Economic Trends in the Timber Industry of the Brazilian Amazon: Evidence From Paragominas

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Introduction

The timber industry of Amazônia is changing rapidly. From a slowly evolving base of extraction in the estuary areas of the Amazon, the industry has expanded along an extensive road network straddling upland areas of *terra firme* forest (Rankin, 1985). At the same time that transportation costs over land have decreased, higher domestic and international wood prices have extended the range of profitable timber extraction (Stone, 1996). The result has been a dramatic increase in the area of economically accessible timber over the last thirty years, and an explosion of logging activity.

Where are these trends leading, and what are the implications for Amazônia? The changes underway in the timber industry of Amazônia will profoundly alter the economy and ecology of the entire Basin. But, as of yet, the economic trends within the industry are little understood, much less what their social and environmental effects might be. This research examines changes in the economic profile of timber extraction and processing in an old frontier area, the county of Paragominas (9°W, 3°S) in the Eastern Amazonian state of Pará (see Figure 1). As one of the earliest centres of upland logging, its experience after twenty years of logging, may offer insights to the likely evolution of the industry as it spreads to other regions of the Brazilian Amazon.

Why are economic trends in the timber industry of the Amazon important? First, over 80% of the Amazon is covered by forest (Skole and Tucker, 1993), containing billions of cubic meters of tropical hardwoods. As prices rise and the costs of extraction decrease, the area of economically accessible forest will grow, and with it, an industry to extract and process the timber. Trends in the timber industry will not only determine how forest rents are distributed among income groups, but also the environmental impact of future logging. For example, a trend towards more capital-intensive extraction and processing may signal a redistribution of rents away from owners of labour to owners of capital. Second, the timber industry has a large impact on land use and figures prominently in the environmental debate over the Amazon. Indirectly, roads opened by loggers may facilitate the colonisation of land. Directly, logging damages forested land after extraction by compacting soil, opening canopy, and increasing the risk of fire (Verissimo et al., 1992). Although there are opportunities for secondary regrowth, few cases of forest management can be found.

To make an informed prediction about the role of an expanding timber industry on the economy and environment of the Brazilian Amazon, we need to know how it will evolve. This paper attempts to make a contribution to our understanding of these trends by studying changes in the timber industry of Paragominas between 1990 and 1995. Although this is a brief interval, the frontier is dynamic. Secular trends in raw material prices and property rights are already apparent. The paper is structured around five parts. In the second section , a general theory of industry response to changing frontier conditions is presented. The third section introduces the methodology used to collect and analyse data for the study, and the next presents the results of the analysis. The final section discusses the results and their implications for forest management and policy in the Brazilian Amazon.

A Theory of Industry Evolution Along Aging Frontiers[1]

In the classical model of forest-based industrialisation, dynamic equilibrium between land and timber markets determines rates of forest clearing (Vincent and Binkley, 1992). Initially, with large amounts of forested land and little infrastructure, stumpage fees may be negative and trees felled and burned in place to clear land for agricultural use. With the arrival of infrastructure, demand for timber and agricultural products beyond the frontier region increases land clearing and stumpage values. Increasing stumpage prices signal scarcity in timber markets, stabilizing area under forest.

In a frontier adaptation of this model, uncertain property rights and high transportation costs affect the spread and development of the timber industry. In the initial stages of occupation, property rights are unstable. As a result, there is little fixed investment. Unstable property rights, cheap timber and high transportation costs result in an industry characterized by highly mobile, low-efficiency saws processing only the highest value species. As the frontier matures, markets for land develop and firms begin investing more in extraction, transportation, and processing equipment. This movement toward more secure property rights and its implications for investment has been discussed by Alston et al. (1996) and Schneider (1995). As in the Von Thünen model, net present value of economic activity declines with increasing distance from the market, due to transportation costs. Beyond a certain distance (d') from established markets, the value of economic activity is so low that collective enforcement of property rights is untenable. Beyond d', property rights are insecure and conflict over land is common. With time, d' shifts outward as the frontier stabilises, extending the area of uncontested property rights and decreasing the risk of investment.

As property rights stabilise and attract increasing investment in the timber industry, demand for timber increases. Stumpage prices rise, as do prices of wood delivered to the mill yard. The increase in price extends the area of economically accessible forest, as illustrated in Figure 2. Increasing extraction leads to local shortages, shifting the supply curve inwards from S to S'; demand increases with new entrants and higher volumes of production, shifting the demand curve from D to D'. As log prices increase, the industry consolidates as successful firms adopt new, cost-cutting technology. Some firms invest in secondary processing, for example, to achieve higher value-added. Higher prices may also induce innovation in transportation, decreasing the slope of the price-distance curve in the north-west quadrant of Figure 2. Reductions in unit transportation costs further increase the area under extraction, from d" to d"'.

At the limit, local shortages of raw material will force firms to choose between closing, relocating, or investing in raw material. For mills with little fixed investment, relocation or exit is the best option. For mills with higher fixed investments, such as large sawmills or plywood factories, investing in raw material may be the most attractive option. It is precisely at this limit, when property rights have stabilised and low cost timber is no longer locally available, that the frontier closes. Logging firms face the transition from extracting spatial Von Thünen rents to an infinite series of rotations, as traditionally envisioned by Faustmann. As the frontier closes, firms must choose between investing in forests, exiting, or relocating to begin the process anew.

[1] I am indebted to William Hyde for his suggestions on developing this theoretical framework.

Methodology

To study change in the timber industry along an aging frontier, we drew on a 1990 survey of wood processing facilities conducted by the Instituto do Homem e Meio Ambiente da Amazônia (IMAZON). This study, published by Verissimo et al. (1992), resulted from extensive interviews with participants in the industry. In late 1989 and early 1990, IMAZON researchers surveyed 238 mills along the Belém-Brasília highway. Then, they selected 33 firms in the county of Paragominas who demonstrated a willingness to share further information for in-depth interviews. Although self-selection clearly played a role in the IMAZON surveys, there is no indication that its sample is unrepresentative. These observations provide points of reference for 1990.

