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Estimating timber depreciation in the Brazilian Amazon*

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ABSTRACT. This study estimates depreciation values for timber extraction activities in the Brazilian Amazon for 1990 and 1995. A generalized approach following Vincent and Hartwick (1997) is applied enabling us to calculate depreciation based on all three methods proposed in the literature. We also calculate Hotelling rents for timber as a whole and for mahogany alone. Apart from the expected differences in the results for each method, the results show substantially low depreciation estimates as a direct consequence of the high timber stocks and scarcity perception by economic agents due to the lack of property rights in the region. For mahogany alone we obtain substantially higher values. We conclude that if scarcity rents are not fully perceived, or they really do not exist in such huge supply conditions as our estimates may suggest, charges related to other forest services are fundamental to make environmental accounting an useful tool for planning in the Amazonian context.

1. Introduction

It is widely agreed that it is important to incorporate environmental depreciation in national accounts. Nevertheless, such a task still faces theoretical as well as methodological controversies. Even though sustainability principles can explain some methodological differences,[1] theoretical issues, such as appropriate discounting and optimal dynamic behavior, play a crucial role.

Recently, Vincent and Hartwick (1997) made an effort to provide methodological guidelines for forestry accounting which would solve this controversy. This study aims at the application of this generalized approach, hereafter denominated as V&H for the estimation of the depreciation caused by timber extraction in the Brazilian Amazon.

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[1] See, for example, Atkinson *et al*. (1997) and Seroa da Motta (1993).

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The Amazonian context was selected on the basis of the widely recognized ecological importance of the region, as well as its increasing economic relevance since it currently generates more than 70 per cent of the total round wood produced in Brazil. However, depreciation calculations require information which is usually difficult to find in developing countries' forestry activities. This problem is accentuated in the Amazonian region due to the lack of institutional enforcement, proper managerial practices, and, consequently, fragile information systems.

Previous estimates for natural capital depreciation in Brazil faced the same data barriers. Apart from being more comprehensive in methodological procedures, our study was able to rely on recent survey data and cover the 1990/5 period which can capture the dramatic deforestation process and the enormous increase in timber production that has been taking place since the late 1980s.[2]

The application of the V&H short-cut formula to the Amazon raises important issues which, though theoretically and methodologically recognized already, are not always revealed in other regional exercises. Being the largest tropical forest in the world, it is not surprising that, even at the actual extraction rate, it would still take some time to completely extract all kinds of timber available. Therefore, the high timber stocks, lack of property rights, and informal economic relations are issues which have to be taken into account in calculating depreciation in the Amazon region.

In order to analyze the effects of the still enormous timber stocks in the Amazon, we also calculate the scarcity rent for a specific species of wood under threat of commercial extinction—mahogany—and try to observe the effect of the lower available stock and higher prices. A sensitivity analysis is then undertaken with different values of extraction cost curve elasticity and discount rates in order to study the robustness of our results.

The article is structured as follows. Section 2 presents an overview of the forest conversion pattern in the Brazilian Amazon and its relationship to the local timber exploitation activity. Following V&H, the methodological approach is presented in the following section. Section 4 describes our estimation procedures and analyzes the results. The last section offers additional comments on the appropriateness of forest accounting in the Brazilian Amazon and raises some questions related to its usefulness for environmental policy and management in the region.

2. Forest conversion pattern in the Brazilian Amazon

Forest preservation in Brazil is legally set in the Forest Code and water legislation, basically by restricting land uses. The Forest Code regulates the use of wood from forests, defines conservation units, restricts farming and logging activities, sets criteria for burning and chainsaw uses, and states sanctions and fines. At the same time, water legislation introduced very strict rules and norms for land uses to preserve forest areas in river basins.

Despite the stringency of these regulations, forest clearing on a large scale has not been avoided in Brazil. No more than 8 per cent of the

[2] See Seroa da Motta (1995) for a general view of these studies and Seroa da Motta and May (1995) for the particular case of forests.

