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Measuring Sustainable Income from Mineral Extraction in Brazil

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Abstract

This paper provides estimates of mineral depletion in Brazil, and their implication to the measurement of "sustainable income" for the mineral sector, during the period 1970-1988. Two alternative approaches are briefly reviewed: the net price approach and the user cost approach. Estimates of sustainable income from mineral extraction in Brazil are computed using both techniques, and the results obtained vary significantly between them. Estimates obtained with the user cost approach are of the same order of magnitude as conventionally measured income, with differences explained in terms of the time horizon of extraction. With the net price approach, on the other hand, large oscillations in sustainable income reflect variation in the underlying estimates of mineral reserves.

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1 INTRODUCTION

In recent years, the traditional approach to economic growth has come under increasing scrutiny with the growth of concern about environmental sustainability. Unfortunately, the empirics of sustainability have not matched the evolution of its theory. Despite the many international attempts to establish systems of Environmental Accounts, the widespread use of the expression "sustainable development" has not yet been matched by corresponding estimates and discussions of "sustainable income", that is to say, growth which is consonant with available natural resources.

Finding a working definition of "sustainable income" is an important first step towards integrating the environment into the National Accounts.[1] The problem extends into the heart of the accounting system, since the depletion or degradation of natural resources are rarely valued at market prices. Moreover, the degradation and depletion of natural resources are treated as pure sources of economic gain; no attribution being made for the loss of natural assets. The problem confronting the environmental national accountant is thus,to find a means of including, in traditional accounts, the value of increases or decreases in the stock of natural resources, which in last instance, represent changes in the set of society's assets, present and future.

The valuation of natural resources has received attention mainly from a neoclassical, microeconomic perspective, in terms of "getting prices right." This perspective is summarised, ironically, by Daly:

> 'once prices are right the environmental problem is "solved" - there is no macroeconomic dimension.' (Daly, 1990. p.19)

In fact, as Daly goes on to argue, the use of natural resources does raise important problems from a macroeconomic perspective. This problem concerns the future availability of resources and how that is reflected in aggregate indicators of macroeconomic performance, i.e., the System of National Accounts. Moreover, any procedure to estimate the impact of resource use at a macroeconomic level should derive from a theoretically justified concept of income. As a consequence, new ways to calculate income and its aggregated values should emerge as natural resource valuation techniques are introduced.[2]

This work aims at estimating the depletion of mineral resources in Brazil and the implications of this for the measurement of Domestic Product. Section 2 presents the definition of income used currently in the System of National Accounts (SNA) and its inadequacy when treating non-produced assets. Section 3 describes alternative methods of valuing the asset losses

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[1] The literature presents several measures of environmentally adjusted income/product: environmentally adjusted product (Bartelmus *et al.* 1993), modified GNP (Peskin 1989), "net" national product (Repetto *et al.* 1989), etc. In this paper the term "sustainable income" is used in the same sense, i.e., an alternative measure for the conventional SNA aggregate which incorporates the depletion of natural resources, observing the identity between income and product.

[2] See a review of the literature in Ahmad *et al.* (1989), Peskin and Lutz (1990), Serôa da Motta (1991), Young (1992), Hamilton (1992).

consequent on the depletion of natural resources. In Section 4, the depletion cost estimates for mineral extraction in Brazil are analyzed. Finally, Section 5 examines the sustainability principles underlying depletion cost measurement.

2 THE CONCEPT OF INCOME

Value Added is the synthesis variable of the National Accounts and the three approaches to it - Output, Income and Expenditure - form the key elements of the accounting framework. In the Output method, value added is equated to the total value of output minus any intermediate consumption required by that production. In the Income approach, value added is equal to the total remuneration accruing to production factors, while the Expenditure approach shows value added as the uses of final goods and services for consumption, investment or exports.[3] The concepts of Income, Output and Expenditure represent different ways of looking at the production process but their values are identical, by definition.[4]

Another important principle of accounting is the difference between Income and Receipts. Income indicates a variation in wealth (accumulation of assets) while receipt (and, symmetrically, expenditure) represents the exchange or transfer of assets. Boulding (1949, p.77-78) insists that:

> '...there is no change in the total of assets as an immediate result of receipt or expenditure, for it is a fundamental accounting convention that in exchange equal values are exchanged. A receipt or an expenditure merely represents a change in the form of assets - from non-liquid to liquid in the case of receipt, from liquid to non-liquid in the case of expenditure. ...Money income is the money value of the gross growth in assets. Real income is the gross growth in assets in physical terms.'

It is this difference that underpins the discussion of the method used to calculate the income derived from the exploitation of natural resources. The clearest example refers to the extraction of mineral resources: the estimate of value added for this activity is obtained as the difference between the gross value of output and intermediate consumption. The latter constitutes expenditure on inputs and industrial operations and other present expenditures but excludes payments to production factors (labour and capital, broadly defined). However, mineral extraction and sale does not imply an increase in the total asset stock. The monetary value of the decrease in the stock of mineral assets must be subtracted from the receipts obtained by the possessor. It cannot be part of income, as defined above. Should extractors consume all of their net receipts by the end of the accounting period, their total stock of assets would have fallen. By definition, therefore, their expenditures would have exceeded their incomes. This implies that the conventional accounting procedure can only be considered sound if resources are infinite.

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[3] For concepts and methodology of national accounting see United Nations (1968).

[4] Income is defined in the SNA as an indicator of levels of activity and not of welfare, as stressed by those who criticize the use of GDP, or GDP per capita, as an indicator of social development.

Environmental and Natural Resources Accounting studies have increasingly called attention to this flaw. The principal focus of the argument is the fallacy engendered by the existing SNA, i.e. that the higher the continuous exhaustion of natural resources the higher the growth of output. That is, they show no concern with the sustainability of extraction. As pointed out by Reppeto *et al.* (1989, p.2):

> '... a country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared.'

An amendment of the SNA is therefore required, to account for the economic losses of natural resources due to production and to avoid the confusion of income with receipts.

3 MEASURING SUSTAINABLE INCOME

Two principal methods have been proposed to measure natural capital consumption in order to determine sustainable income: the "net price method" and the "user cost method." Both treat natural resources depletion as a loss of assets and both attempt to develop a new definition of income compatible with the "true income" criterion of Hicks (1946, p.176):

> '... a person's income is what he can consume during the week and still expect to be as well off at the end of the week as he was at the beginning.'[5]

Where the two models differ is in their treatment of expectations about future economic rents (per unit of output). The net price approach assumes an optimal extraction path, with unit rents rising by the Hotelling efficiency rule.[6] In contrast, the user cost method assumes that future unit rents will be equal to current values. The following sections present a brief description of each approach.

3.1 Net Price Method

This method computes the net price of a resource as the physical variation in the resource stock, over the accounting period, multiplied by the market price of the output, net of production costs and adjusted for price changes. Ideally, this net price would be the Hotelling rent accruing to the owner of the resource. The procedure then subtracts from the gross income the total net revenue derived from the resource extracted, this rent being assumed to

[5] The practical application of this criterion to aggregate estimates is criticized in several papers (see, for example, Reich 1991 and Young 1992). Hicks himself acknowledges the difficulty: "by considering the approximations to this criterion, we have come to see how very complex it is, how unattractive it looks when subjected to detailed analysis. We may allow a doubt to escape us whether it does, in the last resort, stand up to analysis at all, whether we have not been chasing a will-o'the-wisp" (Hicks 1946, p. 176).

[6] As pointed out by Landefeld and Hines (1985) and Hamilton (1992), a rate of increase of unit rent equal to the discount rate is equivalent to a zero discount rate in the present value calculation. See Hartwick (1990) and Hartwick and Hageman (1993) for a discussion of Hotelling rent as the appropriate measure of natural capital depreciation.

reflect the depreciation of the resource stock. Since the decrease in the stock of a non-renewable resource is equivalent to the amount extracted during the year, the depletion (evaluated according to current prices) could be subtracted from the gross income in the same way as capital consumption is deducted from value added in manufacture activities. Revenues from mining extraction would, therefore, be included in the Gross Product, but the value of the associated resource depletion - i.e. the net price - would be deducted to obtain the Net Product.

