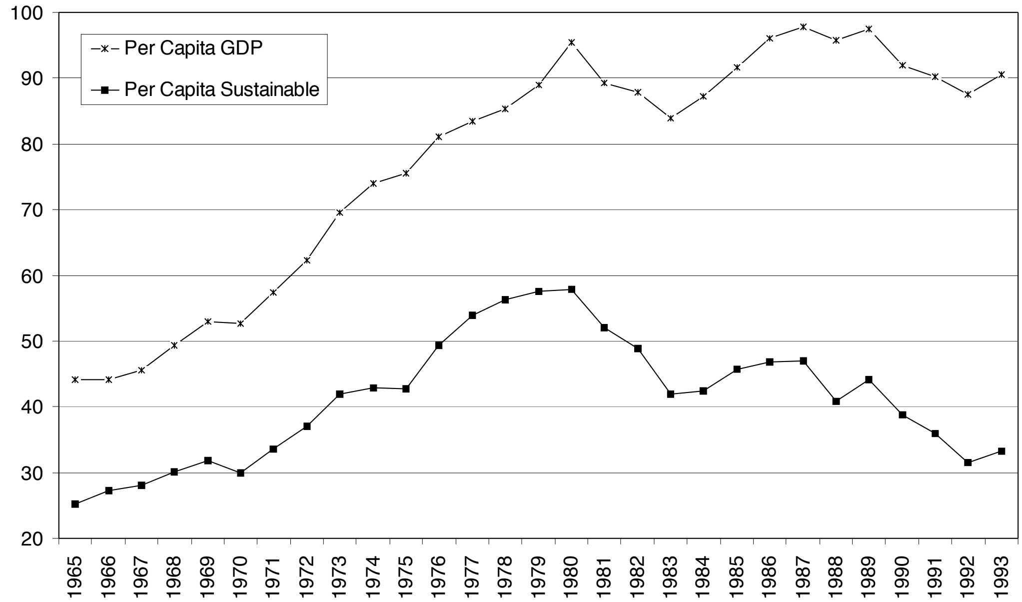

Table 3 best illustrates the sharp difference in resource depletion volume between the 1965-80 sub-period and 1980-93. In the years of the 'economic miracle', including its twilight in the late 1970s, SI per capita actually grew **more rapidly** than GDP per capita (5.7% per annum compared to 5.3%), since the magnitude of resource depletion, while not negligible, grew more slowly than GDP. This is not surprising, since initial attempts at population resettlement ran into problems (hence did not account for significant amounts of forest clearing), and because it was not until the late 1970s or early 1980s that ranching- and mineral extraction-induced deforestation really accelerated in most Amazonian states.

TABLE 3 - ANNUAL PER CAPITA INCOME GROWTH RATES FOR SELECT PERIODS

	1965-93	1965-80	1980-93
Per Capita GDP	2.6%	5.3%	-0.4%
Per Capita Sustainable Income	1.0%	5.7%	-4.2%

Consequently, while SI per capita grew more rapidly than GDP per capita in the earlier sub-period, the accelerated rates of resource depletion are reflected in a complete reversal of this trend after 1980. Because of a dramatic slowdown in

Brazil's macroeconomy - due, in large part, to its international difficulties - even GDP per capita shrank from 1980 to 1993, at a rate of 0.4% per annum. But per capita SI declined far more dramatically - at 4.2% annually - reflecting a much higher depletion-GDP ratio in 1993 than in 1980. Indeed, this reversal almost wiped out earlier gains in per capita SI, as its annual growth rate for the entire period is only one percent (compared with 2.6% for GDP per capita).

3.2 Net Investment Approach

As noted in section 1, there are limitations to using per capita green GDP as a sustainability indicator. As an alternative, we can compare Brazil's gross capital formation with the value of its K_N depletion. Quite simply, if gross domestic investment is less than resource depletion, Brazil is drawing down its capital stock, using its natural resources to finance consumption - an unsustainable practice, given finite natural resources.