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Atlantic forest, which previously covered the most developed areas of the country, is left standing. The savannahs of Cerrados in the central region has been already cleared to half of its original size for farming purposes. Although less than 10 per cent of the Amazon forest has been cleared, the annual deforestation rate is still very high.[3]

Sustainable management practices for logging are already incorporated in the Brazilian environmental regulation. However, they do not succeed, since abundant wood supply is available from agricultural expansion. Nevertheless, even with the introduction of sustainable criteria to agricultural practices, forest clearing will continue to be a major source of wood supply, while governmental agencies fail to deter illegal clearing.

One of the most important characteristics of the Brazilian Amazon is its open access feature. Due to local characteristics, agricultural peasants and timber loggers penetrate the forest, clearing it without any concern about resource scarcity. Some of these peculiarities are presented below:

Land titling is based on 'productive use', such as area allocated to farming. Only very recently has legislation on land taxes been changed to legally recognize standing forest as productive use. Therefore, land titling and taxation have not only legalized clearing, but encouraged it. Forest land conversion to agriculture in the Amazonian region used to be allowed for up to 50 per cent of the farm area. This percentage has been reduced to 20 per cent in 1996 but with no effective enforcement so far. This legal clearing percentage has been used to issue conversion (clearing) permits and has become the main source of timber exploitation. Forestry activities, in fact, are financing forest clearing since extraction for this purpose is legal. Property rights for standing forests can only be viable with high enforcement costs.

Illegal logging has, nevertheless, always been possible since it is difficult to make regulations effective in such an enormous area as the Brazilian Amazon.

The Amazonian timber extraction process is characterized by a formal sector that works 'by the books' with high costs and an informal sector working 'freely' with low costs. This dual market structure is not economically feasible since outputs are not differentiated to receive compensatory higher prices.

Amazonian forest is more heterogeneous and grows at lower rates than any other forest. Consequently, standing trees in this forest have low private values. Not only are extraction costs higher, but wood markets do not accommodate various species. Creaming is unavoidable without proper economic incentives.

Apart form that, states in Brazil are allowed to have their own state forestry policy, and they usually have enough power to use parlia-

[3] See Seroa da Motta (1997) for detailed indicators on deforestation in Brazil and their respective analysis.

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mentary forces to curb centralized governmental protection measures in the region.

Based on these points, it has been claimed that forestry in the region is not undertaken with fully enforceable property rights. In other words, logging is carried out without property account for scarcity parameters in a quasi-open access regime, and therefore market price does not reflect Hotelling rents.[4]

Summing up, deforestation in Brazil is driven mainly by agricultural and logging activities. The expansion of these activities into open access areas has been very active despite legal restrictions. Apart from institutional fragility to enforce norms and rules, deforestation of important ecosystems is also a result of several socio-economic factors, such as land and income inequality, which cannot be easily addressed without significant structural reforms.

3. Methodologies for calculating the depreciation of natural capital

The calculation of the depreciation of natural capital is aimed at adjusting national accounts to reflect the use of natural resources. This kind of adjustment is closely related to the concept of sustainability as an indicator of sustainable development.[5] Although there are many definitions of sustainable development, economic definitions have focused on sustainable development as non-declining *per capita* welfare over time (Pearce and Atkinson, 1995). Hence, along a sustainable path, the overall productive capacity of an economy is not reduced. Furthermore, according to Hartwick (1977), so long as the capital stock of an economy did not decline over time, non-declining consumption is possible by reinvesting all Hotelling rents from the exhaustible resource in physical capital.

Since the work of Weitzman (1976) and Hartwick (1977) economists have built the theoretical foundation for adjusting national accounts to incorporate the impacts of resource depletion on long-run human welfare losses. Nevertheless, there are important difficulties in measuring depreciation using expected future values. Part of these difficulties were solved by Hartwick (1988) which proved that along dynamically efficient paths of extraction, Hotelling rent and economic depreciation (with a negative sign) are equivalent.

Although the theoretical foundation has been notably developed, the literature on depreciation accounting of natural resource extraction is still open to debate about the most appropriate method to be used in its application. Vincent and Hartwick (1997) suggested a simplified formula to get a reliable estimate of depreciation (D) efficiently managed for exhaustible resources. If the marginal cost curve is isoelastic in the quantity extracted and assuming a functional form for the total extraction cost as $C(q(t)) =$

[4] See Seroa da Motta and Ferraz (1998) and Young (1997) for a discussion on property right's assignment in the region.

