Industrial development on logging frontiers in the Brazilian Amazon

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Abstract: In this paper, we review the concept of forest sector industrialisation and technology adoption with the goal of identifying reasons that have shaped the technological development, or lack thereof, in the Brazilian forest sector. The image of the timber industry in the Amazon has been one of excessive harvest, deforestation, and arguable misuse of a renewable resource. In this paper, we use the results of a survey of 499 mills in the Amazon, as well as secondary data, to discuss the drivers of

unsustainable frontier development. Our research suggests that unsustainable logging, or the 'boom-and-bust' scenario, is not an inevitable outcome for the industry. New and intermediate frontiers are sufficiently different from old frontiers, in key issues, to show that the industry can respond rationally to policy interventions.

Keywords: Amazon; forest policy; industrial organisation; sustainable development.

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1 Introduction

Whether following or creating new roads, logging is among the main economic activities on Amazon frontiers. This opportunism is sometimes short lived, as native forest stocks become increasingly difficult to obtain as the frontier matures. The term 'boom-and-bust' is often used to describe the forest industry, reflecting an industry that exploits a finite open access natural resource and then collapses (i.e. Verissimo et al., 2002). This portrayal follows a long history of unsustainable resource extraction in the Amazon (Bunker and Ciccantell, 2005), but may mask the underlying drivers of change in the forest sector and cause us to overlook the potential role of the timber industry in sustainable development. The determining factors of failed industrial development on logging frontiers may in fact be extra-sectoral and driven by a myriad of economic influences and policies. Misunderstanding the elements that drive forest sector change, whether positive or negative, will distort future policy decisions, making solutions to the current mishandling of the forest resource elusive.

In this paper, we discuss the dynamics of industrial development on logging frontiers in the light of a history of temporary, and exploitative, use of natural resources on the Amazon frontier. Our goal is to examine the forest sector for causes of change, rather than the results of it. Can the Amazon timber industry follow theory and transition into sustainable production, or is the 'boom-and-bust' scenario an unfortunate but inevitable outcome? We attempt to answer this question using data from secondary sources and a survey of 499 mills, and ask whether new and intermediate frontiers are exact earlier versions of old frontiers, or if these frontiers are fundamentally different. If the frontiers do indeed have different development trajectories, then one could argue that the sector responds 'rationally'; i.e. it attempts to maximise profits subject to current economic conditions. Finding for a rational sector implies that a sustainable future is only as far away as a set of market and economic incentives and that 'command and control' of the sector is unnecessary. We proceed as follows. Firstly, we outline the theory of forest sector industrialisation in tropical forests. We then link the theory, as well as the other influences, to the development of the forest sector in the Amazon. Secondly, we discuss some descriptive statistics of the industry and then examine the issues outlined above with this new data. Finally, we offer our conclusion with policy recommendations.