Reppeto *et al.* (1989), Solórzano *et al.* (1991) and Cruz and Repetto (1992) follow this procedure in their evaluations of the patrimony loss accompanying the exploitation of natural resources in Indonesia, Costa Rica and the Philippines, respectively. The process utilises physical estimates of stock and extraction which are then monetised. Net variations of the stock value are computed as: annual additions to deposits (discoveries, net revisions, growth or reproductions) minus deductions (depletion, degradation or deforestation) with a correction for resource price changes during the year. Equation (1) summarizes the procedure:

$$X_t.P_t = X_{t-1}.P_{t-1} + \Delta X_t.P_t^* + X_{t-1}.\Delta P_t + \Delta X_t.(P_t - P_t^*) \qquad (1)$$

where: X_{t-1} is the opening stock of the resource in physical units, X_t is the closing stock, P_{t-1} is the net price per physical unit at the open of term, P_t is the net price per physical unit at close of term and P^*_t is the average unit net price during the term. The following relationships can be derived from equation (1):

i) Net variation of stock:

$$X_t.P_t - X_{t-1}.P_{t-1} = \Delta X_t.P_t^* + X_{t-1}.\Delta P_t + \Delta X_t.(P_t - P_t^*) \qquad (1a)$$

ii) Current net additions during the year:

$$\Delta X_t.P_t^* = (Ad_t - Rd_t).P_t^* \qquad (1b)$$

where Ad_t represents stock additions (discoveries, net revisions, extensions, growth and reproduction) and Rd_t represents stock reductions (production, deforestation or degradation).

iii) Reevaluations:

$$Rv_t = X_{t-1}.\Delta P_t + \Delta X_t.(P_t - P_t^*) \qquad (1c)$$

where $X_{t-1}.\Delta P_t$ corresponds to the reevaluation of opening stocks, and $\Delta X_t.(P_t - P^*_t)$ corresponds to the reevaluation of transactions made during the term.

Note that in this method the Hotelling lemma is not properly applied since it is net price, price minus average costs, and not the true rent, price minus marginal costs, which is considered. The use of net price as a proxy would thus only give strictly valid estimates of net domestic product if there were constant returns to scale in extraction.

Since newly discovered reserved can exceed depletion levels, the computed NNP can indicate an accumulation of natural capital rather than a depreciation. Therefore, the new measure ("Net" National Product) can, in theory be negative or exceed the conventional GNP, both results lacking a convincing theoretical justification.[7]

The appropriateness of empirical applications of Hotelling's rule is a further source of contention:

> 'Unfortunately the assumptions required for the Hotelling theory, constant extraction costs for a homogeneous resource of known extent, do not apply in the real world - even moderately more realistic assumptions ... lead to optimal extraction programmes in which rents must increase at some rate less than the discount rate' (Hamilton 1992, p.7).

3.2 User Cost Method

According to El Serafy (1989), depletion of natural resources cannot be conceptually regarded as depreciation since it does not involve use of fixed (produced) capital. Receipts obtained from the extraction of non-renewable resources derive from the sale of assets, a disinvestment, which cannot be regarded as value added (gross or net) - instead of saying that there was a "current production" of gold, it should be stated that there was an extraction. Actually, what should be deducted from GDP is the user cost, which is not explicit in mineral production, but which represents the sacrifice imposed upon future generations when the resource is exhausted. According to Keynes (1973, p.69-70):

> 'User cost constitutes one of the links between the present and the future... It is the expected sacrifice of future benefit involved in present use which determines the amount of this sacrifice which, together with the marginal factor cost and the expectation of the marginal proceeds, determines his scale of production.'

Following the net price approach, on the other hand, if extraction is costless and if all of the rent is considered as capital consumption, then the economy's value added based on exploitable resources would be zero. In this extreme example, rent is equivalent to gross income.

[7] Hamilton (1992, p.6) suggests that these problems can be solved if discoveries are treated only as reconciliation items, linking the value of stocks between accounting periods, therefore showing up neither as current income nor product. As an example, if discoveries were treated this way, he points out that the Indonesian NNP growth rate would be 5.8%, instead of the 4.0% rate shown in Repetto *et al.* (1989), a result closer to the 7.1% growth rate for Indonesian GNP.

El Serafy appeals instead to Hicks's (1946) definition of true income, that is, the amount of present consumption that will not leave one worse off in the future.[8] In this case:

> 'The finite series of earnings from sale of the resource ... has to be converted to an infinite series of true income such that the capitalized value of the two series be equal. From the annual earnings from sale, an income portion has to be identified capable of being spent on consumption, the remainder, a capital element, should be set aside year after year to be invested in order to create a perpetual stream of income that would sustain the same level of "true" income, both during the life of the resource as well as after the resource has been exhausted.' (El Serafy 1989, p. 13)

The portion of net receipts set aside as a capital allowance is, in fact, the user cost and should not be included in GDP. Rather than attempting to hold constant the value of the natural resource, which would be geologically and biologically impossible, sustainable income requires investments in physical capital with the capacity to generate future income flows (not receipts) equivalent to those generated by the natural resource until exhaustion.

The following procedure was used by Serôa da Motta and Young (1991) to estimate the user cost of mineral extraction in Brazil.[9] The exploitation of a natural resource generates a net revenue (R), which is perceived as the receipt net of operation and capital costs. From this revenue, a portion (R - X), the user cost, must be set aside and invested to guarantee an infinite flow of sustainable income (X). That is, the present value of all future (X) should equal the present value of the stream of (R - X) from the current period to the exhaustion date of the reserve.

At the instant t_n when the reserve is exhausted, F{R-X} is the current value of the series of (R - X) accumulated during the period of extraction (n) and compounded at a rate (r), the opportunity cost of capital. Assuming that annual net revenue remains constant during the extraction period:

$$F\{R-X\} = (R-X) \cdot \sum_{t=0}^{n-1}(1+r)^t = (R-X) \cdot \frac{(1+r)^n - 1}{r} \qquad (2)$$

From t_{n+1} onwards this accumulated capital stock will generate annual returns equivalent to the opportunity cost of capital, (r), whose present value P{R-X} will be:

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[8] No reference to the expression "user cost" was made by El Serafy in his 1981 paper, which refers only to the Hicksian true income concept. The term "user cost" and the reference to Keynes (1973) were made *a posteriori*, in the paper published in 1989. Young (1992) argues that there is a theoretical incompatibility between these concepts, because the Hicksian definition of income is an individual welfare measure, while Keynesian user cost is a measure of effective demand, with no reference to welfare status.

[9] A nicety of methodology provides the difference between this and the original procedure used by El Serafy (1981, 1989): the latter failing to distinguish between the opportunity cost of capital and the intertemporal rate of discount. The result, however, is the same.

$$P\{R-X\} = F\{R-X\} \cdot \frac{r}{d} = (R - X) \cdot \frac{(1 + r)^n - 1}{d} \qquad (3)$$

where (d) is a discount factor incorporating the rate of intertemporal preference.[10] Note that (d) does not need to be estimated since it is self cancelling in equation (4).

The sustainable income (X) generated with revenues provided by the resource is equal to the present value of the accumulated capital return described in (3):

$$F\{R-X\} \cdot \frac{r}{d} = (R - X) \cdot \frac{(1 + r)^n - 1}{d} = \frac{X}{d} \qquad (4)$$

Multiplying both sides of (4) by (d) gives

$$(R - X) \cdot [(1 + r)^n - 1] = X \qquad (5a)$$

$$\frac{X}{R} = 1 - \frac{1}{(1 + r)^n} \qquad (5b)$$

For each natural resource it is, therefore, possible to estimate the (X/R) ratio and, consequently, to determine the (R - X) portion of the receipts from exploitation of these resources (that is, the user cost) that should be accounted for as natural asset loss, and the portion of net revenues which should be regarded as sustainable income (X). Hereafter the ratio of user cost to traditional GDP [(R - X)/GDP] will be called the depletion factor.[11]

Note that the user cost method is very sensitive to both the opportunity cost of capital (r) and the depletion period (n). High values of either variable result in low estimates of user cost. The methodology thus reflects the real scarcity of the resource, since deductions from conventional production values are significant only if the actual rate of extraction implies the imminent exhaustion of the resource. The net price approach, on the other hand, requires that all of the surplus obtained from an exhaustible resource is deducted from income, irrespective

[10] (d) is not equal to the discount rate but is instead a generic discount factor that varies depending on the time period in question, i.e. (d) converts the annual return F(R-X)r to present value terms (at t=0).