This is, as suggested in Table 4, precisely what Brazil has done over the 1965-93 period; depletion-adjusted domestic investment (DADI) is negative in every year. Moreover, not only does it increase in absolute terms throughout the period but, again after the mid-1980s, relative to GDP as well. Thus, not only is the Brazilian economy non-sustainable in every year studied, it seems to have strayed further from the sustainability yardstick in more recent years. Although the cause is very much an open question, such an outcome signals the need to restructure the Brazilian economy in such a manner that most or all of the proceeds from natural resource extraction finance investments in other forms of capital, to the point where DADI is, at the very least, non-negative.

TABLE 4 - DOMESTIC INVESTMENT, GROSS AND DEPLETION-ADJUSTED, 1965-1993 (million reais, 1993 prices)

Year	Gross Domestic Investment	Value of Resource Depletion	Depletion-Adjusted Domestic Investment	DADI as Percent of GD
1965	699.1	1,394.1	-695.0	-18.8%
1966	810.3	1,305.0	-494.7	-12.9%
1967	830.8	1,381.7	-551.0	-13.6%
1968	1,011.7	1,551.0	-539.3	-12.0%
1969	1,170.2	1,745.4	-575.3	-11.7%
1970	1,221.5	1,914.1	-692.6	-13.7%
1971	1,414.8	2,032.7	-617.9	-11.0%
1972	1,579.9	2,233.1	-653.2	-10.4%
1973	1,751.7	2,508.0	-756.2	-10.5%
1974	2,060.9	2,883.0	-822.0	-10.6%
1975	1,900.9	3,154.2	-1,253.3	-15.4%
1976	2,013.9	3,088.5	-1,074.6	-11.9%
1977	2,008.3	2,911.1	-902.8	-9.6%
1978	2,207.5	2,913.4	-706.0	-7.1%
1979	2,473.5	3,245.2	-771.7	-7.3%
1980	2,631.1	4,096.8	-1,465.7	-12.7%
1981	2,550.3	4,139.0	-1,588.8	-14.4%
1982	2,432.7	4,346.2	-1,913.5	-17.2%
1983	2,019.2	4,910.7	-2,891.5	-26.7%
1984	1,903.2	5,378.8	-3,475.6	-30.2%
1985	2,365.8	5,624.2	-3,258.4	-26.3%
1986	2,528.9	6,166.1	-3,637.2	-27.5%
1987	3,046.1	6,473.9	-3,427.9	-25.0%
1988	3,108.5	7,210.8	-4,102.3	-30.0%
1989	4,076.0	7,136.2	-3,060.2	-21.5%
1990	2,971.8	7,237.9	-4,266.1	-31.3%
1991	2,562.8	7,565.6	-5,002.8	-36.7%
1992	2,551.2	8,015.4	-5,464.2	-40.5%
1993	2,734.0	8,280.3	-5,546.3	-39.3%

3.3 Pearce and Atkinson Approach

Another well-recognized sustainability indicator is that developed by Pearce and Atkinson (P&A, 1993). Their approach is, in two ways, a variation on the DADI measure discussed above. First, they consider gross **savings** instead of investment, in order to account for the surplus or deficit in a given country's current account. Second, for consistency, the P&A index accounts for depreciation of fixed capital as well as resource depletion.

The index is derived using the following formula:

$$Z = (S/Y) - (\Delta M/Y) - (\Delta N/Y), \tag{5}$$

where $\boldsymbol{Z}$ is the sustainability index, $\boldsymbol{S}$ equals savings, Y represents income, $\boldsymbol{\Delta M}$ equals consumption of fixed or man-made capital, and $\boldsymbol{\Delta N}$ is natural resource depletion, or K_N consumption. By this criterion, an economy is sustainable if and only if $\boldsymbol{Z} > 0$, because such an outcome would signify that gross savings exceed the total value of capital dissipated.