2 Forest sector industrialisation

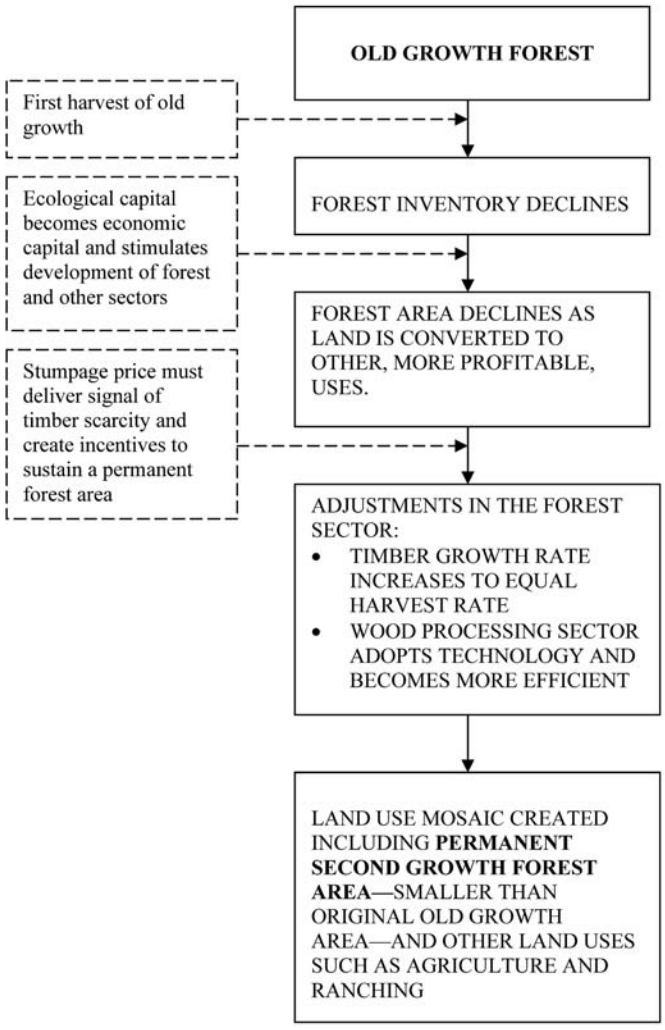
2.1 Theory: rational deforestation

Although well documented in the sustainable development literature, the concept of 'boom-and-bust' and its tie to the tropical timber industry finds its origin in the theory of forest-based industrialisation first proposed by Vincent and Binkley (1992). Their interpretation, depicted in Figure 1, suggests that in the process of forest-based industrialisation, windfall profits are captured from the harvest of accessible old growth primary forests, and some land is initially converted to other more profitable uses (such as agriculture, cattle or even plantation forestry). Producers, both efficient and inefficient, enter the market to capture the windfall profits, which results in an increase in demand for what is essentially a finite exhaustible resource – primary forests composed of old growth timber. Once this stock of old growth is harvested, the potential supply of timber then depends on the annual growth of the remaining secondary forest. In other words, by removing the old growth stock, which by definition has zero net growth (Gentry and Terborgh, 1990), the incremental yield is increased because the removal of the dominant old growth gives the younger stock access to additional light and nutrients, thereby increasing growth rates. The growth rate for such forests in the Amazon has been estimated to equal between 1 and 4% per year – often about 1 m^3 per hectare per year (Silva, 1995).

A reduction of timber supply, the equivalent of economic scarcity, will result in higher market stumpage prices. Higher stumpage prices encourage adjustments in the forest sector; inefficient mills operating at the margin will find their costs of wood procurement higher and will exit the industry. Wood-saving technology adoption also occurs among more efficient processors, allowing production with lower costs and greater yields per cubic meter of stumpage. These changes should increase the rents to forestry sufficiently to allow competition with other emerging land uses, perhaps even enough to stem the

large-scale land conversion to agriculture that is common along frontiers in the Amazon. Eventually, deforestation of primary forests will slow and the result will be a smaller, but permanent, forest estate based on the sustainable harvesting of secondary forests.

Figure 1 Forest sector dynamics – the transition from an old growth to a permanent second growth forest economy



Therefore, although perceived as an environmental tragedy, some deforestation and the harvest of primary forests, absent of government policies that distort economic conditions, might be an important step in economic development (Mendelsohn, 1994). However, the desirability of this transition hinges on the efficient transfer of capital stored in old growth forests to capital investments in other, more profitable, sectors, and the subsequent reliance of forest processors on the renewable secondary forest stocks. The forest industry in the Amazon, however, rarely behaves in this way.

2.2 Practice: a complex economic reality

Very little literature on the Amazon forest sector treats the industry in anything but absolute isolation; an important exception is the emerging work by Soares et al. (2006), which develops large scale ecological and economic models of the Amazon. Indeed, there is a dearth of theoretical application to the practical problems of the timber industry (Merry and Amacher, 2005) and a tendency to view it as independent, wayward, and outside of the rational economic sphere. The timber industry meanwhile is beset by numerous market and government imposed economic drivers that, if we assume it to be made up of rational, profit-maximising agents, would encourage just the illegal, short-sighted, and ill-advised harvesting happening today. While we also discuss the industry in some isolation for parts of this document, we temper our conclusions in the light of global, regional, national and local conditions. Therefore, we broach some of the main extra-sectoral influences briefly in the following paragraphs: competition from domestic substitute products in plantations; property rights; government bureaucracy; the emerging agricultural sector; and land use policies.

Take for example, the competitive wood markets in Brazil, where more than 60% of Amazon logs are sold. The total value attributable to forest production in Brazil is R$7.9 billion (approximately US$3.2 billion); that production includes logs, firewood and charcoal. Of that total value, 35% originates from natural forests and the other 65% from plantations – of the total natural forest value 85% is attributable to wood products and 15% to non-timber forest products (IBGE, 2004). The Brazilian timber industry that is based on the harvest of logs from natural forests produced some 20.6 million m^3 of logs in 2003, a 3.33% decline from 2002. Of this some 17 million m^3 came from the northern region, or Amazon states. The main product from these logs is sawnwood (63%) and its main use is housing frames (as frames, roof trusses and as temporary concrete forms). Furniture manufacture is touted as one of the best alternatives for value added, but will find tough going in markets with stiff competition from pine and eucalyptus plantations, which not only produce easily worked, uniform products but eclipse the volume available. In 2003, plantations generated 99.7 million m^3 of logs, of which half ($\approx$ 50 million m^3) enters the market for furniture, construction and other uses – the other half goes to cellulose and paper. Indeed, of the total volume of logs produced in Brazil in 2003, 82% came from plantations.