[5] For the importance of sustainability principles in environmental accounting, see, for example, Seroa da Motta (1994).

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$\alpha q(t)^{1+\beta}/(1+\beta)$, the marginal cost can be expressed as $MC = (1+\beta)AC$. Therefore the Hotelling rent can be expressed as

$$D(t) = [p - (1+\beta)C(q(t)) / q(t)]q(t), \tag{1}$$

where p is the market price, β is the elasticity of the marginal cost curve with respect to the quantity extracted (q) and $C(q)/q$ is the average cost.

An alternative approach proposed by Vincent (1997), which uses total cost instead of average cost, is to use the previous total cost function and the fact that under an optimal extraction path, the transversality condition implies that $q(t) = MC = AC = 0$ in the final period. Using the Hotelling rule Vincent (1997) derives the following expression for the Hotelling rent

$$D(t) = [pq(t) - C(q(t))](1+\beta)/[1+\beta\,(1+i)^{S(t)/q(t)-1}], \tag{2}$$

where i is the discount rate and $S(t)$ is the stock of the resource in period t. The previous expression is a generalization of the net price (NPM) and El Serafy methods (ESM) in the sense that it embodies both estimations as particular cases. If $\beta \to \infty$, equation (2) simplifies to the ESM and, if $\beta \to 0$, the Hotelling rent would just equal the net price method expression.

The usefulness of the previous formulae is that in practice it is much easier to find data available for the average or total cost than for the marginal cost. However, estimating β can be a practical complication. Obviously the elasticity of marginal cost will vary depending on the nature of the source (timber, oil, etc.) and type of industries.[6]

Although equations (1) and (2) are presented by Vincent and Hartwick (1997) as being equivalent, the choice of which one to use is said to depend just on the availability of data—average or total cost. Nevertheless it is noted in Vincent (1997) that expression (1) would yield less accurate estimates of economic depreciation than (2). This would happen due to the fact that the former is based on current marginal rent while the later is based on long-run principles.

Although Vincent (1997) is correct in his concern for estimating long-run instead of short-run Hotelling rent, it is not clear why the formula from expression (2) would take into account disequilibrium behavior in the timber market. Since it also uses current prices and costs of logged wood, any tendency of resource prices to fluctuate in the short run will be incorporated into his estimates using expression (2) as well as expression (1).

Moreover, since expression (2) incorporates a discount rate and formula (1) does not, any errors caused by fluctuation in prices could be compounded by errors caused by an incorrect choice of the discount rate. Consequently, there does not seem to exist any *a priori* reason why errors in the discount rate chosen would not be even worse than errors caused from price fluctuations or out of the equilibrium behavior in timber markets.

In spite of previous points, our estimates of depreciation values will follow equation (2). Based on the Amazon deforestation process, we

[6] Apart from being difficult to estimate, this function may vary over time and over place. Therefore, such mathematical simplification may lose economic meaning for prediction purposes. We thank Salah El Serafy for this point.

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assume permanent conversion of forest land to agriculture and pasture purposes. Therefore we do not consider any form of reforestation or second growth forest conversion.

4. Estimation procedures

4.1 Methodological issues

The model adopted, as said before, calculates depreciation under the optimal use of an exhaustible resource, employing the Hotelling rule relationship and arriving at estimations of depreciation approximated by the Hotelling rent.

The main objective of this study is to estimate depreciation values of forests in the Amazon. It is assumed that timber is a non-renewable resource based in the fact that timber exploitation derives from forestland conversion devoted to agricultural production and cattle-raising. This abundant source of timber from forestland conversion does not create incentives for forestry management. Therefore land is usually fully converted and the possibility of second growth forest is almost nil. Consequently, our depreciation values will not consider any charges for forest regrowth.[7]

Since stumpage values (logging revenue minus logging costs) and timber stock size seem to be the main parameters driving the results in V&H formulation, we compare depreciation results using the estimated average price and timber stock for the whole timber species with scarcity rent obtained for mahogany, a specific species under threat of extinction.

Mahogany has been the royal wood exploited in the region for many years, accounting for almost 50 per cent of Brazilian timber export value. Its stock has been decreasing rapidly during the past decade. Its logging and its export were temporally banned by the Brazilian Ministry of the Environment in 1996. As will be seen, mahogany prices are far higher than any other timber variety.