Not surprisingly, this indicator is also strongly negative for Brazil in all the years surveyed (Table 5). After fluctuating considerably in the years prior to 1980, the P&A index more than doubles by 1993 (from -18.9 to -41.8), again suggesting that Brazil is increasingly distant from its sustainability objective. Also, as P&A note, their index is a measure of **weak** sustainability - that is, the extent to which total, as opposed to natural, capital is maintained - suggesting that the results could be even more unfavorable if less conservative assumptions were adopted. In sum, the three indicators considered here, in combination, provide strong evidence both that Brazil's economic growth from 1965 to 1993 was far more modest than indicated by conventional measures, and that government policies designed to promote such growth have (thus far at least) been unsustainable.

TABLE 5 - PEARCE AND ATKINSON SUSTAINABILITY INDEX

Year	Gross Domestic Saving-GDP Ratio	Fixed Capital Consumption-GDP Ratio	Resource Depletion-GDP Ratio	Pearce & Atkinson Sustainability Index
1965	21.4%	5.2%	37.7%	-0.214
1966	21.3%	4.3%	34.0%	-0.170
1967	20.3%	4.3%	34.2%	-0.182
1968	21.7%	4.3%	34.6%	-0.172
1969	21.4%	4.4%	35.5%	-0.184
1970	23.7%	5.3%	37.9%	-0.195
1971	23.6%	5.3%	36.2%	-0.178
1972	23.4%	5.2%	35.5%	-0.173
1973	23.3%	4.8%	35.0%	-0.165
1974	20.9%	4.8%	37.2%	-0.210
1975	19.4%	4.7%	38.7%	-0.240
1976	20.0%	4.7%	34.3%	-0.190
1977	20.6%	4.6%	30.8%	-0.148
1978	21.1%	4.6%	29.4%	-0.130
1979	21.3%	4.5%	30.7%	-0.139
1980	20.5%	4.0%	35.5%	-0.189
1981	22.7%	4.3%	37.4%	-0.191
1982	21.1%	5.5%	39.0%	-0.233
1983	21.1%	4.7%	45.4%	-0.289
1984	22.4%	4.7%	46.7%	-0.290
1985	24.2%	4.7%	45.4%	-0.259
1986	21.5%	4.7%	46.5%	-0.298
1987	25.5%	4.7%	47.3%	-0.265
1988	27.9%	4.7%	52.7%	-0.295
1989	32.3%	4.7%	50.1%	-0.225
1990	23.6%	4.7%	53.1%	-0.343
1991	20.8%	4.7%	55.5%	-0.394
1992	22.4%	4.7%	59.4%	-0.417
1993	21.6%	4.7%	58.7%	-0.418

CONCLUSION

The period of the Brazilian 'economic miracle' appears to have been welfare-improving for most if not all Brazilians. Not only did per capita GDP improve, but per capita sustainable income did as well, and at a more rapid rate. The respective annual growth rates from 1965 to 1973 were 5.9 and 6.6 percent, and even extending the sub-period to 1980, the annual growth rates are only marginally lower: 5.3% for per capita GDP, and 5.7% for per capita sustainable income.

Yet according to both the depletion-adjusted domestic investment or Pearce and Atkinson measures, these rapid growth rates were not in a single year sustainable economically. This fact, along with the Brazil's international financial problems, may have had a hand in the subsequent economic decline. Even per capita GDP shrank from 1980 to 1993, at an annual rate of 0.4%, and we find that after factoring in resource depletion, per capita sustainable income decreased at *4.2% per annum*. This sub-period, moreover, appeared to be far more economically unsustainable than in earlier years. By 1993, the extent to which Brazil was 'disinvesting' from its future, relative to GDP, was two to three times what it had been prior to 1980.