The second most important product, firewood (*lenha*) shows a similar pattern whereby 70% of the 47.2 million m^3 produced in 2003 came from plantations. The final sector, charcoal (*carvão vegetal)*, has seen an increasing percentage of its demand coming from natural forests. The national demand hovers around 4 million metric tons per year, and currently natural forests provide approximately 50%, up from 28% in 1997. This trend suggests that charcoal from natural forest is becoming less expensive relative to charcoal from plantations and a devaluation of forest products. The main demand for charcoal comes from the iron smelting operations, which up until recently had been investing in plantations as a main source of fuel but have shifted to charcoal from natural forests (IBGE, 2004). This demand has had a strong impact on the old frontier regions of Eastern Pará, which can provide charcoal transported on the paved BR010 and PA150.

Two other mitigating factors, directly related to government management rather than markets, are insecure property rights and a rent-seeking, inefficient bureaucracy. Lima et al. (2006) and Merry and Amacher (in review) suggest that only 26% of

smallholders on the Transamazon hold formal title; this number contrasts to an estimate of an even smaller 11% by Alston et al. (1999). Loosely stated, property rights in the Amazon are the weakest where forest cover is the most expansive. Indeed, Mato Grosso, the home of soybean and cattle production, has quite effective property rights. Poor property rights increase investment risk for natural forestry, which has rotations of more than 25 years and problematic formal acceptance as a unique productive land use. This high level of investment risk, coupled with the high opportunity cost of capital (average interest rates for the last 10 years have been 20%), leads to a short-term profit maximising outlook for any given forest area – loggers move to a new area once the old one is exhausted leaving no chance of investment in silvicultural treatments to improve the second harvest. To add to the insecurity faced by forest firms, the government bureaucracy in the forest sector has been relentlessly corrupt and inefficient. A culture of bribery puts firms that wish to act within the established regulations at a disadvantage. Complex forest management legislation and requirements ensure that these firms have costly barriers to overcome that illegal loggers simply bribe through.

With these obstacles, is not surprising that forest rents are depressed, and can even be at zero when forest management plans are not forthcoming from the government. Recall theory suggests that some deforestation is rational due to the relative rents of land use options. In some cases, other land uses may have higher rents than forestry, and absent government intervention land will exist in the highest valued use in the market. But if forest rents are artificially depressed by government actions, or other land use rents are increased, then the playing field as such is tilted. For example, the requirement of productive use to establish land title increases returns to other uses because it captures the land value within that use; cattle production, as the least cost alternative, is the preferred method of capturing this implicit subsidy. Another 'hidden' subsidy includes spending on information and technology. Brazil is a leader in soybean production because, among other factors, of high government spending in technology through EMBRAPA. Finally, in the current agricultural crisis in Brazil, brought on by a strong currency that dampens exports and a very high rainfall, the government has reacted with an emergency support package. While these are ad hoc examples, they do illustrate that there is government support in non-forest sectors, intentional or not, and spending in those sectors is increasing while the timber industry is ignored, leading to a decline in relative forest sector rents.

Many of the industrial development examples are based on selected spots on old frontiers; particularly in and around the municipalities of Paragominas in the Sate of Pará, Sinop in Mato Grosso, and Ariquemes in Rondônia. The actual frontiers of economic activity are, however, broader than these important centres. Paragominas produces only 8% of the total production the State of Pará, and so any discussion of frontiers must include other centres. An obvious, and well documented, factor determining the growth of timber production in early large centres such as Paragominas, was subsidised land conversion to non-forest uses that occurred during the transition phase of the late 1970s and early 1980s (Binswanger, 1991; Browder, 1988). The effect of the subsidies was to lower the raw material (stumpage) costs to the mills. Landowners often paid loggers to remove trees, or trees were free in exchange for road construction. The large market supply of logs depressed stumpage prices and provided incentives for producers to enter the market with the prospect of very low costs of securing raw material. Coupled with sudden access to domestic markets by road improvements,

the subsidies resulted in a considerably large increase in production. This rapid expansion, however, obscured signals that might otherwise have induced technology adoption among producers.

As the 'new' frontiers develop, it is important that we investigate what incentives and disincentives the forest sector faces and how these will affect land use choices. Comparison of conditions in old and intermediate/new frontiers will allow a more accurate picture of the similarities and differences between these production centres. Where then do the similarities lie? While some older frontiers have veneer and plywood manufacturing, the main product continues to be sawnwood. Whereas the old frontiers may now have access to markets for short wood, charcoal, and even sawdust, the large transportation costs (due to distances) of moving these products to markets from newer frontiers render their production largely infeasible.