To develop a current economic profile, a survey was prepared and applied to a sample of 40 firms randomly selected from the population of some 200 wood processing firms existing in the county of Paragominas in August of 1995.[2] Data were collected on fixed costs (investments in infrastructure and machinery), variable costs (energy, raw materials, and labour), and the quantity and type of goods produced. Of the 40 firms, 33% had previously been surveyed by IMAZON, 15% had closed or changed hands, 8% were new, and 8% refused to be interviewed. Of the three firms that refused an interview, none exhibited any characteristics that would suggest a bias in the sample.

Data from the surveys were analysed to determine if any significant changes had occurred in the industry. First, stumpage fees were compared to see how the price of clearing rates varied over space and over time. Second, the prices of labour and capital inputs were compared over time. Third, data on timber extraction and processing were analysed from a financial perspective to determine present levels of profitability, and to compare these results with those from the 1990 survey. For purposes of comparison, all values from the 1990 survey were expressed in 1995 dollars using the best available approximation to the United States' GDP deflator (we used 1 1990 US$=1.2 1995 US$).[3] To facilitate comparison, the methodology for the financial analysis adopted by Verissimo et al. (1992, hereafter VBMTU, 1992) was followed, except where noted.

Finally, to test whether size of firm conferred any significant economic advantage, firms in the present survey were classified into two size groups according to processing capacity.[4] Those with one band saw (n=19) are referred to as "small," and those with two or more (n=7) are referred to as "large." Given the limited sample size, this two-way classification serves as a proxy for testing economies of scale. The balance of firms in the sample which were still operating produced laminates and plywood (n=7) or served as clearing houses for exports (n=2).

[2] Given differences that became apparent within the industry, a future survey might be best stratified by mill type and size.

[3] Brazil has suffered severe inflation and monetary instability over the last two decades. Several currencies have been introduced and withdrawn over this period. To simplify the analysis, all values are reported in constant US dollars.

[4] Some firms in the sample processed both sawnwood and plywood. In these cases, the firm was treated as two separate observations, one on producing plywood and one on producing sawn wood. The number of observations is therefore higher than the number of firms.

Results

A profile of wood processing firms in Paragominas

At present, more than 200 firms operate in Paragominas, processing timber from an area that covers 22,000km^2. Thirty years ago, in 1966 when Paragominas was founded, the area was covered by forest and no mills were in operation. This situation changed rapidly as the newly opened Belém-Brasília highway opened the frontier, attracting entrepreneurs from all over Brazil to abundant and cheap raw materials. In 1975, twelve mills were operating; by 1985 this number increased to 154 and by 1990 had reached 238 (see Figure 3).

At the time of the IMAZON surveys in 1990, about 80% (196) of these 238 firms involved in wood processing were small sawmills operating with one band-saw. In our random survey of 35 firms, only 54% operated a single-band saw. Of these, most were established between 1975-1988; only 3 were established in the 1990-1995 period (see Table 1). In the larger classed mills, 12% of the 238 firms had two or more band-saws operating; in our survey, this figure rose to 23% of the total (8 out of 35 firms). Veneer mills comprised only 5% of the total population of firms in 1990, but in our random sample in 1995 that figure rose to 22% of the total.

Part of this change in relative proportions is attributable to the growing diversification of wood processing firms in Paragominas. For example, export clearing houses, which were not present in the IMAZON survey, comprised 6% of our sample in 1995. The presence of these clearing houses, which dry, plane, and package wood for export, marks a substantial investment in increasing local value-added. However, no large mills or veneer mills were established between 1990-1995, suggesting that much of the change in relative proportions may be attributable to closures at small mills or consolidation within the industry. Proportionally, small sawmills are less numerous than before.

Costs of raw material

As an older frontier area, land rights in Paragominas are relatively more secure and well-established than in other *terra firme* areas of the Amazon. Although “invasions” still occur and land conflicts are common, most of the public lands have been claimed. Rights to extract timber on these privately held lands are bought and sold. As time passes, the cost of collective enforcement is decreasing and property rights are stabilising.

As land tenure has stabilized and areas of accessible forest have receded, the price of clearing rights - as reflected in stumpage fees paid to land owners - have risen dramatically over the last five years. Stumpage fees have more than doubled in real terms between 1990 and 1995, from an average of 84 to 193US$/ha (in 1995 dollars).[5] This rise in clearing rights is reflected in the upward shift of the price-distance curve presented in Figure 4. Although prices also vary according to the quality of

[5] Stumpage fees are bought and sold in Paragominas on an area basis. Although more accurately expressed in per volume terms (which might mitigate price increases if yields were increasing as well), no data on volume extracted per hectare are available for 1995.

forest (leading to low R^2 of 45% and 36%, for 1990 and 1995, respectively), the slope and intercept parameters from the 1990 and 1995 trend lines are statistically significant at the 95% confidence level. At present, mills are extracting timber from as far as Maranhão to the east and beyond the Rio Capim to the west, at distances of over 130km (see Figure 1).

As local forest supplies are diminished and the price of clearing rights rise, the foundation of the industry - cheap raw material - is eroding. Data from the 1995 survey suggest that log prices have increased by 10-30% over the past five years (see Table 2). The average mill price of logs for first quality timber (*madeiras nobres*) for example, increased from an average of 60 to 82$US/m^3 in real terms. Second and third quality timber increased from 38 to 43US$/m^3 and 24 to 30US$/m^3, respectively (see Table 2). Increasing prices have stimulated a widening area of extraction, and induced significant changes in transportation technology.