Some might find these conclusions exceedingly pessimistic. To begin with, Brazil's GDP growth rates over the past thirty years compare favorably with those of most developing countries - so favorably, in fact, that the natural resource accounting probably does not discernibly alter this result. Furthermore, the natural resource valuation was based exclusively on world market price and extraction cost (and, in the case of soil, world price of fertilizer). Had the value of projected substitutes and potential natural resource-saving technological innovations been considered, it is likely that the resource value estimates would have been considerably lower, potentially leading to more favorable findings.

Regarding the first objection, if per capita incomes in other developing countries declined more rapidly after 1980 than they did in Brazil, this should hardly be a consolation. Many Brazilians, especially the poorest groups, still suffer if their basic needs are not met irrespective of whether the shortfall in other countries is greater. No attempt was made to factor in distributional changes over time. The fact that income inequality worsened significantly, coupled with the observed decline in income per capita after 1980, further limits the scope for any optimistic assessments of what transpired.

With respect to the valuation question, while true that resources may have been overvalued for the reasons stated above, there are a few countervailing reasons for which they may have been **under**valued. First, the study only considered three natural resources - minerals, timber, and soil - and omitted others - e.g., fisheries, mangrove swamps, etc. - from consideration. Second, changes in environmental quality were not included in the revisions. We can expect that the pollution of, say, the atmosphere or fresh water in Brazil to have worsened in the face of significant increases in population, industrialization, and energy use. Finally, as mentioned earlier, only marketable benefits were considered in the resource valuations; other yet-unrealized or unrecognized (e.g., ecological, option) values were excluded.

What are we to conclude? The need to provide at least basic sustenance for all Brazilians makes it extremely difficult to justify, even if it were possible, a complete halt to resource depleting activities. The greatest challenge, therefore, is to balance the need for long-run sustainability with continued efforts to combat poverty and other social problems. Two policy implications follow from this assessment.

First, the Brazilian government should introduce incentives to increase the rate of private savings, so that capital investment might 'crowd out' consumption in determination of national income. More specifically, greater investment in natural capital (e.g., programs to promote reforestation or less soil-degrading agricultural practices) are strongly advised. Second, such changes entail the elimination of subsidies or tax breaks to the mining and cattle ranching industries - the principal beneficiaries of earlier policies - and new incentives to promote continued economic diversification toward manufacturing activities that do not require continued clearing of the Amazon forest. If achieved, this will aid Brazil on its path to greater self-sufficiency in the secondary and tertiary sectors. This would diminish dependence on foreign imports and would, in turn, imply less emphasis on cash-crop and primary material exports. These events might, in the shorter run, put Brazil back on an economically sustainable course and, in the longer run, deliver consistent well-being improvements nationwide once again.

REFERENCES

ADGER, W. N., BROWN, K. CERVIGNI, R. & MORAN, D. Toward estimating total economic value of forests in Mexico. Centre for Social and Economic Research on the Global Environment, University of East Anglia and University College London, *Working Paper* 94-21, 1995.

AGUIRRE, A., & FARIA, D. M. C. P. de. Avaliação contingente de investimentos ambientais: um estudo de caso. *Estudos Econômicos,* v. 26, n. 1, p. 85-109, jan./mar. 1996.

ALMEIDA, A. C. O Brasil no final do século XX: um caso de sucesso. *DADOS - Revista de Ciências Sociais,* v. 41, n. 4, p. 785-830, 1998.

BARTELMUS, P., LUTZ, E. & SCHWEINFEST, S. Integrated environmental and economic accounting: a case study for Papua New Guinea. *World Bank Environment Working Paper* n. 54, Washington, DC: World Bank, 1992.

BASTOS FILHO, G. S. *Contabilizando a erosão do solo: um ajuste ambiental para o produto bruto agropecuário paulista*. Dissertação de Mestrado, Universidade de São Paulo, Brasil, 1995.

BUNKER, S. The impact of deforestation on peasant communities in the medio Amazonas of Brazil. In Studies in Third World Societies, *Where have all the flowers gone? Deforestation in the Third World*. Williamsburg: College of William and Mary, Department of Anthropology, 1981.