That said, there are several questions left unanswered in the theories of forest development discussed above. Where (if at all) does the process of industrialisation falter in the Amazon, and why? Are all frontiers alike? The explicit differences, or similarities, between new, intermediate and old frontiers are difficult to establish, and their processes and rates of technological adoption are unknown. However, there are some signals we can observe. We can consider whether technologies are adopted, and how they are adopted across frontiers. We can determine whether markets will play a different role for the future of intermediate and new frontiers than they have for old frontiers. Many frontiers were opened simultaneously, but we can observe ways in which their development trajectories have been different. If we identify differences, then it would be difficult to argue that new and intermediate frontiers are simply earlier versions of older frontiers, as the theories advanced above would suggest. Couple this to the broad spectrum of interacting factors described at the start of this section and we may hold some key to understanding the factors that determine change in the Amazon forest sector.

3 Comparing forest frontiers

In this section, we use secondary and primary data to examine the development of the logging frontiers in Brazil and address the question of whether the forest sector is essentially rational. We first describe the data and then compare frontiers.

3.1 Data

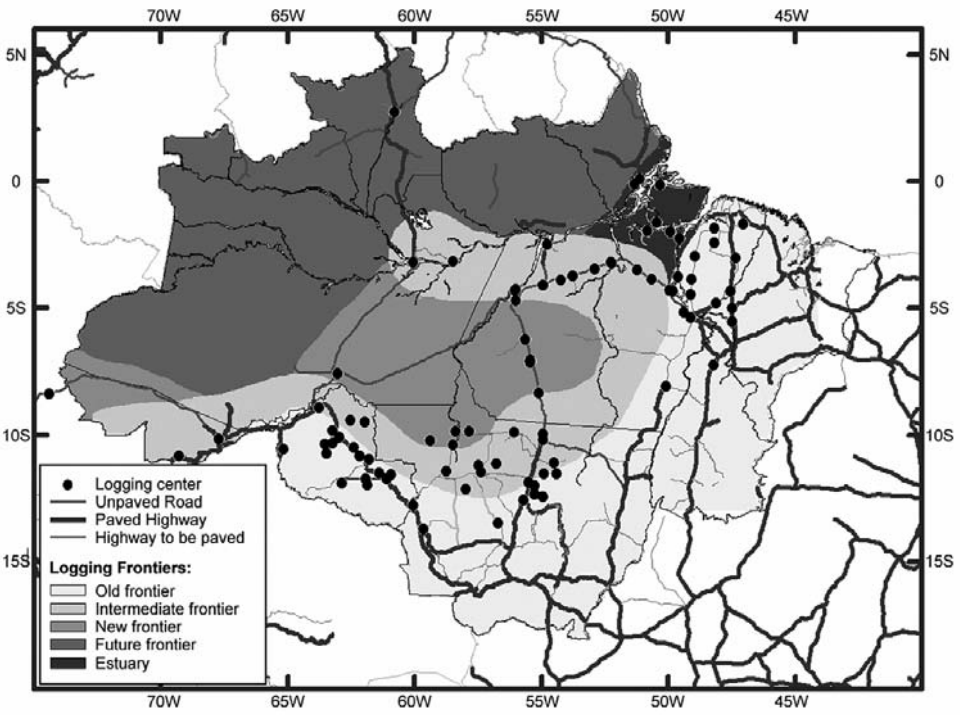
We use two data sets to support our discussion of industrial development on the forest frontiers. The first is data collected from secondary sources, principally the Brazilian Institute of Geography and Statistics (IBGE), which maintains a reliable database on forest production in Brazil. In addition, some values presented in this section are calculated from data presented by Lentini et al. (2003). We also draw on a detailed survey of 499 forest processors completed between June and December 2003 in conjunction with the Instituto de Pesquisa Ambiental da Amazônia (IPAM). One author and one other principal enumerator conducted this survey through interviews in the States of Acre, Mato Grosso, Pará, and Rondônia, which are responsible for over 90% of production. The surveys were collected on old (n = 291), intermediate (n = 189) and new (n = 19) frontiers. The data collection methodology follows Lentini et al. (2005),

Lima and Merry (2003), Nepstad et al. (1999) and Stone (1998), where production centres are identified and survey teams visit and interview all available mills. The refusal rate of this type of interview was very low, about 5%, which is similar to Stone (1998). The data compares favourably with other available data on the industry and we are confident that these data accurately represent the conditions of the timber industry in the Brazilian Amazon.