Costs of capital

In addition to increases in raw material costs, capital costs have risen dramatically. The Brazilian Government's *Plano Real*, introduced in July of 1994, has relied on a strategy of high interest rates to reduce inflation of 40-60% per month. By increasing the cost of liquidity, the government has managed to contract the money supply, reduce consumption, and control prices. However, the policy of high interest rates has hit the timber industry particularly hard. First, by raising the cost of credit, it has decreased investment in housing and construction, reducing domestic demand and depressing prices for sawn wood. Second, it has made wood exports more expensive by strengthening the value of the Brazilian currency with respect to the dollar and other international currencies. Third, it has drastically increased the cost of capital. Figure 5 illustrates the wide swings in real interest rates over the period 1990-1995. Since the *Plano Real*, interest rates (corrected for inflation by the IPC, an index of consumer prices) have risen to about 2-3% per month or 20-30% per year *in real terms*. In an industry which relies on continued investment in heavy machinery and land purchases, high rates of interest have significantly increased the debt burden and the capital costs carried by firms.

Costs of labour

One of the salient facts about the timber industry in the Amazon is the division of labour between the formal and informal sectors of the economy. Because of stringent labour laws, firms must pay taxes of approximately 50% on the total cost of labour (VBMTU, 1992). Firms that abide by these laws pay significantly higher wage bills than do firms operating outside of the law. As a result, there is a large incentive for firms to minimise the number of officially hired labourers - and to under-report them when they do.

Even with the taxes, however, the cost of labour is relatively inexpensive. The minimum wage, earned by the majority of workers in the industry, was 134US$/month in 1990 (expressed in 1995 US$), or about eighty cents per hour. Five years and several economic plans later, the minimum wage has actually decreased by 20% in real terms, to 108 US$/month in August 1995. As a result, unit labour costs for mill owners have decreased. In 1990, it cost about US$21 in labour and benefits to process 1m^3 of sawn wood. In 1995, that figure had dropped to US$19 (see Table 3).

For larger firms, the unit labour costs were roughly the same, although we are unable to compare this figure with 1990 since no data was collected on large firms at that time.

Similarly for extraction, unit labour costs also decreased, from 3.05US$/m^3 in 1990 to 2.21US$/m^3 in 1995.[6] For large firms, unit extraction costs for labour were slightly lower, at 1.91US$/m^3. Declining unit labour costs could reflect productivity gains. Comparing decreases in real wages to decreases in unit labour costs, we see that for extraction the drop in unit labour costs exceeds the real wage drop: 25% as opposed to 20%. This difference suggests that some savings in the wage bill for extraction might be attributable to gains in labour productivity. However, for processing, the average decrease in unit labour costs was only 9%, suggesting no gains in productivity. Overall, one cannot escape the conclusion that labour costs have decreased over time, simultaneously easing the wage bill on firms and providing less income to labour.

Prices of sawn wood

Most of the wood produced in the Amazon is consumed beyond its borders, meaning that prices are exogenously determined and that firms are price-takers - they have no ability to influence prices. The policy of high interest rates has reduced demand for civil construction, depressing demand for wood and leading to a cyclical decline in the real price of sawn wood. Premium sawn wood prices have dropped an average of 15% in real terms, from 336 to 291$US/m^3; medium grade sawn wood prices have declined by 24%, from 216 to 174$US/m^3 (see Table 2). The only exception to these falling prices has been in the area of exports, where firms which are able to reach the higher quality standards and international marketing networks can obtain prices of US$350/m^3 (although in domestic currency terms, export prices have fallen recently due to appreciation of the Brazilian *Real*).

Thus, at the same time that there has been a secular tendency of increasing raw material prices, sawn wood prices have dropped. This phenomenon can be at least partially explained by the fact that sawn wood prices are set outside of the Amazon, while the demand for logs is locally determined. With increasing investments in extraction and transportation, firms are operating at higher levels of volume. This tendency to process more wood increases demand for logs and decreases the supply of timber, both of which exert upward pressure on local prices of raw material. Each of the 200 mills in Paragominas has a substantial fixed investment (to the order of US$1million) which precludes easy entry and exit from the industry in the response to rising costs. As such, they appear to be locked in a pattern of competing for ever scarcer resources, while receiving a price for sawn wood that is determined by a widely fluctuating national economy.

[6] The only significant increase in labour costs occurred in the area of transportation, where the average salary of a truck driver rose from 408 to 550 US$/month.

Costs of transportation

One of the salient facts about receding supplies of timber is that firms must go farther in search of raw material. From Section 2.2, we saw that stumpage fees are now more expensive than they were in 1990. These trends reflect the growing scarcity of unexploited timber in the county of Paragominas. In 1990, the average distance to extract logs was 71km (n = 10, sd. = 49); by 1995, this distance had risen to 98 (n = 24, sd = 21). Thus, the average round-trip to transport logs back from the forest had risen by 38%.

To reduce transportation costs, the industry response has been to use larger trucks to haul logs. At the time of the IMAZON surveys, the "typical" mill used 3 flat-bed trucks with a capacity of 13m^3 of logs each, at a total investment cost of US$234,000 (1995 dollars). In the 1995 survey, the average small firm possessed two eighteen-wheel rigs, each with a capacity of 30m^3 logs (see Table 4). Combined with one flatbed truck, the average total investment cost of the small firm in transportation was US$474,000. As a result, unit transportation costs are estimated to have dropped from approximately 0.13 to 0.10US$/km/m^3. By reducing unit costs per kilometer, firms have secured a larger stock of raw material by extending the frontier of extraction. But even with these savings, the overall cost of transporting wood has increased - to the order of 5-10US$/m^3 - because of increased distance to the forest. Additionally, the capital outlay required by firms more than doubled, meaning more debt exposure and higher entry and exit costs.

Another, less common industry response is the relocation of the mill to the forest. Of the seven large firms in our sample, 28% had installed or planned to install a satellite operation closer to the wood source to reduce transportation costs. Due to the high costs of establishing and maintaining a satellite operation, this option is not available to small mills, signalling a size advantage for larger firms.