The all-timber variable is a composite good for which the data on cost and output are not differentiated among species. Consequently we treat timber as a single stock with an unique exhaustion time. Implicitly, we are assuming for the all timber measurements that loggers see timber stock as a whole and do not differentiate species in their decisions on exploitation levels.[8] Mahogany estimates, on the other hand, are specific for this species and reflect its greater scarcity.

In order to calculate depreciation values for all-timber and mahogany,

[7] Note that, although agricultural and cattle raising activities are driving forces for timber exploitation in the region, our depreciation estimates are related to timber scarcity which is the parameter affecting timber prices. Nevertheless, timber depreciation estimates could be charged against agricultural value added in the case of calculating this sector's sustainable income.

[8] If exploitation of species are treated separately, each species user costs, as those estimated for mahogany, should be separately measured and then added up. In that case, production cost estimates should be carefully determined since joint exploitation may occur for some species.

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we apply the H&V generalized formula with different values for the beta parameters. Values of the elasticity of the marginal cost curve are set to zero for the NPM, infinity for the ESM, and intermediate values for the H&V approaches.

The determination of a social discount rate is always full of controversy, and its value should be between the social rate of time preference and the opportunity cost of capital. Dixon, Hamilton and Kunte (1997) suggest values in the 2–4 per cent range for developed countries. However, according to Seroa da Motta (1988), the opportunity cost of capital in Brazil has been historically around 10 per cent.

Following Markandya and Pearce (1988), the social discount rate is given by the pure rate of time preference, varying between 0 and 2, and the consumption discount rate which is the product of the elasticity of marginal utility, varying between 1 and 2, and the rate of change in consumption. If we take the per capita GDP growth rate of 1–2 per cent per year for Brazil over the last two decades and combine all these parameters, we would come up with a range of social discount rates of 2–6 per cent. Based on these rough estimates, we opt to undertake a sensitivity analysis with discount rates of 2 per cent, 4 per cent and 10 per cent to enable us to analyze the differences in the scarcity rents due to differences in time preferences.

It is important to note that we are interested in the national macroeconomic perspective since the depreciation calculated should be deducted from the national GDP to incorporate a sustainability perspective in national accounts. Therefore we are not estimating depreciation values for a single state or region; we are looking at the Brazilian Amazon as a whole. Consequently, we are taking into account the fact that economic agents perceive stock of wood across political frontiers as equally accessible. We would have obtained high depreciation values if we had studied a highly cleared area, but this verification would not yield any perspective on the Brazilian sustainability issue, unless the region could be regarded as a closed economy.

4.2 The data

All calculations are carried out for the years 1990 and 1995 only, due to data availability. The study area is the so-called Legal Amazon, excluding the State of Mato Grosso, due to the lack of data on timber stocks.

As was presented in the previous sub-section, the data required for the estimation sets are log prices, output, average cost, timber stock, the elasticity of the marginal cost curve, and the discount rate.

Two kinds of data were used in this study: official aggregate data from the National Statistical Office (IBGE), and results from specific and occasional studies undertaken for academic and research purposes with a more limited coverage. There is a trade-off in using each of these sources. The official aggregate figures, although reliable, do not provide details for species and locations, and are based on declarations which certainly exclude illegal output. On the other hand, specific studies present good data and particular information, but the generalization of this information for the Amazon as a whole has to be done carefully.

The extraction of timber and the production of sawn wood in the

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Amazon is very diversified. Not only does it take place in many of the states, but it is also carried out by many economic agents. A great variety of trees are harvested in a very heterogeneous way and, consequently, it is very hard to monitor the extraction of logs and their processing. As a result, a general database containing prices of wood, quantity extracted, extraction costs, and stock of timber in the Amazon is not available.

The most complete national dataset on timber quantity extracted and production value is organized by the national statistical office (IBGE). Dividing the latter by the former it is possible to obtain an implicit price for timber. However, these implicit prices presented very erratic behavior once compared to other data sources.