3.2 Frontiers and industry production trends

Logging frontiers in the Brazilian Amazon have previously been defined as 'old' or 'new', depending largely on the presence of primary forest stocks defining frontiers as new. As the industry matures, this classification is now changing to include what are essentially 'intermediate' frontiers. The age of the road corridors and other infrastructure characteristics are now included in the definition. *Old frontiers* are estimated to be over 30 years old with good infrastructure. *Intermediate frontiers* are defined as between 10 and 20 years old. *New frontiers* are those with less than 10 years of activity (Lentini et al., 2003). While the definition and development paths of these frontiers has not been yet studied in detail, the frontier outlines, shown in Figure 2, are a modification of a classification produced by Lentini et al. (p.30). Thus, our frontier definitions follow those currently accepted as frontier boundaries.

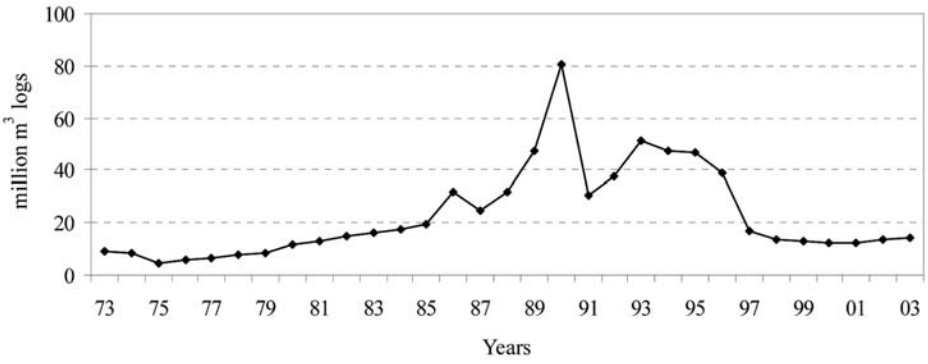
Figure 2 Logging frontiers in the Brazilian Amazon showing logging activity location and roads



Source: Frontier outlines modified from Lentini et al. (2003, p.30)

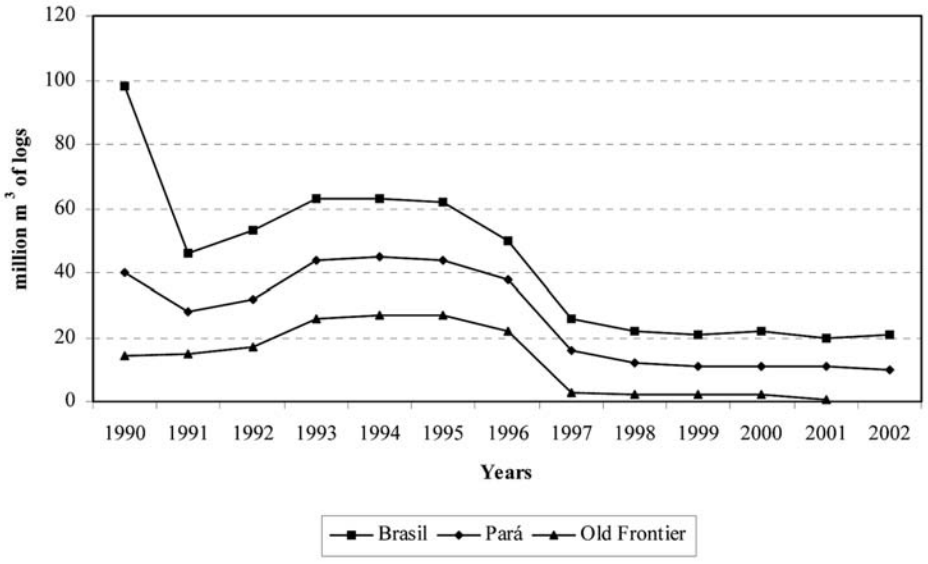
Historical production is presented in Figures 3 and 4. Figure 3 shows roundwood production for the North region of Brazil from 1974 to 1994. A substantial surge in production is very apparent between 1985 and 1994. This surge can be attributed, in some part, to the government policies of the period, which gave tax breaks and land clearing incentives to encourage settlement of the Amazon. Also in Figure 3, our data also show that, for 10 years between 1974 and 1984, production was growing at a rate of about 9% per annum (range: –46–37%). For the period between 1984 and 1994 the industry grew on average 19% per annum with a range of –63–70%. We then see a subsequent and relatively steady decline in production, as the industry appears to be shrinking back to its original path.