[11] In El Serafy (1989) the depletion factor used was X/R. In practical terms the relationship adopted here is preferable, since it can be applied directly to product values.

of the availability of that resource. In fact, the net price approach can be considered as a special case of the user cost approach, when $n = 0$ (i.e. immediate exhaustion).[12]

Another advantage of the User Cost Approach is that it dispenses with assumptions about market structure; however, the extreme simplicity of its treatment of rent expectations is clearly unrealistic. Indeed, the major criticism of the approach is the absence of a clear statement as to why expected user cost should be constant when prices and extraction costs may vary over time.[13]

4 ESTIMATES OF SUSTAINABLE INCOME FROM MINERAL EXTRACTION IN BRAZIL: 1970 - 1988

4.1 Introduction

This section addresses the estimation process and results of attempts to measure the sustainable income generated through mineral extraction in Brazil. To facilitate comparison between the two methods presented in the previous section, both the net price technique, summarized by equation (1), and the user cost approach, outlined by equation (5b) are used.

In order to make direct comparison between the two approaches feasible, the estimation procedures and the tables of results are presented as follows: time to exhaustion (depletion period), depletion factors (see Section 3.2), value added for the extraction of selected minerals and the sustainable income calculated according to both methods.[14]

The information required to assemble the data set was obtained from the Annual Industrial Censuses and Researches (PIAs) of the Brazilian Institute of Geography and Statistics (IBGE) and from the Mineral Year Book published by the National Department of Mineral Production (DNPM). For the petroleum analysis, data was provided by the annual surveys of the National Oil Council (CNP). Proxies used to overcome the lack of information that may occur are described with the estimation procedures.

[12] Note also that both methods assume perfect substitutability between natural and produced assets, from an accounting perspective.

[13] Another criticism, from a more neoclassical point of view, is that the extraction path assumed in the user cost approach is sub-optimal with respect to the Hotelling efficiency condition. The latter point of view assumes the existence of an optimal extraction path that can be derived from the present until the end of the planning period, i.e. the future can be perfectly foreseen. In reality, uncertainty about the future can lead to the rationale selection of alternative extraction paths. It must be remembered that the Hotelling condition is merely one of portfolio efficiency; it is not a forecasting system.

[14] The figures for sustainable income presented here are based on new estimates of value added in the mineral extraction industry and cannot be compared to the figures presented in Serôa da Motta and Young (1991), which are adapted from values obtained in the official Brazilian National Accounts.

4.2 Estimation of the Depletion Period

The depletion period (n_t) reflects the period of time at the end of which reserves would be exhausted at the current rate of extraction. It is computed by simply dividing the mineral Basic Reserve (the sum of the Measured and Indicated Reserves of the DNPM) by the volume of the mineral extracted that year.[15]

When data on the base year reserves of a mineral were not available, the Basic Reserve was approximated by adding to the reserve reported in a later year the amount extracted in the intervening period. This procedure presumes that stock variations occur only as a consequence of extraction, not considering discoveries or revaluations. Where the only data available were those for final output of refined metal, the amount of ore initially extracted was computed by using the average mineral content of the ore as observed in previous years.

The depletion period was estimated for 23 different minerals, representing 80% and 90% of the total output value of the mineral sector for the years 1970 and 1980, respectively. At current rates of extraction, many of the minerals exhibit periods of exhaustion of hundreds or thousands of years, suggesting ease in attaining sustainability. Among these are: slate, sand, bauxite, calcarious rock, coal, white clay and marble.

Nevertheless, there is a set of minerals for which the estimated depletion period is under one hundred years. In some cases, this simply reflects the under-estimation of the extent of reserves. This is true of most non-metallic minerals of relatively low unit value (feldspar, granite, agalmatolite, calcareous shells and talc) for which registered mines occupy an area far smaller than that in which these minerals exist. On the other hand, low depletion periods also characterise certain metallic minerals and fuels (iron, tin, lead, chromium, manganese, tungsten, gold and petroleum) that have high unit values. This set of minerals forms the primary focus with regard to sustainability, consequently they are considered in the following estimation procedure. Table 1 presents the depletion period estimates for these minerals.

4.3 Estimation of the Depletion Factors

The depletion factors (DF_t) represent the portion of the surpuls that may be regarded as sustainable income according to the user cost approach ([R-X]/GDP). They are calculated from the values obtained for the depletion period and for the opportunity cost of capital, through equation (5b).

$$DF_t = 1 - \frac{1}{(1 + r)^{n_t}} \tag{6}$$

The estimates of the depletion periods employed were those obtained in the previous section. A sensitivity analysis was performed using three alternative opportunity costs of capital: 5%, 10% and 15% per annum. This reflects the measurement difficulties observed in previous

[15] The reserves are evaluated using the first working day of the year as the basis.

attempts to estimate Brazil's opportunity cost of capital.[16] The highest rate used is based on surveys conducted in the 1970's and 80's, which revealed annual rates between 12% and 20%. Since the available studies were neither up to date nor sufficiently precise, an intermediate value (15%) is used.[17] The use of lower alternative values (5% and 10%) is motivated by the argument that the rate of discount should be lowered to reflect environmental concerns and inter-generational equity issues.

Tables 2.1, 2.2 and 2.3 show the results obtained for the set of chosen minerals. The lowest depletion factors are for petroleum, tungsten, chromium, tin and gold, implying that only a small portion of the rent obtained in their extraction can be regarded as sustainable income. On the other hand, almost all of the rent obtained from the extraction of iron and manganese (given $r=10\%$ or 15%) can be considered sustainable income. Note that the depletion factor for those minerals not included in the sample is always equal to one, due to their long depletion periods.[18]

4.4 Rent Estimates for the Extraction of Selected Minerals

Data on output in the mineral sector in Brazil, for the period 1970-88, were obtained from industrial census data (IBGE). For years in which census data were not available, synthetic estimates were derived from indices of aggregate value (based on data from the Annual Industrial Research (PIA) by IBGE), or from indices of physical production (Monthly Industrial Research (PIM) by IBGE or annual surveys of DNPM and CNP).

Disaggregated estimates of mining activity were not available for each year, preventing a direct calculation of the rents obtained from extraction of each mineral.[19] To circumvent this problem, an alternative series for value added was computed, disaggregated by the production level of each mineral and compatible with the data on reserves and depletion factors. This procedure was rendered additionally necessary by considerations of data quality described below.

The value added (Y_t) is obtained as the difference between output value (OV_t) and intermediate consumption (IC_t). This difference corresponds to the sum of, wages (WA_t), social charges (SC_t) and the gross operating surplus (OS_t). The gross operating surplus can be divided into two parts: the capital remuneration (CR_t), including the opportunity cost of capital (taking into account fixed capital depreciation) and total rent (TR_t). Consequently the rent may be obtained residually if the other variables are known, as shown by the equations below:

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[16] See Serôa da Motta (1988) and Serôa da Motta and Young (1991).

[17] Moreover, the recent Brazilian Privatisation Programme has used 14% as the basic rate.

[18] With an opportunity cost of capital equal to 15%, any depletion period equal or superior to 70 implies a depletion factor greater than 0.9999.