Other changes in technology

Changes in transportation technology have spilled over into extraction. With the larger truck capacity to fill, firms must invest more in extractive machinery. On average, small mills now employ two bulldozers (n = 15, sd = 1) as opposed to only one in 1990. In addition, small firms in our sample reported a higher number of chainsaws active in extraction, 4 as opposed to 2 in 1990 (see Table 4). This evidence points in the same direction as the earlier sections: an increased volume of wood being extracted, hauled and processed to maintain profits at smaller margins.

By contrast, there have been no substantial changes in processing technology. Sawmills are still using the same band-saws present in the 1990 survey, with the same low level of efficiency in converting logs into sawn wood. In fact, a recent IMAZON study suggests that conversion efficiency may be substantially lower than first thought. VBMTU, for example, estimated that 47% of the timber volume was successfully converted into sawn wood; in the new study, this figure is estimated to be 34% (Gerwing and Uhl, forthcoming).[7] A difference of this magnitude can have significant implications for profits, given the costs of extracting, transporting and sawing.

[7] By comparision, Gerwing and Uhl cite an average mill efficiency of 60% in the United States. These figures include all losses which may occur, from forest extraction (lost or irretrievable boles) to mill yard to final processing.

In any event, there are no signs that efficiency of conversion has improved. There have been no innovations in preserving logs from decay in mill yards, and no investments in improved sawing equipment that might increase yields and improve quality control. Several mills invested in secondary processing machinery (lathes, planes etc.) to increase efficiency and value-added, but most of the these machines were idle.[8] Only one mill had a functioning production line in processed secondary goods. The obstacles to improved efficiency include lack of markets for secondary goods, high capital investment costs for new machinery, and, until recently, a cheap and locally abundant stock of raw material.

Costs of energy

The timber industry depends crucially on diesel fuel and electricity. Over the period 1990-1995, the real price of diesel rose by 8%, from 0.36 to 0.39US$/liter in real terms. The cost of electricity rose even more. In 1990, the average firm profiled by VBMTU produced 4,300m^3/yr, spending US$11,788 on electricity (in 1995 dollars) or about 2.74US$/$m^3$ (see Table 5). However, by 1995 the average cost of electricity (used primarily in processing) had risen by almost 70%, to 4.65US$/$m^3$. For large firms, the average was slightly less, but still over 4US$/$m^3$. At the time of the 1995 survey, Paragominas was experiencing electricity rationing and severe brown-outs during peak operating hours. In effect, firms were paying more, and receiving lower quality electricity. In December of 1995, however, a new line opened from the Tucurui Hydroelectric facility, ending the rationing of electricity.

Financial analysis

How do these changes affect profits? Our analysis shows that there have been substantial investments in extraction and transportation equipment, and an increasing volume of wood being processed. Labour costs have fallen, but other variable costs, such as electricity, have increased. This section compares the effect of these changes over time by conducting a financial analysis based on survey statistics.[9]

Based on our analysis, the profit margin for the average small mill has dropped from 15% to only 2% - this with an increase in the average production from 4,300m^3/yr. to 5,600m^3/yr (see Table 1). The average mill is producing more and earning less than it was in 1990. This analysis includes diversification into export markets; we estimate that the average mill now sells about 20% of total sawn wood by volume to export clearing houses for drying and marketing. If the average mill sold only to domestic buyers, our analysis indicates that profits would be negative. Part of this drop in revenues is a function of the cyclic nature of timber prices, following as they do civil construction and

[8] Although funds are available to subsidize capital investments in secondary processing from the *Fundo Constitucional de Financiamento do Norte* (FNO), none of the mill owners reported using these funds.
[9] A note on the financial analysis is in order prior to examining changes over time. The benchmark observation by IMAZON is based upon a representative small firm in 1990. No data are available on the costs and investment patterns of large mills. As such, the present analysis is limited to comparisons between small mills. Also, the original IMAZON work used an interest rate of 4% p.a., which is below the cost of borrowing capital in Brazil; for the purposes of comparison, the analysis that follows uses 20% p.a., a conservative estimate of the real interest rates in 1995.

the business cycle. Part also reflects the new, local scarcity of raw materials and increases in energy and transportation costs.

Disaggregating the financial analysis by activity reveals that the extraction and transportation phases remain profitable. In our sample, 75% of the small mills interviewed, and 100% of the large mills, were involved in all phases of extraction, transportation, and processing. Tables 6 shows that for a small firm, profit margins for extraction and transportation have dropped only slightly, from 11% to 8%; for a large firm, the average profit margin is 18%. By adopting high-capacity trucks and increasing the volume of timber extracted, firms have maintained profits in transportation and extraction.

This is not the case in processing. For firms involved exclusively with processing, profits have dropped significantly, from 8% in 1990 to -3% in 1995 for the small mill (see Table 7). Had the mill portrayed by VBMTU remained selling only to domestic buyers at 1990 levels of production, ie 4,300m^3/yr, profits to processing would have dropped to -27%. Higher log prices and energy costs have cut into processing margins. Working with a thinner margin, firms have increased the volume of wood processed and actually become more economically efficient in processing. These poor financial results for processing help explain why firms vertically integrate on the frontier.

This trend can be seen more clearly in Table 8, which summarises unit costs of extraction, transportation and processing. Despite rising costs of energy, processing costs actually decreased from 50US$/$m^3$ in 1990 to 47US$/$m^3$ in 1995. For larger mills, average costs are even lower: 40US$/$m^3$, which reflects their ability to save on wages and machine time. To illustrate one obvious instance of savings, most mills regardless of size keep one log-lifter in the mill patio to move and position logs for sawing. Yet one log-lifter, which costs about US$90,000 new and some 10,000-20, 000US$/yr to operate and maintain, can easily service a mill with up to three band-saws.