Figure 3 Roundwood production in the North region of Brazil (1973–2003)



Source: IBGE

Figure 4 Roundwood production in Brasil, Pará, and the combined Old Frontier Municipalities of Paragominas, Dom Eliseu, and Ulianopolis (1990–2002)

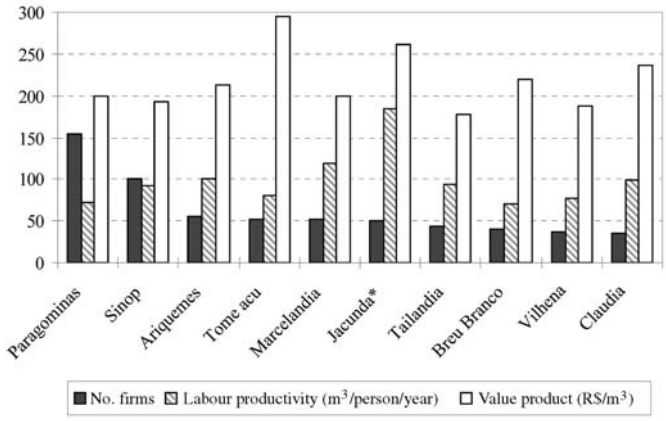


Source: IBGE; www.sidra.ibge.gov.br

Looking at this shrinkage in more detail, we present roundwood (log) production at three levels: all Brazil; the State of Pará; and the combined old frontier municipalities of Paragominas, Dom Eliseu, and Ulianopolis (1990–2002).[1] This shows that the industry itself appears to be driven by outside forces as, across the board, production drops off consistently at all levels and dramatically between 1996 and 1997. This may be in part attributable to the Plano Real, implemented on July 1st 1994, which changed macroeconomic conditions of the country (as well as the legal tender and exchange rate), leaving many sawmill owners who had extended sales credit to buyers in difficult financial conditions. The resulting crash may have had a lag of a year or so as firms slowly went bankrupt. These examples show that the industry was clearly influenced by macroeconomic conditions in addition to whatever forest resource scarcity may have been developing locally. Other consequences of the initial production overdrive and subsequent decline include an excess supply of used milling equipment, and a principal market that did not/does not attach value to a higher quality product (see Scholz, 2000, 2002; Sobral et al., 2002). Furthermore, an import substitution policy for harvest and processing equipment in place until the 1990s served to depress technological innovation and economic efficiency.

When making comparisons across firms, economic efficiency is normally defined as producing a given output at lowest cost, or with the least amount of inputs (Bengston and Gregerson, 1992). With this definition in mind and referring to Figure 5, we find that, in 1998, the 10 largest centres control approximately 36% of total log use and, with the exception of Jacundá MT, are located on the old frontiers. However, Paragominas and Sinop, the two largest and oldest centres, compete surprisingly poorly with other centres. For example, although adoption of wood saving technologies, often complementary with labour, should improve efficiency among wood processors and make labour more productive, we find that Paragominas, which has the largest number of firms and highest total log demand, is ranked eighth in labour productivity with a volume produced of 71.26 m^3 per employee per year; tenth in labour production; seventh in production volume per firm at 5491 m^3 per year; seventh in production value per firm at R$1,092,258 per year; and sixth in value product at R$199 per m^3 produced. Sinop shows slightly better figures, but it is still in the bottom half of the ranking.

Figure 5 Labour productivity in large production centres: number of firms, volume of sawnwood produced per employee, and product value (1998)



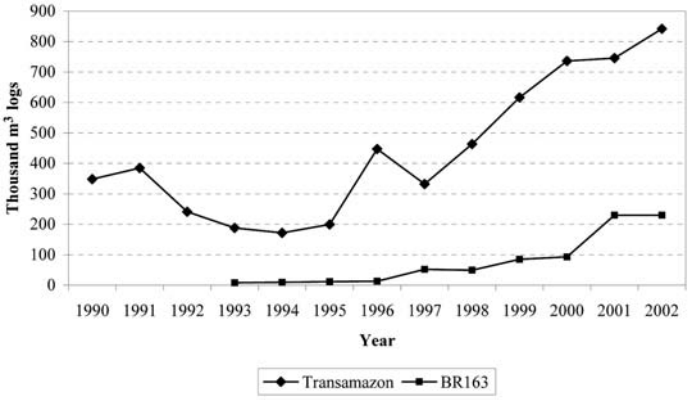
Source: Calculated from Lentini et al. (2003)

Why might the larger centres be at or near the bottom of the table for these categories? The combination of low production value per item and low labour productivity suggest that firms in the older and larger centres have indeed not adopted the technology improvements necessary to increase economic efficiency. This is opposite to the theoretical expectations of forest sector industrialisation discussed earlier; but probably has a lot to do with the regional extra-sectoral and market influences. The larger and older centres were most affected by the influence of early land clearing incentives, and both have good access to domestic markets. This access may have kept demand high for poorly inefficiently processed lumber. Also telling is that both Paragominas and Sinop are now large grain producers, providing further incentive to transfer investment of capital into other non-forest sectors within these frontiers and perhaps even migrate away.