[19] Due to the lack of measures of marginal cost, this analysis uses average unit receipts net of costs (or the net price), calculated from the average costs of production.

$$Y_t = OV_t - CI_t \quad (7)$$

$$Y_t = WA_t + SC_t + OS_t \quad (8)$$

$$TR_t = OS_t - CR_t \quad (9)$$

A brief description of the procedures used to estimate the magnitude of these variables is provided in Appendix A. Additional information is presented in Young (1992).

Table 3 presents the aggregate results of these estimations. It can be seen that the rate of growth of rents for the sector as a whole (169% for r=5%; 128% for r=10% and 85% for r=15%) was much lower than that observed for the value of output. This disparity arises from the greater increase in industrial operating costs (1141%), salaries (1338%) and, in particular, estimated capital returns (more than 2000% in all cases), the latter due to the significant expansion of investment in the sector. These tendencies, present for almost all selected minerals, indicate that the expansion of mineral extraction has been followed by gradual increases in operating costs as well as in expenditures on exploration. This contributes to a decline in unit rents, obtained as the ratio of rent to output in each year.

4.5 Estimates of Sustainable Income Using the Net Price Approach

The net price approach to the calculation of sustainable income uses equation (1) to compute depreciation of natural capital; the depreciation for one year being the difference between the mineral stocks of the previous and the current year. The mineral stock in any year (S_t) is taken as the basic reserve, and it is multiplied by the unitary rent (P_t) observed in that year. The sustainable income is then the value added minus the natural capital depreciation.

$$YSI_t = Y_t - Dep_t \quad (10)$$

$$Dep_t = S_{t-1}.P_{t-1} - S_t.P_t \quad (11)$$

Calculated levels of natural capital depreciation and sustainable income computed using the net price approach are summarized in Table 4 and Figure 1. It can be seen that the absolute value of estimated depreciation is consistently higher than that of value added, being more than 10 times higher in certain years. This was a consequence of reserve variations due to discoveries and revaluations which exceeded depreciation caused by extraction.

An economic explanation of the oscillations in sustainable income calculated using the net price approach is not easily provided. A comparative analysis which considers the results obtained with this approach and those observed using the user cost approach is presented in section 4.7.

4.6 Estimates of Sustainable Income Using the User Cost Approach

Sustainable income in terms of the user cost approach is obtained as the difference between the value added and the user cost (UC_t) for each of the selected minerals. The user cost is obtained by applying the depletion factors, calculated in section 4.3, to the rent estimates for each selected mineral, obtained in section 4.4, using equation (5b).

$$YS2_t = Y_t - UC_t \qquad (12)$$

$$UC_t = (1 - DF_t).TR_t \qquad (13)$$

Table 5 and Figure 2 show the aggregate results. In contrast to the estimates obtained with the net price method, sustainable income is now always smaller than the value added as conventionally calculated and, significantly, does not assume negative values.

In the base case (r=15%), the user cost approach shows that approximately 90% of the value added from mineral extraction in the early 1970's may be considered sustainable income. Nevertheless, as a consequence of significant reserve discoveries and revaluations in the second half of the 1970's, there was an increase in the surplus portion that could be considered as sustainable income. Consequently sustainable income is seen to have been virtually equal to conventional income over the period 1978-1983. This was especially true of the expansion of tin reserves in Amazonia and of off-shore petroleum reserves. Significant gold and iron reserves were also discovered in Serra Pelada and Carajás respectively, although the previously known reserves of these minerals had already conferred high levels of sustainability on them, i.e. depletion factors close to one.

After 1984, sustainable income tends to increase at a lower rate than value added. Two phenomena may explain this deviation: the acceleration in rates of reserve discoveries and the maturation of investments ini xated in the second half of the 70s, which had begun to manifest themselves in expanded levels of extraction. This deviation is particularly evident in the extraction of petroleum, tin, chromium and tungsten. The difference between sustainable income and value added begins to vary, from this year on, between 5% and 10%.

At lower rates of discount, sustainable income represents a lower percentage of the conventional measure (approximately 73% for r=5%, and 88% for r=10%). Rates of growth, however, remain roughly the same as in the 15% base case, and the analysis made for the latter can be extended to the former.

The results obtained show that the income obtained from the extraction of Brazilian mineral resources over the period 1970-88 was generally "sustainable," at prevailing levels of production, according the definition of sustainability set out above. However, for a particular set of minerals the degree of sustainability is much lower. This is particularly true of petroleum resources, which require increasing investment for decreasing returns as the most readily accessible reserves are exhausted. Discoveries during the period effectively replaced the quantities extracted, but the new reserves are generally more costly to exploit.

4.7 Comparison of Results

Table 6 compares the sustainable incomes obtained in sections 4.5 and 4.6 and shows that significantly different results are obtained depending on the method used. The first of these is a difference of magnitude. Sustainable income according to the net price approach varies between + 9,000% and - 15,000% of gross value added for the selected minerals, while the estimates of sustainable income according to the user cost method range between 86% and 98% of conventional value added in the base-case.

This discrepancy is a consequence of the adjustment of conventional income by the variation in total reserves, in the net price approach. This procedure does not rule out negative values for adjusted income nor the possibility of an adjusted income much greater than the conventional value, if new discoveries or revaluations exceed current extraction. This occurred in all years except 1987.

In contrast, sustainable income calculated by subtracting user cost from value added cannot be less than the sum of capital returns, wages and social charges, nor can it exceed conventional income. These results are not possible because the user cost has a maximum value equivalent to the total rent (when current extraction implies the immediate depletion of the resource) and a minimum value of zero (when current rates of extraction are very low relative to available stocks).

Note also that sustainable income calculated through the net price approach varies in an abrupt and cyclic manner, in such a way that sharply negative values are followed by high positive values in subsequent years. This is a consequence of erratic estimates of mineral reserves, in which undervaluation and overvaluation commonly follow one another over time. Being significantly larger than output this generates cyclic imbalances in computed sustainable incomes.

In contrast, the user cost technique offers estimates of sustainable income which reflect three clear periods. The first one corresponding to the first half of the 70s, shows an increasing gap between sustainable and conventional incomes. During the second period, covering the years 1975-1982, there is an increasing proximity in these values, a consequence of the increasing sustainability of mineral extraction due to revaluations and discoveries of reserves of the selected minerals. The final period shows decreased mining sustainability especially in the extraction of petroleum and tin; a result of reduced levels of successful exploration and of accelerating rates of extraction as earlier physical investments matured. It should be noted that this tendency has slowed down in recent years as the rates of growth of extraction have fallen.

5 FINAL COMMENTS

Environmental Accounting is still in the early stages of development. Efforts are being made in two directions: accounting for losses caused by the degradation of renewable resources, and accounting for the depletion of non-renewable resources. These efforts are true precursors and there is still no consensus about uniform methodological procedures that could homogenise the results, or at least make them comparable.

Empirical applications of environmental accounting face a number of problems, in particular methodological problems associated with the lack of statistical data. These constraints vary from case to case and stimulate the improvement of environmental data and their introduction in the National Statistical System. Moreover, conventional economic theory is still unable to establish precise relations between current utilization of natural resources and the capacity to maintain sustainable levels of production in the future. Therefore, despite their initial purpose being the evaluation of sustainable income, the study of Environmental Accounts plays a crucial role in presenting new issues to be investigated by economic theory.

These issues are related to the concepts of product and income from economic activities involved in the utilization of natural resources. It is clear that current definitions ignore the losses arising from the degradation or depletion of these resources. The SNA was always associated with a short term macroeconomic perspective; it was not intended to address long term issues of sustainability. The solution to this problem requires the definition of economic variables utilising a longer time horizon than that used by conventional analysis.

Nevertheless, the development of an alternative approach is problematic. Attempts to ascribe monetary values to non-marketed resources have confronted fundamental methodological difficulties. Consequently, the focus of concern has shifted to valuation procedures and the search for an optimal pricing system capable of maximizing social welfare. Recent work in this field has moved away from the original issue of Environmental Accounting, as a complement to the SNA, and towards theoretical models of welfare maximization.