Despite technological innovation, unit transportation costs have sharply increased for the small mill, from 13 to 21US$/$m^3$. For large mills, unit transportation costs are somewhat less, but not to the point that would suggest any large economies of scale: 19US$/$m^3$. In terms of extraction, costs have only risen marginally, from 16 to 18US$/$m^3$ for small firms. Overall, the total cost of extracting, hauling and processing one cubic meter of sawn wood (at 34% efficiency) has increased from 136 to 160US$/$m^3$ for the small firm. For the large firm, it cost 142US$/$m^3$ to produce sawn wood.

Secular increases in raw material costs - as opposed to cyclical variations in demand - have profound implications for the future of the timber industry in Paragominas. There have been three distinct industry responses to these market pressures:

1. increases in the volume of production;
2. attempts to increase the value added; and
3. increasing mill size.

Although the first response, increasing production in the face of rising costs, seems counter-intuitive, it has the effect of spreading the costs of fixed investment over more production - of reducing average fixed costs. Our survey indicates a significantly higher level of production (at the 95%

confidence level) between 1990 and 1995 for the small firm (see Table 1). Given the large investments in extraction, transportation and milling machinery (estimated at over US$1,000,000 for the small mill), a low volume of production implies high average fixed costs. If the mill portrayed in VBMTU, for example, had continued producing boards at the level of 4,300m^3/yr, it would be operating at a significant loss (see Table 7). A frequently heard complaint by mill owners in Paragominas is that they seem to be producing more and earning less - and they are.

The second industry response to rising costs has been to increase the value of their production. These attempts have taken two forms: a) secondary processing; and b). improving the marketing of wood. Efforts at secondary processing have largely floundered. Although 35% of the mills in our sample had invested in machinery, no more than 10% of the volume of any firm at present received any secondary processing. When asked, mill owners complained of unskilled labour, high staff turnover and difficulties in competing with pine furniture from the south of Brazil.

In the second case, attempts to increase value-added have proven successful. There are now three export clearing-houses in Paragominas, two of which were installed since 1990. These exporting firms have the advantage of reducing drying and marketing costs for individual firms. By combining resources, firms achieve economies of scale in oven-drying and marketing that would not otherwise be possible. Two species in particular, curupixá (*Micropholis venulosa* Pierre) and tauari (*Couratari spp.*), are in high demand in Europe, principally France. Other, lower grade timbers are being exported to the Philippines. The average price of oven-dried, export grade timber in August 1995 was US$350/m^3 - significantly higher than most domestic prices (see Table 2).

The third important industry response is a trend towards ever larger mill sizes. Of the 10 mills surveyed in our sample and by IMAZON in 1990, 3 had added an extra band-saw between 1990 and 1995. Tables 6, 7, 8 and 9 show the advantages of the larger firms in producing sawn wood. Combining the results of the financial analysis from the extraction, transportation and processing phases, large mills enjoy substantially higher profit margins. The average small mill in 1995 earned about US$1,000,000 a year, of which only US$16,000 was profit (assuming a 34% conversion efficiency). For the large mill, the calculated revenues were to the order of US$2,590,000, of which US$300,000 were profit (see Table 9). If these calculations are correct, they may imply a cost advantage that comes with size. Large firm size conveys other advantages as well: for instance, several large firms have moved some or all of their milling capacity to areas closer to the forest. Moving to the forest would be impossible for a small firm, which could not spread the investment, infrastructure and maintenance costs over a large volume of production. The analysis shows that in a business environment where prices are falling and costs are climbing, there will be a selective process that on average will favor larger firms.

Sensitivity analysis

The financial analysis relies on a number of technical parameters which lie outside of the scope of the present analysis, but which have significant implications for profits. For example, VBMTU assume that mills convert logs to sawn wood at the rate of 47% - that is, they require 2.13m^3 of logs to produce 1m^3 of sawn wood. This conversion parameter has since been revised downward to 34% by Gerwing and Uhl (in press), which has significant implications for the economic and financial analysis. [10] In the base scenario, we used the new 34% conversion efficiency to calculate the financial return to small and large mills.[11] However, given the large impact of this technical parameter on production costs, sensitivity analysis was conducted on the rate of conversion efficiency to determine its effect on profitability.

The analysis indicates that the level of efficiency in conversion can have strong effects on profits. For example, using the 47% efficiency rate increased the calculated profit margin for the small firm from 2% to 20%; for the large firm, the related increase in profits was from 14% to 27%. Or, put another way, a one percent change in milling efficiency can increase profits for the firm by 3.3% and 1.8% for the small and large firm, respectively (see Table 9). That these changes can be so large stems from the present distribution of costs in the production of sawn wood. For every cubic meter of sawn wood produced, the firm has to cut, extract, haul, and mill an extra $0.81m^3$ of timber. The implication is that increasing mill efficiency can drastically improve profits and save on residual waste of timber, which would otherwise be burned or used to produce charcoal.

Environmental impacts of changes in the timber industry

Very little has changed since the VBMTU study in terms of the environmental impacts of the industry. The most significant change we observed was the recent adoption of the skidder by large firms, used to extract timber from the forests. On average, large firms possessed at least one skidder (see Table 4). The advantage of the skidder in environmental terms is that it runs on rubber tires, which cause less damage to the soil than bulldozers. The main motivation for firms, however, is that it can also lower operating costs by enabling loggers to retrieve felled trees from longer distances. However, most skidders are imported and not well adapted to conditions in the tropics (which include little forest management, operator training, or planning of skid trails); mill owners complained of frequently punctured tyres and difficulty in obtaining spare parts.