As the old frontiers mature, much has been made of the migration of firms to the intermediate and new frontiers. Ironically, the same government (General Medici 1969–1974) built both the Transamazon highway (an intermediate frontier) and the BR 163 highway (a current 'new' frontier). The roads were part of a strategy by the military dictatorship to secure control of the Amazon region through settlement. Furthermore, currently old frontiers along the BR010 (Belém-Brasília highway) and the PA150 were both opened around that time. Although considered an intermediate frontier, the forests along the Transamazon highway have been logged, at varying intensity, for more than 30 years. Today, the most populated section of the Transamazon highway extends approximately 900 km through the centre of the State of Pará parallel to and about 200 km south of the Amazon River. It is unpaved and virtually impassable for roughly four months of the year. This severely retards economic development of any kind and is an important reason why this region can still be considered an intermediate frontier, even though it has been occupied, and logged, for the same length of time as some recognised 'old' frontiers. After suffering the industry-wide decline in the early 1990s, however, production on the Transamazon highway is steadily increasing and has now surpassed 800,000 m^3 of roundwood per year (Figure 6). Yet this intermediate frontier cannot match the volume changes being experienced on the new frontier. Even with a transportation advantage, the intermediate frontiers are probably less exploited because of the formal and informal settlement of smallholders and their subsequent control of large areas. Lima et al. (2006) estimate that more than 60% of the land 100 km on either side of the main stretch of the Transamazon highway is in the hands of, or is destined to, smallholders. With no easily accessible forest management programme for small farms – the average size is 82 ha – the productive use of forests on these lots is retarded.

On the other hand, the new frontier, an area that is concentrated on the BR163 in western Pará state and Northern Mato Grosso, has seen production double, reaching 13.2% of the total volume, up from 6.5% in 1998 (Lentini et al., 2005). It is, however, still a relatively small percentage of the total production. Furthermore, this production is increasingly inefficient; in 1998, 4.3% of firms were located on new frontiers, whereas in 2004, 12.8% of firms were located on the new frontier (Lentini et al., 2005). That is, any 1% of new frontier firms in 1998 produced 1.52% of the total volume, whereas in 2004, 1% of the firms on the new frontier produced only 1.03% of total volume.[2] This result points to two things: the entry of many smaller firms due to the lack of regulation on the frontier, but also the end of windfall profits associated with accessible old growth on new frontiers and a rapid end to the 'boom' period on this new frontier.

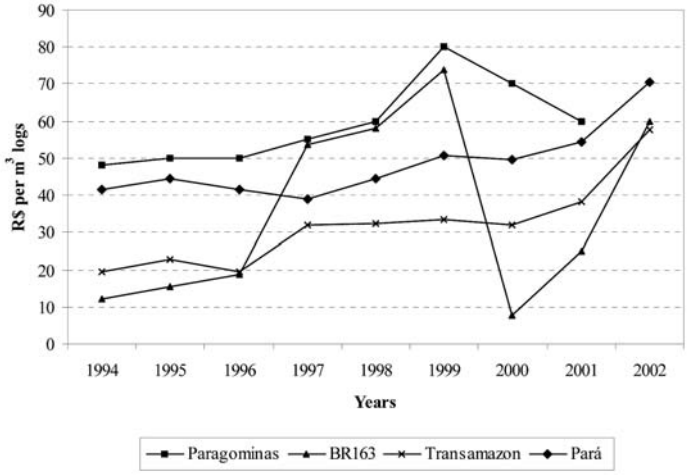
Figure 6 Roundwood production on the Transamazon highway and the BR163 (1990–2002)



Source: IBGE, www.sidra.ibge.gov.br

Newer frontiers are likely to involve higher economic risk conditions than old frontiers. Figure 7 shows an average log price in the State of Pará, and also prices for old, intermediate, and new frontiers (Paragominas, the Transamazon, and the BR163, respectively), from 1990 to 2002. While nominal prices appear to be steadily increasing, it is clear that prices on the new frontier are more volatile with a higher variance over time. This indicates higher risks in those locations than for other frontiers and the state. However, there is some indication that new frontier rents will not suffer due to price volatility. For example, land-clearing legislation is considerably stricter on paper than it is in practice. Also one might expect that mill owners who migrated from the older frontiers have some experience are therefore more efficient managers. Whether that means they will increase rents or simply liquidate the forest resource quicker is unclear.

Figure 7 Roundwood prices (nominal) in Paragominas, on the BR163, the Transamazon Highway, and a Pará State average (1994–2002)



Source: Calculated from IBGE, www.ibge.gov.br.