_______. *Underdeveloping the Amazon: extraction, unequal exchange, and the failure of the modern state*. Urbana: University of Illinois Press, 1984.

CASTAÑEDA, B. *An index of sustainable economic welfare (ISEW) for Chile*. Solomons: Institute for Ecological Economics, 1997.

CAVALCANTI, J. E. *Valoração econômica das perdas de solo no Vale do Rio São Francisco*. Codevasf/FAO, Relatório Final de Consultoria, 1995.

COSTANZA, R., & DALY, H. Natural capital and sustainable development. *Conservation Development,* v. 6, n. 1, p. 37-46, 1992.

COSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R. V., PARUELO, J., RASKIN, R.G., SUTTON, P. & VAN DEN BELT, M. The value of the world's ecosystem services and natural capital. *Nature*, 15, p. 253-260 May 1997.

DAVIS, S. H. *Victims of the miracle*. London: Cambridge University Press, 1977.

EL SERAFY, S. The proper calculation of income from depletable resources. *In:* AHMAD, Y. J., EL SERAFY, S. & LUTZ., E. (eds.), *Environmental accounting for sustainable development*, Washington: World Bank, 1989, p.10-18.

HARRISON, A. Introducing natural capital into the SNA. *In*: AHMAD Y. J., EL SERAFY, S. & LUTZ, (eds.), *Environmental accounting for sustainable development*. Washington, DC: The World Bank, 1989, p. 19-25.

HECHT, S. Environment, development, and politics: capital accumulation and the livestock sector in eastern Amazonia. *World Development,* v. 13, n. 6, p. 663-684, 1985.

HICKS, J. R. *Value and capital: an inquiry into some fundamental principles of economic theory*. Oxford: Oxford University Press, 1946.

HOFFMAN, H. Poverty and prosperity: what is changing? *In*: BACHA, E. L. & KLEIN, H. S. (eds.), *Social change in Brazil, 1945-1985: the incomplete transition*. Albuquerque: University of New Mexico Press, 1989.

INPE. Extensão do desflorestamento na Amazônia legal. http://www.dpi.inpe.br/ amazonia/desflora.html, 1995.

JACKSON, T. & MARKS, N. Consumption, sustainable welfare, and human needs - with reference to UK expenditure patterns between 1954 and 1994. *Ecological Economics,* v. 28, n. 3, p. 421-441, 1999.

KATZMAN, M. T. Paradoxes of Amazonian development in a 'resource-starved' world. *Journal of Developing Areas,* v. 10, n. 4, p. 445-460, 1976.

LÉLÉ, S. Sustainable development: a critical review. *World Development,* v. 19, n. 6, p. 607-621, 1991.

MARGULIS, S. Back-of-the-envelope estimates of environmental damage costs in Mexico. World Bank, *Working Paper Series*, #824, January 1992.

MARTÍNEZ-ALIER. Deuda ecológica y deuda externa. *Caderno de Estudos Sociais,* v. 13, n. 2, p. 183-214, 1997.

MUELLER, C. C. Avaliação de duas correntes da economia ambiental: a escola neoclássica e a economia da sobrevivência. *Revista de Economia Política,* v. 18, n. 2, p. 66-89, 1998.

MUNASINGHE, M. Is environmental degradation an inevitable consequence of economic growth: tunneling through the environmental Kuznets curve. *Ecological Economics,* v. 29, n. 1, p. 89-109, 1999.

PEARCE, D. W. & ATKINSON, G. Capital theory and the measurement of sustainable development: an indicator of "weak" sustainability. *Ecological Economics* 8, p. 103-108, 1993.

PEARCE, D. W., BARBIER, E. & MARKANDYA, A. (1990). *Sustainable development: economics and environment in the Third World*. London: Elgar, 1990.

PEARCE, D., HAMILTON, K. & ATKINSON, G. Measuring sustainable development: progress on indicators. *Environment and Development Economics* 1, p. 85-101, 1996.