Consequently, the dominant tool for removing timber from the forest is still the bulldozer, which causes considerable damage as it searches for, retrieves and drags downed trees to a landing. The key findings of VBMTU still hold: for every m^3 of timber extracted, on average $2m^3$ of wood are damaged, $73m^2$ of road and patio are opened, and $221m^2$ of forest canopy are opened.
However, as mill owners like to point out, loggers do not raze the forest - it is simply too much work. Clearing and burning has largely been the work of ranchers, who in the 1970s faced largely negative stumpage values and, until the late 1980s, received various subsidies and incentives to convert land from forest to pasture. Left alone for thirty to forty years, the forest will regenerate over time and provide timber for a second cut (Silva et al., 1995). The difficulty with natural regeneration is that there are frequently more lucrative land use options than allowing the residual stand to reach maturity. For example, it is common for loggers to make a second and third pass at stand within a short period of time as more species become valuable.

[10] The parameter for volume of timber harvested per hectare is another parameter open to question. VBMTU developed this estimate from a sample of only three field observations. There was a large variation in volume harvested between the three sites, resulting in a standard deviation of 22 m^3/ha around a mean of 38 m^3/ha. However, the figure of 35 - 40 m^3/ha is within the range of observed values in Paragominas.

[11] It is unlikely that conversion efficiency varies much by firm size. Investments in processing machinery are uniformly low.

Limiting the negative environmental impacts of extraction and ensuring the future productivity of the region's forest depends largely on how forests are managed. Technically, forest management is feasible. The most efficient means of limiting logging damage and improving the productivity of the stand are:

1. cutting vines one year prior to harvest;
2. locating harvestable trees, and planning extraction routes and felling direction; and
3. periodic thinning and vine-cutting to open up growing space for desirable trees.

VBMTU estimate the costs of these treatments at 25, 20, and 135US$/ha, respectively. Given their low cost, why are these most basic features of forestry management not being implemented?

The most compelling reason not to invest in forest management is the short planning horizon most firms employ. The right to clear forest tracts are generally purchased in the same year as they are harvested. Purchasing one year in advance to cut vines or take an inventory implies extra capital costs with no foreseeable return (although it may be in the interest of land owners to allow or request vine thinning on their land). Indeed, to invest in management runs the risk of land invasion by squatters or cutting by "wildcat" loggers - a risk that grows with increasing distance from the market centre. Second, few individuals are trained in low-impact extraction techniques. Although mill owners express interest in training which can help increase productivity, there are as yet no initiatives by the loggers syndicate or the state to provide this service.

To encourage improved forest management practises, changes are needed in forest policy. Recent legislation has abolished the forest tax levied to fund reforestation after it was demonstrated that IBAMA, the Brazilian environmental agency, had invested little of the revenues in replanting. Now firms are required to submit management projects for authorisation to IBAMA, which has spurred the development of a large business in producing forest inventory reports. These authorisations are apparently worth about 1.30US$/m^3 in Paragominas. As far as we can tell, the reports and authorisations have produced no environmental benefits, have added to the operating costs of firms, and have merely spawned a bustling consultancy business for trained forestry engineers. A realistic economic appraisal is urgently needed to evaluate the costs and benefits of the current environmental legislation.

Although forest management is lagging, there are signs of investments in replanting in Paragominas. One of the largest plywood producers in Paragominas has initiated a plantation of *paricá* or Pinho cuiabano, a fast growing leguminous tree from Rondônia. Planted at a density of 625 trees/ha., the firm estimates that in eight years each tree will produce 1m^3 of wood useable for making plywood. At a present cost of US$30/m^3 for the white and soft woods peeled to make plywood laminates, the net present value of their plantation is about US$2,800/ha.[12] If the trees yield as expected, the internal rate of return (37%) is estimated to be well above the opportunity cost of capital. Given the

[12] The net present value is calculated as:

NPV US$/ha. =

where: .20 is the annual real rate of interest, 30 $US/m^3 is the price of wood, and 625 m^3/ha. is the expected yield in eight years. No data was available on planting costs; the value cited above assumes total capital, land and labour costs of US$ 1,500/ha based on best available estimates from Paragominas.

abundance of relatively cheap land in the Paragominas region, plantation forestry may become an attractive investment for mill owners as the native forests are cut and cleared. Such a development would mark a complete transition from extraction of Von Thünen rents to a series of infinite rotations, as envisioned by Faustmann.

Discussion

Since 1990, the timber industry of Paragominas has changed considerably. It has expanded its chain of marketing to reach foreign markets for tropical wood; it has innovated in transportation technology; and it has become more capital intensive. There have been the first signs of change from an ever widening circle of extraction to investments in plantations.

These changes reflect the industry's response to changing factor prices, principally raw material, and increasingly secure property rights. As forested land has become scarcer in close proximity to Paragominas, the industry has shifted to a larger truck size to decrease transportation costs. By collectively organising to establish several exporting houses, firms in the industry have increased the value of their production and reaped economies of scale in oven drying and marketing wood for export. With lower costs of enforcing property rights, firms have increased their investments in fixed assets. Mill owners have invested heavily, especially in timber extraction and transportation equipment. Some are beginning to invest in future stocks of raw material.

If these trends are representative of the larger timber industry in the Amazon (and they should generalise to upland logging), then they imply a further concentration of productive capacity. Given the cost reductions that accrue with higher output, large firms appear to have an advantage over small firms. Survival in the industry depends on the ability to weather wild swings in the business cycle, which means limiting debt exposure (a lesson painfully taught during the *Plano Real*) and diversifying output between domestic and international markets. For many mills, it was the luck of the draw whether they had made large investments just prior to the *Plano Real*. Those that did, are paying for it now.

Finally, to date there are few signs of improvement in forest management in Paragominas. If present trends continue, we will see the liquidation of native forests, their conversion to pasture and other uses, and possibly their replacement by plantations. Indeed, many firms in Paragominas are considering the exit option more seriously. The governor of the state of Amazonas has offered to provide infrastructure and income tax credits to attract firms from Paragominas, in search of the jobs and extra revenues they can bring to the area. However, if timber extraction and processing is to be more than just the first of many passes on frontier resources, then some measures will be needed to induce forest management. Brazil needs to seriously re-evaluate its environmental laws and how they are being implemented. Barring this, only time and the slowly dwindling expanse of the Amazon forest will protect it from the market drive to convert natural capital into liquid assets.