Attempts to estimate the aggregate losses caused by resource depletion are closer to the original purposes of Environmental Accounting. Where market prices are available, the focus of analysis turns to the theory and mechanics of income accounting. Two recent proposals are briefly reviewed in this paper: the net price approach, initially proposed by Repetto *et al.* (1989), and the user cost approach, first developed by El Serafy (1989). The estimates of sustainable income from mineral extraction in Brazil vary profoundly according to the technique used. Estimates obtained with the user cost approach are of the same order of magnitude as conventionally measured income and the differences between them are readily explained in terms of the time horizon of extraction.

A very different result is provided by the net price approach. Large oscillations in the estimates of mineral reserves mean that values obtained for sustainable income are both much less and much greater than conventionally measured values. This makes it difficult to correlate the behaviour of the series with levels of mineral extraction observed over the same period. The erratic results obtained from the net price approach are a consequence of its main conceptual flaw: i.e. both computed output and income depend on variations in reserves. The net price approach is thus incompatible with a basic premise of the SNA, according to which income and output depend exclusively on production.

In addition, both methods make questionable assumptions about future rents from the exploitation of natural resources. The net price approach assumes that rents and prices will follow an "efficient" path, as described by the Hotelling rule. The user cost approach, on the other hand, assumes that rents remain constant over time. The historical experience is far more varied.

No doubt these limitations will be overcome. This remains a significant objective for future research on Environmental Accounting.

Table 1 - Exhaustion Period for Selected Minerals (1970/1988)

Year	Exhaustion Period (in years)							
	Iron	Tin	Gold	Lead	Chromium	Manganese	Tungsten	Petroleum
1970	231	13	14	5	46	36	7	14
1971	223	20	15	4	14	34	4	13
1972	518	16	14	3	7	43	3	13
1973	674	15	232	4	11	46	2	12
1974	135	11	9	5	11	42	3	12
1975	166	9	31	62	10	42	3	12
1976	136	10	30	69	12	40	6	14
1977	151	10	116	73	17	44	4	18
1978	177	9	533	56	8	40	5	19
1979	130	10	348	59	9	45	6	20
1980	113	12	295	67	17	40	7	20
1981	135	10	208	65	11	48	12	19
1982	146	20	244	64	15	43	6	18
1983	148	15	168	53	25	49	8	15
1984	123	12	171	53	15	42	7	12
1985	105	9	66	63	16	41	5	11
1986	99	9	67	76	20	52	7	11
1987	98	18	50	108	15	59	10	12
1988	91	11	28	69	27	90	12	13

Table 2.1 - Depletion Factor for Selected Minerals (r = 5%)

Year	Depletion Factor: r = 5%							
	Iron	Tin	Gold	Lead	Chromium	Manganese	Tungsten	Petroleum
1970	1.00	0.47	0.49	0.22	0.89	0.83	0.29	0.49
1971	1.00	0.62	0.52	0.18	0.49	0.81	0.18	0.47
1972	1.00	0.54	0.49	0.14	0.29	0.88	0.14	0.47
1973	1.00	0.52	1.00	0.18	0.42	0.89	0.09	0.44
1974	1.00	0.42	0.36	0.22	0.42	0.87	0.14	0.44
1975	1.00	0.36	0.78	0.95	0.39	0.87	0.14	0.44
1976	1.00	0.39	0.77	0.96	0.44	0.86	0.25	0.49
1977	1.00	0.39	1.00	0.97	0.56	0.88	0.18	0.58
1978	1.00	0.36	1.00	0.93	0.32	0.86	0.22	0.60
1979	1.00	0.39	1.00	0.94	0.36	0.89	0.25	0.62
1980	1.00	0.44	1.00	0.96	0.56	0.86	0.29	0.62
1981	1.00	0.39	1.00	0.96	0.42	0.90	0.44	0.60
1982	1.00	0.62	1.00	0.96	0.52	0.88	0.25	0.58
1983	1.00	0.52	1.00	0.92	0.70	0.91	0.32	0.52
1984	1.00	0.44	1.00	0.92	0.52	0.87	0.29	0.44
1985	0.99	0.36	0.96	0.95	0.54	0.86	0.22	0.42
1986	0.99	0.36	0.96	0.98	0.62	0.92	0.29	0.42
1987	0.99	0.58	0.91	0.99	0.52	0.94	0.39	0.44
1988	0.99	0.42	0.74	0.97	0.73	0.99	0.44	0.47

Table 2.2 - Depletion Factor for Selected Minerals (r = 10%)

Year	Depletion Factor: r = 10%							
	Iron	Tin	Gold	Lead	Chromium	Manganese	Tungsten	Petroleum
1970	1.00	0.71	0.74	0.38	0.99	0.97	0.49	0.74
1971	1.00	0.85	0.76	0.32	0.74	0.96	0.32	0.71
1972	1.00	0.78	0.74	0.25	0.49	0.98	0.25	0.71
1973	1.00	0.76	1.00	0.32	0.65	0.99	0.17	0.68
1974	1.00	0.65	0.58	0.38	0.65	0.98	0.25	0.68
1975	1.00	0.58	0.95	1.00	0.61	0.98	0.25	0.68
1976	1.00	0.61	0.94	1.00	0.68	0.98	0.44	0.74
1977	1.00	0.61	1.00	1.00	0.80	0.98	0.32	0.82
1978	1.00	0.58	1.00	1.00	0.53	0.98	0.38	0.84
1979	1.00	0.61	1.00	1.00	0.58	0.99	0.44	0.85
1980	1.00	0.68	1.00	1.00	0.80	0.98	0.49	0.85
1981	1.00	0.61	1.00	1.00	0.65	0.99	0.68	0.84
1982	1.00	0.85	1.00	1.00	0.76	0.98	0.44	0.82
1983	1.00	0.76	1.00	0.99	0.91	0.99	0.53	0.76
1984	1.00	0.68	1.00	0.99	0.76	0.98	0.49	0.68
1985	1.00	0.58	1.00	1.00	0.78	0.98	0.38	0.65
1986	1.00	0.58	1.00	1.00	0.85	0.99	0.49	0.65
1987	1.00	0.82	0.99	1.00	0.76	1.00	0.61	0.68
1988	1.00	0.65	0.93	1.00	0.92	1.00	0.68	0.71

Table 2.3 - Depletion Factor for Selected Minerals (r = 15%)

Year	Depletion Factor: r = 15%							
	Iron	Tin	Gold	Lead	Chromium	Manganese	Tungsten	Petroleum
1970	1.00	0.84	0.86	0.50	1.00	0.99	0.62	0.86
1971	1.00	0.94	0.88	0.43	0.86	0.99	0.43	0.84
1972	1.00	0.89	0.86	0.34	0.62	1.00	0.34	0.84
1973	1.00	0.88	1.00	0.43	0.79	1.00	0.24	0.81
1974	1.00	0.79	0.72	0.50	0.79	1.00	0.34	0.81
1975	1.00	0.72	0.99	1.00	0.75	1.00	0.34	0.81
1976	1.00	0.75	0.98	1.00	0.81	1.00	0.57	0.86
1977	1.00	0.75	1.00	1.00	0.91	1.00	0.43	0.92
1978	1.00	0.72	1.00	1.00	0.67	1.00	0.50	0.93
1979	1.00	0.75	1.00	1.00	0.72	1.00	0.57	0.94
1980	1.00	0.81	1.00	1.00	0.91	1.00	0.62	0.94
1981	1.00	0.75	1.00	1.00	0.79	1.00	0.81	0.93
1982	1.00	0.94	1.00	1.00	0.88	1.00	0.57	0.92
1983	1.00	0.88	1.00	1.00	0.97	1.00	0.67	0.88
1984	1.00	0.81	1.00	1.00	0.88	1.00	0.62	0.81
1985	1.00	0.72	1.00	1.00	0.89	1.00	0.50	0.79
1986	1.00	0.72	1.00	1.00	0.94	1.00	0.62	0.79
1987	1.00	0.92	1.00	1.00	0.88	1.00	0.75	0.81
1988	1.00	0.79	0.98	1.00	0.98	1.00	0.81	0.84