Instead, we opted to use price data obtained from Stone (1998), which presents average prices of logs and sawn wood and classifies them into five groups, based on the value of the wood, from high to very low value. The data were obtained from field surveys in the Paragominas region (State of Pará) conducted by the Instituto do Homem e Meio Ambiente da Amazônia (Imazon) in 1990 and 1995. The survey included 33 wood-processing firms for 1990 and 49 firms for 1995. Given the predominance of the Pará wood industry in the region, these values can be considered to be fairly representative for the Amazon as a whole.

Estimates of costs extraction and processing of wood in the Amazon are very rare. Once more, we have relied on Stone (1998), which presents average extraction costs and transportation costs for 1990 and 1995 for both small and large firms.

For the logging activity, the difference between small and large loggers is based on the number of chain saws, trucks, bulldozers, and log-lifters used in the extraction process. For the sawmills, the size is determined by the sample by the number of band-saws. Small mills operate with one band-saw while large mills operate with two or more. The data on the cost structure of logging for 1990 are based only on small firms. These are the only data presented in Stone (1998). This would not cause a significant bias since the majority of firms operating in 1990 were small (approximately 80 per cent). However for 1995, we had data available for small and large firms. To calculate the unit cost, we created a composite cost as the average of costs from small and large firms, weighted by their relative contributions to the total production volume.

Man-made capital costs of extraction and transportation average costs were also calculated with the three discount rate scenarios using the same rates applied to the depreciation formula.[9]

Data on timber output was taken from the IBGE figures. Although there was some concern about their poor spatial coverage, they were the only available source for the region as a whole.

Data on the total aggregate stock of timber in the Amazon was estimated by Prado (1995) for the year 1990, based mostly in IBGE data, in fairly detailed spatial coverage but without distinction for wood species. The only caveat is the absence of data for the State of Mato Grosso. It is

[9] Stone (1998) adopted a 20 per cent rate since that was the bank rate prevailing in 1995 in Brazil after the real stabilization plan.

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Table 1. *Economic indicators for depreciation estimation*

Indicator	*Mahogany 1990*	*All timber 1990*	*All timber 1995*
Stock (S)[a]	21,000,000	11,549,565,600	11,334,419,900
Output (q)[a]	500,000	44,490,600	46,828,500
Price (p)[b]	148.29	33.02	40.81
Average cost (AC)[b]	64.75	22.59	26.72
Net price (NP)[b]	83.54	10.43	14.09

Notes: [a] m^3.
[b] 1995 US$/$m^3$, AC at 2% capital rate of return.

important to note that in our estimates of the stock figures, we have deducted timber stocks in conservation areas.

To estimate the 1995 stock we have used data from the IBGE on the quantity of timber extracted, assuming that the stock evolution was proportional to the rate of change in log extraction. This is a strong assumption since there is illegal logging and output lost in the harvesting process, which are not taken into account in the IBGE calculations. Both cases allow for an overestimation of the timber stock.

Mahogany stock and output were only available for 1990 from Barros, *et al*. (1992). Log prices were obtained from the *projeto Mogno* undertaken by Funatura/ITTO (1993).

Table 1 presents the selected data indicators for timber stock (S), output (q), price (p), average cost (AC) and net price (NP) for the years 1990 and 1995.

Estimates for the elasticity of the marginal cost curve (β) are not available in the literature for the Brazilian case and our efforts to estimate it econometrically did not succeed due to data availability limitations. Such lack of accurate estimates of β is also noticed in other studies applying similar methodology where such a value span was also adopted.[10] Therefore, apart from 0 and ∞ values, we have also assumed two arbitrary values for β—1 and 3—to apply the V&H approach following ranges assumed in the relevant literature for other cases.[11] Note, however, that such a span gives a reasonable sensitivity analysis of β which is the key parameter differentiating each method, as discussed in section 3.

4.3 Results

Tables 2 and 3 present the depreciation estimates for the years 1990 and 1995, respectively. Due to data availability, mahogany estimates are only presented for 1990.

[10] Vincent (1990), for example, uses values varying from 1.5 to 4.5 while Vincent, Panayotou and Hartwick (1997), analyzing the case of oil extraction in Indonesia, use the range 1–3. Vincent and Castañeda (1997) use a value of 1 for several timber and oil studies in Asian countries, considering it a 'neutral' elasticity. The only estimate of β based on a specific estimation exercise is quoted by Vincent (1997) who uses a value of 3 for timber depreciation in Malaysia.