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Table 1: Profile of Wood Processing Firms in Paragominas, 1995

Mill Type	Obs. No.	No. of Band Saws	Year of Establishment	Annual Production
Small Mills	1	1	na	6,000
	2	1	1975	8,500
	3	1	1979	4,800
	4	1	1979	4,800
	5	1	1980	4,800
	6	1	1980	4,488
	7	1	1980	3,984
	8	1	1981	6,600
	9	1	1983	4,250
	10	1	1984	2,484
	11	1	1985	7,700
	12	1	1985	4,800
	13	1	1986	9,600
	14	1	1986	4,992
	15	1	1986	3,960
	16	1	1987	9,600
	17	1	1988	4,200
	18	1	1992	6,000
	19	1	1992	6,000
	20	1	1994	5,280
Avg.				*5,642*
Std. Dev.				*1,910*
Large Mills	21	2	na	9,600
	22	2	1980	9,600
	23	2	1981	9,408
	24	2	1987	9,600
	25	3	1981	20,400
	26	3	1983	11,520
	27	5	1980	26,640
Avg.				*13,824*
Std. Dev.				*6,902*
		No.of lathes		
Veneer Mills	28	2	1980	9,000
	29	2	1986	6,000
	30	3	1978	27,600
	31	3	1984	31,200
Avg.				*18,450*
Std. Dev.				*12,788*
Plywood Factories	32	1	1980	6,000
	33	1	1981	6,600
	34	3	1980	17,760
	35	3	1989	34,000
Avg.				*16,090*
Std. Dev.				*13,108*

		Ovens		
Export	36	1	1992	4,000
Houses	37	3	1988	24,996

Source: Author's Field Surveys, 1995.

Table 2: Wood Prices in Paragominas, 1990 and 1995
(all prices in constant 1995 US$/cubic meter)

Value	Product	Average 1990	Std. Dev.	Average 1995	Std. Dev.
Export	Sawnwood	na	na	350	na
High	Log	60	16	82	7
	Sawnwood	336	50	291	15
Medium	Log	38	16	43	3
	Sawnwood	216	35	174	10
Low	Log	24	10	30	4
	Sawnwood	168	20	98	8
Very Low	Log	18	6	27	2
	Sawnwood	96	17	89	6

Source: 1995 Prices taken from field surveys, in August, 1995
Note: 1990 US$ converted to 1995 US$ at rate of 1:1.2 Sample size of VBMTU unknown; 1995 sample size = 5. Export price represents an average taken from one export-clearing house, for oven-dried and packaged rough sawn boards.

Table 3: Labor Costs in Wood Processing, US$/cubic meter
(Constant 1995 US$)

Mill Size	Item	1990 Avg.	Std. Dev.	n	1995 Avg.	Std. Dev.	n
1 Band Saw	Processing	20.97	na	na	19.09	4.00	15
	Extraction	3.05	na	na	2.29	0.89	14
2 or More Band Saws	Processing	n/a	na	na	18.59	7.17	5
	Extraction	n/a	na	na	1.91	0.81	4

Source: Field Surveys, August 1995. VBMTU for 1990 data.

Table 4 : Changes in Extraction and Transportation Investments by Mill Size, 1990 and 1995

		Chainsaws[1/]	Trucks	Rigs	Bulldozers	Log-lifters[1/]	Skidders	Graders[2/]
Small 1990	Avg.	3	3	1	1	2	0	0
n=5	sd.	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Small 1995	Avg.	4.7	0.9	2.1	1.7	1.9	0.0	0.0
n=15	sd.	3.4	0.8	1.1	1.0	0.3	0.0	0.0
Large 1995	Avg.	14.0	1.5	8.0	4.0	3.5	1.2	0.33
n=7	sd.	13.3	2.2	8.8	3.0	2.5	0.9	0.53

Source: 1990 data from VBMTU; 1995 data from Author's field surveys.
Note: 1/ At least one loglifter and one chainsaw remain in mill yard.
2/ Graders are used exclusively to build and maintain roads.

Table 5: Energy Costs of Processing Timber, 1990 & 1995 (in constant 1995 US$)

Size	Year	Cost of Energy/m^3 Avg.	sd.	n
Small[1]	1990	2.74	0.73	na
Small	1995	4.65	1.27	19
Large	1995	4.11	0.52	3

Source: 1990 data from VBMTU, adjusted to US$1995 values.
1995 data from author's field surveys.
Note: 1/ Calculated using 4,300 m^3/yr.

Table 6: Financial Analysis of Extraction and Transportation of Timber (Constant 1995 US$)

	Small 1990	Small 1995	Large 1995
Extraction, cubic meters 1/	12,642	16,464	40,572
Costs of Extraction:			
Stumpage Fees 2/	27,945	82,320	202,860
Salaries and Benefits 3/	35,372	36,373	77,362
Fuel 4/	14,616	22,078	44,156
Maintenance 5/	22,800	33,600	67,200
Depreciation 6/	29,248	38,674	77,349
Capital Costs 7/	50,736	66,720	133,440
Forest Tax 8/	23,362	n/a	n/a
Forest Management 8/	n/a	10,000	20,000
Total Extraction Costs	204,080	289,765	622,367
Costs of Transport			
Salaries and Benefits 9/	13,536	24,780	49,560
Fuel 4/	30,098	33,335	74,597
Maintenance 5/	18,000	33,600	67,200
Insurance 10/	23,400	47,400	104,000
Depreciation 6/	37,440	96,800	230,400
Capital Costs 7/	46,800	94,800	208,000
Total Transportation Costs	169,274	330,715	733,757
Total Costs	373,354	620,480	1,356,124
Value of Production 11/	417,450	671,568	1,656,072
Net Profit	44,096	51,088	299,948
Profit margin	11%	8%	18%