PRUGH, T. *Natural capital and human economic survival*. Solomons: ISEE Press, 1995.

REPETTO, R., MAGRATH, W., WELLS, M., BEER, C. & ROSSINI, F. *Wasting assets: natural resources in the national income accounts*. Washington: World Resources Institute, 1989.

SACHS, I. Estratégias de transição para o século XXI. *Cadernos de Desenvolvimento e Meio Ambiente* 1, p. 47-62, 1994.

SERÔA DA MOTTA, R. & MAY, P. Loss in forest resource values due to agricultural land conversion in Brazil. *Texto para discussão n. 248*. Rio de Janeiro: Instituto de Pesquisa Econômica Aplicada, 1992.

SOLÓRZANO, R., DE CAMINO, R., WOODWARD, R., TOSI, J., WATSON, V., VÁSQUEZ, A., VILLALOBOS, C. & JIMÉNEZ, J. *Accounts overdue: natural resource depreciation in Costa Rica*. Washington: World Resources Institute, 1991.

TORRAS, M. Inequality, resource depletion, and welfare accounting: applications to Indonesia and Costa Rica. *World Development,* v. 27, n. 7, p. 1191-1202, 1999.

______. The total economic value of Amazonian deforestation, 1978-1993. *Ecological Economics,* v. 33, n. 2, p. 283-297, 2000.

VEIGA, J. E. DA. Problemas da transição à agricultura sustentável. *Estudos Econômicos,* v. 24, Número Especial, p. 9-29, 1994.

VIEDERMAN, S. A economia da sustentabilidade: desafios. *Cadernos de Estudos Sociais,* v. 11, n. 1, p. 141-168, 1995.

YOUNG, C. E. F. & SERÔA DA MOTTA, R. Measuring sustainable income from mineral extraction in Brazil. *Resources Policy,* v. 21, n. 2, p. 113-125, 1995.

DATA SOURCES

BASTOS FILHO, G. S. See references list. 1995.

CAVALCANTI, J. E. See references list. 1995.

COMMODITY RESEARCH BUREAU, Inc. *Commodity Yearbook*. CRB, 1975.

CRB *Commodity Yearbook*. 1984.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. *Censo Agropecuário*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1970.

IBGE. *Pesquisa Industrial*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1972.

IBGE. *Anuário Estatístico do Brasil*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1973a.

IBGE. *Pesquisa Industrial*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1973b.

IBGE. *Censo Agropecuário*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1975.

IBGE. *Anuário Estatístico do Brasil*. Rio de Janeiro: Ministério do Planejamento e Orçamento,. 1978.

IBGE. *Censo Agropecuário*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1980.

IBGE. *Censo Agropecuário*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1985.

IBGE. *Anuário Estatístico do Brasil*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1986.

IBGE. *Anuário Estatístico do Brasil*. Rio de Janeiro: Ministério do Planejamento e Orçamento, 1994.

INTERNATIONAL MONETARY FUND - IMF. *International Financial Statistics Yearbook*. Washington, DC., 1990.

IMF. *International Financial Statistics Yearbook*. Washington, DC, 1996.

IMF. *International Financial Statistics Yearbook*. Washington, DC, 1997.

JOHNS HOPKINS PRESS, THE. *Commodity Trade and Price Trends, 1989-1991*. For the World Bank, 1992.

REPETTO, R., MAGRATH, W., WELLS, M., BEER, C. & ROSSINI, F. See references list. 1989.

SERÔA DA MOTTA, R. & MAY, P. See references list. 1992.

SILVER INSTITUTE, THE. *World Silver Survey 1950-1990*. 1990.

SOLÓRZANO, R., DE CAMINO, R., WOODWARD, R., TOSI, J., WATSON, V., VÁSQUEZ, A., VILLALOBOS, C. & JIMÉNEZ, J. See references list. 1991.

U.S. DEPARTMENT OF THE INTERIOR. *Statistical Compendium*. Bureau of Mines. 1993.

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