Table 3 - Value Added in the Extraction of Selected Minerals (Millions of 1980 US$)

Year	Production	Intermediate Consumption	Value Added	Wages	Social Contributions	Normal Capital Return			Rent		
						5%	10%	15%	5%	10%	15%
1970	2,570	108	2,462	67	11	49	99	148	2,335	2,286	2,237
1971	2,610	113	2,497	70	11	62	125	187	2,354	2,292	2,229
1972	2,709	117	2,591	76	13	74	147	221	2,428	2,354	2,281
1973	2,741	125	2,616	81	15	90	181	271	2,430	2,340	2,249
1974	3,060	170	2,891	97	19	110	219	329	2,665	2,555	2,446
1975	3,092	197	2,895	77	13	134	269	403	2,670	2,536	2,401
1976	3,158	237	2,921	89	17	148	297	445	2,667	2,519	2,370
1977	2,964	218	2,746	95	19	174	349	523	2,458	2,283	2,109
1978	3,209	210	2,999	284	19	216	433	649	2,479	2,263	2,047
1979	3,165	193	2,972	288	18	266	533	799	2,400	2,133	1,867
1980	3,545	494	3,051	325	19	284	567	851	2,423	2,139	1,856
1981	3,847	547	3,300	370	19	349	699	1,048	2,562	2,212	1,863
1982	4,336	637	3,699	435	18	428	857	1,285	2,818	2,390	1,961
1983	5,254	776	4,478	541	20	481	962	1,443	3,435	2,954	2,473
1984	7,093	1,074	6,019	750	26	573	1,146	1,719	4,670	4,097	3,524
1985	8,333	1,271	7,062	887	30	677	1,354	2,031	5,467	4,790	4,113
1986	8,861	1,336	7,524	936	33	733	1,465	2,198	5,824	5,091	4,358
1987	9,112	1,340	7,772	944	36	914	1,829	2,743	5,877	4,963	4,048
1988	9,683	1,340	8,343	959	46	1,063	2,125	3,188	6,276	5,213	4,150

Table 4 - Mineral Sector: Sustainable Income Using the Net Price Approach (Millions of 1980 US$)

Year	Value Added	Natural Capital		Depreciation	Sustainable Income
		Initial	Final		
1970	2,462		209,278		
1971	2,497	209,278	146,306	62,972	(60,474)
1972	2,591	146,306	378,314	(232,008)	234,599
1973	2,616	378,314	544,987	(166,673)	169,290
1974	2,891	544,987	87,826	457,161	(454,271)
1975	2,895	87,826	183,785	(95,959)	98,854
1976	2,921	183,785	169,390	14,394	(11,474)
1977	2,746	169,390	172,412	(3,022)	5,768
1978	2,999	172,412	232,614	(60,202)	63,200
1979	2,972	232,614	183,759	48,855	(45,883)
1980	3,051	183,759	193,977	(10,218)	13,269
1981	3,300	193,977	161,436	32,541	(29,241)
1982	3,699	161,436	221,396	(59,960)	63,660
1983	4,478	221,396	250,296	(28,900)	33,377
1984	6,019	250,296	226,106	24,190	(18,171)
1985	7,062	226,106	170,290	55,817	(48,755)
1986	7,524	170,290	254,383	(84,094)	91,618
1987	7,772	254,383	244,715	9,668	(1,896)
1988	8,343	244,715	272,927	(28,212)	36,555

Table 5 - Mineral Sector: Sustainable Income Using the User Cost Approach (Millions of 1980 US$)

Year	Value Added	User Cost			Sustainable Income		
		r=5%	r=10%	r=15%	r=5%	r=10%	r=15%
1970	2,462	654	312	166	1,808	2,150	2,296
1971	2,497	907	464	260	1,590	2,033	2,237
1972	2,591	852	465	270	1,739	2,126	2,321
1973	2,616	794	429	248	1,822	2,188	2,369
1974	2,891	1,198	672	385	1,692	2,218	2,505
1975	2,895	854	438	236	2,041	2,457	2,659
1976	2,921	762	361	177	2,159	2,560	2,744
1977	2,746	621	250	113	2,125	2,496	2,633
1978	2,999	527	215	100	2,472	2,784	2,899
1979	2,972	532	191	76	2,440	2,781	2,896
1980	3,051	533	184	65	2,517	2,867	2,986
1981	3,300	718	261	97	2,581	3,039	3,203
1982	3,699	751	253	81	2,948	3,446	3,619
1983	4,478	1,030	397	148	3,448	4,080	4,330
1984	6,019	1,927	949	458	4,092	5,070	5,561
1985	7,062	2,543	1,332	690	4,519	5,730	6,372
1986	7,524	2,138	1,035	494	5,386	6,490	7,031
1987	7,772	2,074	882	349	5,698	6,890	7,423
1988	8,343	1,971	648	176	6,373	7,696	8,167

Table 6 - Sustainable Income: Comparison of the Results in the Mineral Sector (% of Conventional Income)

Year	Depreciation Approach	User Cost Approach		
		r=5%	r=10%	r=15%
1970		73.4%	87.3%	93.3%
1971	-2421.8%	63.7%	81.4%	89.6%
1972	9054.1%	67.1%	82.1%	89.6%
1973	6470.5%	69.6%	83.6%	90.5%
1974	-15715.7%	58.5%	76.7%	86.7%
1975	3414.6%	70.5%	84.9%	91.8%
1976	-392.8%	73.9%	87.7%	93.9%
1977	210.0%	77.4%	90.9%	95.9%
1978	2107.5%	82.4%	92.8%	96.7%
1979	-1544.0%	82.1%	93.6%	97.4%
1980	435.0%	82.5%	94.0%	97.9%
1981	-886.1%	78.2%	92.1%	97.1%
1982	1720.8%	79.7%	93.1%	97.8%
1983	745.4%	77.0%	91.1%	96.7%
1984	-301.9%	68.0%	84.2%	92.4%
1985	-690.4%	64.0%	81.1%	90.2%
1986	1217.6%	71.6%	86.2%	93.4%
1987	-24.4%	73.3%	88.6%	95.5%
1988	438.1%	76.4%	92.2%	97.9%