Notes:
1/ The figures for volume of wood extracted are derived from the total production of sawnwood, using a conversion factor. The original figure used by VBMTU was 47%, or 2.12 m^3 of logs to produce 1m^3 sawnwood. However, this was revised downward by a later IMAZON study to 34% by Gerwing and Uhl (1995), which is used in this analysis.
2/ Average cost of clearing rights rose from 84 US$/ha in 1990 (1995 dollars) to 190 US$/ha in 1995. Per m^3 stumpage fees calculated using estimate of 38 m^3/ha removed, from VBMTU.
3/ Salaries and benefits from Table 3.
4/ Fuel costs were recalculated for 1990 as a result of the change in conversion rate to 34%. Using the proportion of fuel needed to extract 9,200 m^3, the new fuel figure was adjusted proportionally to reflect the extra time needed to extract the higher volume of wood. See Table A2 for calculations.
5/ Maintenance costs are from VBMTU, adjusted to 1995 prices. Maintanence costs for 18-wheel rigs are assumed to be proportional to purchase value (8%, or US$ 8,400), following VBMTU.
6/ Straight-line depreciation calculated on basis of scrap value of 20% at end of useful life of equipment.
7/ Capital costs reflect opportunity cost of investment. Interest rate of 20% per year was used for analysis.
8/ Logs were taxed at $2.00 per cubic meter until 1994. Now, IBAMA requires forest management projects, which entail costs to prepare and submit an application. We conservatively estimate these costs at $10,000 and $20,000 for small and large firms.

9/ 1995 salaries calculated from survey results as US$ 550/month (n=6 sd = 34), plus the cost of benefits (50% of total).
10/ Insurance costs estimated to be 10% of total value of fleet.
11/ Value of production calculated using prices in Table 1 following VBMTU.

Table 7: Financial Analysis of Processing Costs (in constant 1995 US$)

	1990 Small (A)	1995 Small (B)	1995 Small (C)	1995 Large (D)
Export Profile	no exports	no exports	20% exports	20% exports
Cost of Capital	20%	20%	20%	20%
Number of Band-Saws	1	1	1	2
Production, cubic meters	4,300	4,300	5,600	13,800
Processing Costs:				
Raw Material: 1/	411,246	508,450	671,731	1,656,072
Labor 2/	111,790	115,439	143,809	344,357
Electricity 3/	11,788	21,062	27,429	56,732
Fuel 4/	3,600	3,900	3,900	3,900
Office Expenses 5/	10,620	10,620	10,620	21,240
Maintenance 6/	15,624	15,624	15,624	21,648
Depreciation 7/	18,631	18,631	18,631	24,919
Capital Costs 8/	41,280	41,280	41,280	82,560
Total Costs	624,578	735,005	933,024	2,211,428
Total Revenues	804,960	656,180	1,051,680	2,591,640
Taxes 9/	117,926	96,131	154,071	379,675
Net Profit	62,455	(174,956)	(35,415)	537
Profit Margin	8%	-27%	-3%	0%

Notes: 1/ Assumes a conversion coefficient of 34% (from Gerwing and Uhl, 1995).

2/ Labor costs from Table 3. Salary of manager (US$21,600) included; large mill labor costs includes management costs of US$43,200.

3/ Electricity costs from Table 5.

4/ Fuel consumption for one log-lifter, 40 liters/day x 250 days/yr. Cost of diesel rose from 0.36 to 0.39 US$/liter in real terms from 1990 to August 1995.

5/ Office expenses include communications, supplies and a car.

6/ Maintenance costs calculated as in VBMTU, with $US 6,024 additional maintenance costs for large firms for the second band saw and related equipment.

7/ Depreciation calculated as in VBMTU, with $US 6,288 additional depreciation for the second band saw and related equipment.

8/ Capital costs calculated as the opportunity cost of having capital invested in machinery. Total investment taken from VBMTU, at $US 206,400 (in 1995 dollars) for a mill with one band saw. Total investment for a mill with two band saws calculated by linear extrapolation, at $US 412,800.

9/ Tax rate taken from VBMTU, at 14.65% of total revenues.

Table 8: Per Unit Extraction, Transportation and Processing Costs in Paragominas, 1990 & 1995 (in constant 1995 dollars/m^3 sawnwood equivalent[1])

	1990 Small	1995 Small	1995 Large
Interest Rate	20%	20%	20%
Extraction Cost	47.48	51.76	45.12
Transportation Cost	39.38	61.28	56.67
Processing Cost	49.61	46.66	40.24
Total Cost	136.47	159.70	142.03
Avg. Price			
w/ 20% Exports	na	188	188
w/o Exports	187	153	153
Profit per m3			
w/ 20% Exports	na	28.30	45.97
w/o Exports	50.53	-6.70	10.97

Source: Tables 6 & 7.
Note: 1/ uses 34% conversion efficiency.

Table 9: Sensitivity Analysis of Profits to Changes in Conversion Efficiency

	1990 Small	1995 Small	1995 Large
At 34% Efficiency			
Total Costs of:			
Extraction	204,080	289,765	622,367
Transportation	169,274	330,715	733,757
Processing	213,332	261,293	555,356
Total Revenues	687,034	897,609	2,211,965
Profit	100,347	15,836	300,484
Profit Margin	15%	2%	14%
At 47% Efficiency			
Total Costs of:			
Extraction	187,642	249,627	528,363
Transportation	160,982	208,755	542,734
Processing	213,332	261,293	533,756
Total Revenues	687,034	897,609	2,211,965

Profit	125,077	177,934	607,112
Profit Margin	18%	20%	27%

Source: Tables 6 & 7.