[11] In principle, other region's elasticity values may not have any relevance for the Amazonian region. As we will observe later, higher elasticity values lead to results similar to those employed here.

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Table 2. *Depreciation estimates in the logging activity for the Brazilian Amazon in 1990 (1995 US$)*

Estimation set				
$i = 0.02$				
β	0	1	3	∞
All timber	464036540.8	5507983.2	3686575.0	2770433.7
Mahogany	41770000.0	25687223.5	21540361.8	18546306.5
$i = 0.04$				
β	0	1	3	∞
All timber	429778809.6	33840.5	22560.9	16920.9
Mahogany	41380000.0	13809302.7	10358476.1	8287500.6
$i = 0.10$				
β	0	1	3	∞
All timber	326560710.4	0.012908	0.008605	0.006454
Mahogany	40225000.0	1584123.5	1070130.1	807971.3

Notes: i = discount rate and β = elasticity of marginal cost curve.

Table 3. *Depreciation estimates in the logging activity for the Brazilian Amazon in 1995 (1995 US$)*

Estimation set				
$i = 0.02$				
β	0	1	3	∞
All timber	659813621.4	11070093.8	7421567.9	5581872.1
i = 0.04				
β	0	1	3	∞
All timber	618604537.8	97134.7	64759.8	48571.1
$i = 0.10$				
β	0	1	3	∞
All timber	494509002.2	0.104609	0.069739	0.052304

Exhaustion time for all the timber stock in the Amazon was estimated as 258.6 years for 1990 and 242 years for 1995 and the exhaustion period for mahogany was estimated as 42 years for 1990.

Also as expected, increases in the discount rate decrease the depreciation values, as shown in table 2. At a 10 per cent discount rate, all-timber user cost and H&V values decrease significantly approaching an almost negligible value. Mahogany values are, however, significant at all rates.

Changes in the depreciation values in table 2, which are based on the net price method, are due to the effect of the discount rate on the average cost. When discount rates vary, it affects physical-made capital charges. This would not occur in the absence of physical-capital charges, since the net

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price simplification of the V&H depreciation formula (as beta goes to zero) does not allow for any discounting.[12]

Observing again table 2, for given discount rates, depreciation values decrease as the elasticity of the marginal extraction cost increases. We can easily identify these differences in our estimates. The user cost estimate ($\beta = \infty$) is eminently lower than the estimate for the net price ($\beta = 0$). This result goes in the direction expected based on other estimates of depreciation in the natural resource accounting literature.

The results for 1995 in table 3 show that depreciation magnitudes are higher than the similar ones for 1990 in all cases, although still with low values at 10 per cent discounting. That upward variation confirms with the adopted methodology due again to the increase in net profits and the reduction of the exhaustion time.

As can be observed from table 2, as β increases the user cost becomes larger for mahogany relative to all timber. This is a consequence of the fact that we are treating all species together to estimate the all-timber depreciation value whereas for mahogany we treat it separately.

For all-timber estimates, depreciation values in the Amazon as a whole were very low in the ESM and V&H approaches. Nonetheless, for the case of mahogany alone, depreciation is more prone to reflecting depletion costs.

Even considering the overestimation of our stock figures, exhaustion time would still be significant, and lead to low depreciation values due to discounting procedures.

In order to analyze the relative importance of the depreciation values with respect to national account figures, we compared them to timber activity value added. The relative magnitude of our depreciation estimates when charged against the timber activity value added were close to zero,[13] apart from values at the very low discounting rate of 2 per cent, as shown in table 4. Even though, user cost and H&V relative values were very low, varying from 0.24 per cent to 0.69 per cent of the value added.[14]

As can be observed, the percentage of depreciation as a proportion of the timber value is only meaningful for the net price approach estimates which accounted for 41.17 per cent in 1995 and 39.72 per cent in 1990. However, this approach can only grasp scarcity rents in special cases.

On the other hand, mahogany depreciation measures, if compared to timber value added, revealed higher values even at the 10 per cent discount rate, as shown in table 5. Charges for mahogany depreciation against

[12] Remember that if $\beta = 0$ the formula used is $pq - c(q)$, although it can also be argued that the net price method is the special case of the zero rate of discount.