Figure 1 - Net Price Approach

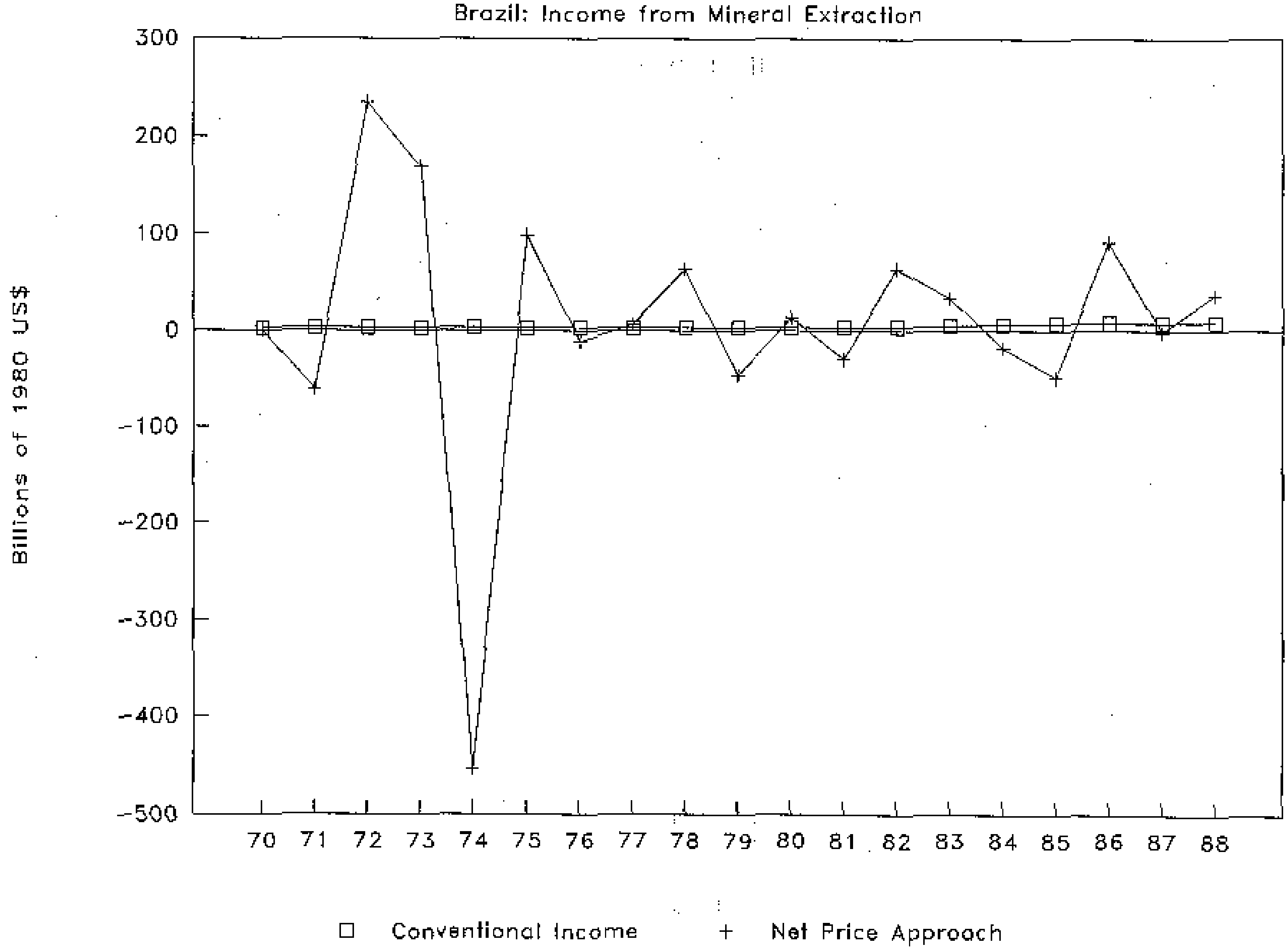
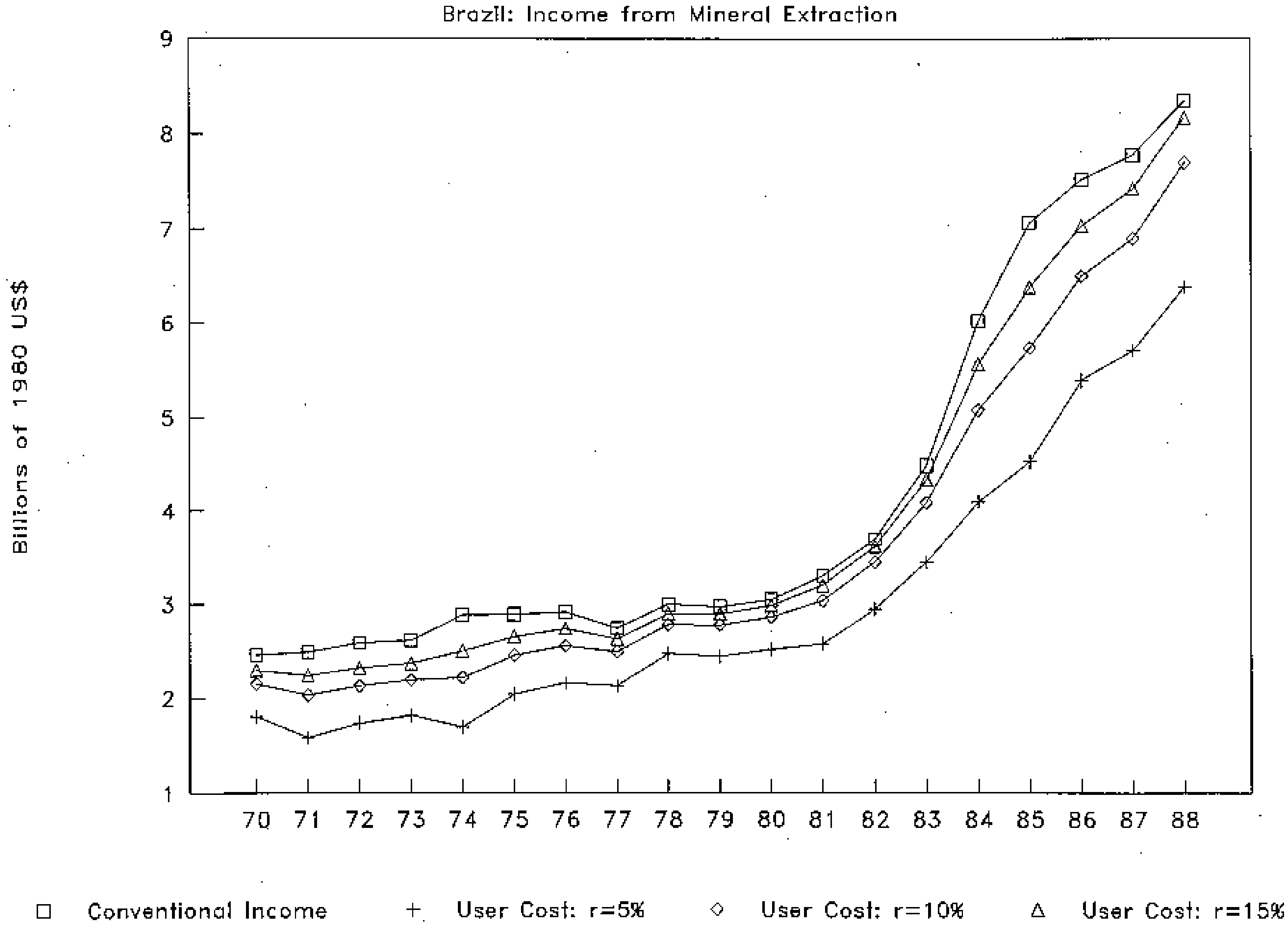


Figure 2 - User Cost Approach



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Appendix. Value Added in the Mineral Sector: Brazil 1970 - 1988

Estimating output values for the mineral sector in Brazil is complicated by certain policy interventions which may influence the reporting of production statistics by industry. In particular, royalties on the value of mineral extraction create an incentive for vertically integrated companies to adopt internal transfer prices below market value. In this situation, the operating surplus accruing to the firm exploiting the resource is not fully represented by the data presented in official surveys. This problem is aggravated by a system of classification which separates extractive from processing activities in the mining industry, making it impossible to distribute the processing production value among extractive activities. The extent to which this procedure impaired data quality was verified during the survey application when an attempt was made to establish the difference between extractive and processing activities. A comparison of census data with DNPM's output values for the sector as a whole revealed a systematic undervaluation in the former, amounting to 30% in 1980 and 20% in 1975.

The calculation of the output value for petroleum production is worthy of special mention. The state petroleum company (Petrobrás) defines transfer values which depend basically on the government pricing policy for petroleum derivatives, on output costs and on the investments required for prospecting and exploration activities. These transfer values are distorted by government price interventions which vary over time.

Clearly data from DNPM cannot reflect rents which have been transferred out of the extractive sector of the petroleum industry, being distributed instead among the prices of derivatives. To diminish the problem the output values of petroleum extraction used in this study are the import prices (converted to national currency according to the average annual exchange rate calculated by the Getulio Vargas Foundation). It is obviously an ad hoc solution, but these shadow prices reflect a more accurate estimate of the opportunity costs of petroleum extraction than those defined by Petrobrás' transfer criteria.

The data on intermediate consumption (IC_i) and the total remuneration of the labour (WA_i), were obtained from the series, 'expenses of industrial operations' and, 'total salary payments', available at the level of subgroups in Industrial Censuses and "PIAs" of the IBGE. In order to consider the social charges (SC_i), not available at a subgroup level, the payment of salaries was increased by 30%. This 30% factor was chosen as being close to the estimated ratio between social charges and salaries paid in the mineral extraction sector as a whole. The utilization of this data was considered appropriate to the calculation of general expenses and remuneration of labour because the undervaluation in IBGE's estimates is regarded as essentially related to output values and not to a problem of coverage or sample definition.

Gold mining presents a problem in isolating intermediate consumption and labour remuneration from the figures available which show aggregate values for the extraction of precious metals as a whole. It was decided that values for the subgroup as a whole would be used, since the levels of expenditure on exploration for this metal are so large relative to those on other precious metals. Consequently, the operating surplus value is undervalued for gold extraction, a problem exacerbated by the difficulty in obtaining information from clandestine mining prospectors.

For the years where data at subgroup level is not available (1971 and 1981-84), and where there were no industrial censuses and surveys (1972-73 and 1986-88), an output index based on the data on production by the DNPM and the General Price Index (IGP) by the Getulio Vargas Foundation is used. This procedure is based on the hypothesis that operating costs and remunerations grow at the same rate as output in real terms. The results are adjusted for inflation according to the IGP.

In the specific case of petroleum, since they were not identified in the 1975, 1980 and 1985 censuses, intermediate consumption and labour remuneration costs of the respective input-output matrixes are used. The above mentioned output index is used for the intermediate years.

It is worth mentioning that the correct procedure would be also to deduct other general expenditures that can be considered as intermediate consumption. However, this data is not presently available at a subgroup level. The result may be an overestimation of the operating surplus.

Estimating the "normal" return on capital (CR_t) demands a more elaborate procedure. A series of capital stocks was constructed for each selected mineral using the "perpetual inventory" method. This involves calculating the value of the capital stock in a certain year through the reported sum of investment fluxes in previous periods. In order to do so, a base-year is assumed and, from that, the variations in the capital stock are determined using information on subsequent investments.

Equation (14) shows this procedure as applied to the base-year value of the capital stock involved in the extraction of each selected mineral:

$$K_t = \frac{I_{t-3} + I_{t-2} + I_{t-1}}{3} \cdot \frac{1}{g + d} \qquad (14)$$

where:
K_t is the value of the capital stock in the base-year t.
I_{t-h} are the expenditures on fixed capital (including geological research) for the years t-h, h=1,2 or 3.
g is the historical growth rate for the mineral's extraction for the years prior to t.
d is the annual depreciation rate of the capital.

DNPM data on investment in exploration and extraction were applied for each selected mineral. The aggregation of values for investments realized in different years was possible through the utilization of the index of fixed capital formation employed in the National Accounts System in Brazil.

As data on investments are only available from 1972 on, 1975 is taken as the base-year.[20] For the years after the base-year, the capital stock is calculated as the sum of the investment realized two years before, net of depreciation, and the capital stock of the previous year.[21] Analogously, the capital stock for 1974 is estimated by subtracting from the capital stock for the base-year the investment realized in 1972 and adding the depreciation which occurred in 1975. Finally, for the years 1970-73 the capital stock is obtained by multiplying the capital/value added ratio for 1974 and the value added for each of these years. The annual depreciation rate used for the period is 10%, while the historical growth rate is taken as the geometric average of the growth rates in the extraction of each mineral during the 70's. In order to express the results in nominal values, the series has been adjusted by the index of gross fixed capital formation for the intermediate years.

Once the series of fixed capital stock involved in the extraction of the selected minerals has been determined, the "normal" capital return can be obtained by the multiplication of this series by the opportunity cost of capital. As discussed in the previous section, this opportunity cost is treated in a range; 5%, 10% and 15%.

The total rent derived from the extraction of each mineral (TR_t) can be estimated as a residual; being the output value (OV_t) minus the intermediate consumption (IC_t) and the other components of the value added (WA_t, SC_t and CR_t), all expressed in nominal values.

To facilitate intertemporal comparisons, a series of values added at constant prices has been constructed, using a procedure of "double deflation". The output value is deflated by the Laspeyres price index calculated for each mineral, using the base-year 1980 and data from DNPM. Intermediate consumption is deflated by the IGP, again with 1980 as base-year. The differences between them form the values added at 1980 prices. Such a value added in constant prices can be distributed among its components (salaries, social charges, capital return and rent) using the proportions observed in the series at current prices.

[20] Except for petroleum and lead, for which the base years were 1973 and 1976, respectively.

[21] A two-year lag was assumed between investment and operation.

DISCUSSION PAPERS

Discussion Papers examine a wide range of issues in environmental economics, including theoretical questions as well as applications, case studies and policy analysis. They are directed mainly at academics and researchers. Discussion Papers may be purchased for £3.50 each unless otherwise stated.

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BOOKS

Edward B. Barbier
Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views, Earthscan, London, 1989 (paperback £17.50)

The history of environmental and resource economics is reviewed; then using insights from environmentalism, ecology and thermodynamics, Barbier begins the construction of a new economic approach to the use of natural resources, particularly to the problem of environmental degradation. With examples from the global greenhouse effect, Amazonian deforestation and upland degradation on Java, Barbier develops a major theoretical advance and shows how it can be applied. This book breaks new ground in the search for an economics of sustainable development.

David W. Pearce, Anil Markandya and Edward B. Barbier
Blueprint for a Green Economy, Earthscan, London, 1989 (paperback £8.95)

This book was initially prepared as a report to the Department of Environment, as part of the response by the government of the United Kingdom to the Brundtland Report, *Our Common Future*. The government stated that: '...the UK fully intends to continue building on this approach (environmental improvement) and further to develop policies consistent with the concept of sustainable development.' The book attempts to assist that process.

Edward B. Barbier, Joanne C. Burgess, Timothy M. Swanson and David W. Pearce
Elephants, Economics and Ivory, Earthscan, London, 1990 (paperback £10.95)

The dramatic decline in elephant numbers in most of Africa has been largely attributed to the illegal harvesting of ivory. The recent decision to ban all trade in ivory is intended to save the elephant. This book examines the ivory trade, its regulation and its implications for elephant management from an economic perspective. The authors' preferred option is for a very limited trade in ivory, designed to maintain the incentive for sustainable management in the southern African countries and to encourage other countries to follow suit.

Gordon R. Conway and Edward B. Barbier
After the Green Revolution: Sustainable Agriculture for Development, Earthscan Pub. Ltd., London, 1990 (paperback £10.95)

The Green Revolution has successfully improved agricultural productivity in many parts of the developing world. But these successes may be limited to specific favourable agro-ecological and economic conditions. This book discusses how more sustainable and equitable forms of agricultural development need to be promoted. The key is developing appropriate techniques and participatory approaches at the local level, advocating complementary policy reforms at the national level and working within the constraints imposed by the international economic system.

David W. Pearce, Edward B. Barbier and Anil Markandya
Sustainable Development: Economics and Environment in the Third World, London and Earthscan Pub. Ltd., London, 1990 (paperback £11.95)

The authors elaborate on the concept of sustainable development and illustrate how environmental economics can be applied to the developing world. Beginning with an overview of the concept of sustainable development, the authors indicate its implications for discounting and economic appraisal. Case studies on natural resource economics and management issues are drawn from Indonesia, Sudan, Botswana, Nepal and the Amazon.

David W. Pearce, Edward B. Barbier, Anil Markandya, Scott Barrett, R. Kerry Turner and Timothy M. Swanson
Blueprint 2: Greening the World Economy, Earthscan Pub. Ltd., London, 1991 (paperback £8.95)

Following the success of *Blueprint for a Green Economy*, LEEC has turned its attention to global environmental threats. The book reviews the role of economics in analyzing global resources such as climate, ozone and biodiversity, and considers economic policy options to address such problems as global climate change, ozone depletion and tropical deforestation.

E.B. Barbier and T.M Swanson (eds.)
Economics for the Wilds: Wildlife Wildlands, Diversity and Development, Earthscan Pub. Ltd., London, 1992 (paperback £12.95).

This collection of essays addresses the key issues of the economic role of natural habitat and wildlife utilization in development. The book argues that this role is significant, and composes such benefits as wildlife and wildland products, ecotourism, community-based wildlife development, environmental services and the conservation of biodiversity.

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