[13] Value added figures for timber extraction were not available for the region from national accounts, therefore, we constructed these figures using the survey data used for the depreciation estimates.

[14] It could be claimed, considering the forestland conversion process in the region, that these depreciation values should instead be compared to the regional value added from cropping and cattle raising activities. If we perform such comparisons, these relative values would be even lower since agricultural value added is almost four times larger than that for timber extraction.

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Table 4. *Depreciation measures of all timber as proportion of all-timber value added (%)*

1990				
$i = 0.02$				
β	0	1	3	∞
All timber	39.72	0.47	0.32	0.24
1995				
$i = 0.02$				
β	0	1	3	∞
All timber	41.17	0.69	0.46	0.35

Table 5. *Depreciation measures of mahogany extraction as proportion of all-timber and mahogany value added (%)*

1990				
$i = 0.02$				
β	0	1	3	∞
All-timber proportion	3.58	2.20	1.84	1.59
Mahogany proportion	59.03	36.30	30.44	26.21
$i = 0.04$				
β	0	1	3	∞
All-timber proportion	3.54	1.18	0.89	0.71
Mahogany proportion	58.48	19.52	14.64	11.71
$i = 0.10$				
β	0	1	3	∞
All-timber proportion	3.44	0.14	0.09	0.07
Mahogany proportion	56.85	2.24	1.51	1.14

its own value added may reach up to 36 per cent with $i = 2\%$ and $\beta = 1$. Although this charging procedure may not be appropriate when mahogany can be substituted for other species, these figures again give a clear picture of the sensitivity of the results to the exhaustion time of the resource.

As the forest is used up, considering the transversality condition, the ratio between the Hotelling rent and the total rent tends to one, once the resource is exhausted completely. Using our 1990 all-timber data and dividing the V&H depreciation values (with $\beta = 1$) by the total rent ($\beta = 0$) at a 2 per cent rate, we obtain a very low ratio of approximately 0.012. At higher discounting rates, this ratio decreases dramatically to negligible values, confirming the absence of timber scarcity rent in the Amazonian context.

For mahogany, this ratio is approximately 0.62 at 2 per cent discounting and only reduced to 0.34 at the 4 per cent rate. These results suggest that mahogany exploitation is being undertaken in a *mining* process and scarcity is reflected in market transactions. It also emphasizes once more

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the importance of exhaustion time and the price over the discount rate in the estimation of the scarcity rent.

5. Final comments

Our results confirm that the distinction between depreciation calculation methods is very important. As already noted by Atkinson *et al*. (1997), 'The distinction between net-price and user-cost is not just of theoretical interest: for countries with very long-lived deposits, even small discount rates will yield user costs that are much smaller than current rents.'

Considering the still large timber stock available in the region, depreciation values were not found to be meaningful. Moreover, taking into account the quasi-open access features of timber exploitation, an important question arises related to the existence and capture of this scarcity rent in the Amazonian context. Both high stocks and distorted low prices due to the lack of property rights are closely related and drive down depreciation estimates for all timber.

Since the formulae applied in our estimates cannot account for such open-access features, the depreciation values reported here are certainly approximations of the real scarcity rents.

Consequently, the debate on the controversy of methodological approaches covered in the literature may lose importance when one is considering management policies in regions where a lack of property rights is present. Charges related to other forest services are fundamental to make environmental accounting a useful tool for planning in the Amazonian context.

In a policy context, it is important to note that if scarcity rents are not fully perceived, or they really do not exist in such huge supply conditions as our estimates may suggest, an increase in timber extraction through the growth in the local market or timber exports may accelerate the deforestation process without the promising welfare gains.[15]

Such a perspective leads to actions aimed at changing the property right system and enforcement controls. Scarcity has to be introduced into economic agent's behavior by market mechanisms. Therefore, the current initiatives of the Brazilian Ministry of the Environment to create large areas of National Forests for concession schemes, for timber exploitation on a sustainable basis, are important steps in promoting the exploitation of the Amazon taking into account user costs.[16]

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[15] See Ferraz (1997) for a discussion on this issue.

[16] See Ferraz and Seroa da Motta (1998) for details on this initiative.

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