But have the lessons of the old frontier been learned? Although the trends in the forest sector seem apparent, there is still sporadic government presence on the new frontier. This is, perhaps, because the government must maximise its return on enforcement spending subject to a budget constraint, and control of less than some 13% of the logging production takes little precedent over the rest of the industry. This, perhaps, is why the government has recently chosen to manage the new frontier through a series of Federal timber concessions. In addition, because it is more costly to enforce on new frontiers – transportation is more expensive and the likelihood of successful action lower – the net benefits of monitoring the newer frontier may be lower than that of the old and intermediate frontiers.

3.3 Comparing theory to reality on logging frontiers

We continue the comparison of firms on the old, intermediate, and new frontiers, discussing trends emerging from the data and using survey results to test for significant differences between old and intermediate frontiers.[3] We concentrate on differences in harvest and milling technology use, capital investment, firm age, raw material procurement strategies, and other important defining variables of industrialisation and development. Holding temporarily to the assumption that intermediate frontiers are younger versions of old frontiers, we use our data to elaborate upon changes over time and ask whether the process of forest sector industrialisation holds to theoretical expectations in the Amazon timber industry.

The absence of statistically significant differences or differences of unexpected signs between characteristics of firms on intermediate and old frontiers suggests unique development paths for the two frontier types. Therefore throughout the discussion below we identify whether the trends in our data are as theory suggests – in Table 1 a check mark (✓) indicates the result holds to the expectations created by theory and a (ϕ) indicates it does not. While reference is made to trends on new frontiers as well, the statistical comparison is solely between intermediate and old.

Table 1 Selected statistics for old, intermediate, and new frontiers

Activity	*Unit*	*Old Frontier*	*Intermed.*[a] *Frontier*	*New Frontier*	*Sig. Diff.*[b]	*Expected*
Land						
Land values[c]	R$/ha	400.27	191.02	112.97	*	✓
Stumpage fees	R$/ha/year	34.02	20.67	11.00	*	✓
Rental ratio	Per cent	8.50	10.82	9.74	n.t.	
Harvest						
Harvest volume	m^3/ha	30.20	27.48	35.00	n.s.	ϕ
Harvest cost	R$/$m^3$	53.46	36.59	30.00	*	ϕ
Number bulldozers[d]	Units	1.48	1.16	1.00	*	✓
Age bulldozers	Years	10.99	14.05	15.00	*	✓

Table 1 Selected statistics for old, intermediate, and new frontiers (continued)

Activity	*Unit*	*Old Frontier*	*Intermed.*[a] *Frontier*	*New Frontier*	*Sig. Diff.*[b]	*Expected*
Number skidders	Units	0.72	0.57	1.00	n.s.	ϕ
Age skidders	Years	11.97	11.80	25.00	n.s.	✓
Do harvest operation	Per cent	33.00	42.00	30.00	*	✓
Purchase logs	Per cent	82.00	89.00	95.00	*	
Transport						
Transport distance	Km	98.24	84.27	73.16	*	✓
Distance asphalted	Km	17.46	8.13	0.00	*	✓
Transport costs	R$/m^3	28.48	34.71	37.00	*	✓
Transport costs II	R$/m^3/km	0.32	0.54	0.57	*	✓
Log prices						
Log prices (H)	R$/m^3	218.89	178.96	180.77	*	✓
Log prices (M)	R$/m^3	104.82	97.09	103.93	n.s.	ϕ
Log prices (W)	R$/m^3	66.49	71.90	69.42	n.s.	ϕ
Processing						
Log consumption[e]	m^3/year	9,156.58	5,801.39	3,929.17	*	ϕ
Firm age	Years	7.31	7.19	2.50	n.s.	ϕ
Mill age	Years	11.51	10.09	n.a.	n.s.	ϕ
Number band saws[f]	Units	1.07	1.03	0.80		ϕ
Age band saws	Years	14.95	15.41	9.63	*	✓
Milling costs	R$/m^3	64.59	75.25	57.33		ϕ
Milling yield	Percent	51.00	46.00	39.00	*	✓
Labour						
Wages	R$/month	508.74	593.97	534.11	*	ϕ
Labour costs	R$/m^3	56.86	82.67	103.32	*	ϕ

Notes: *Indicates significant differences of the means at $P \leqslant 0.05$; n.t. = not tested; n.s. = not significant

n.a. = not available

[a]Intermed. is an abbreviation for Intermediate

[b]The *t*-tests are conducted on the data from old and intermediate frontiers only

[c]During the period of data collection, the exchange rate was approximately 3R$ to 1US$

[d]Only one observation was available for the number of bulldozers and skidders on the new frontier

[e]Francon measure common throughout the Amazon. One m^3 Francon ≈ 0.75 m^3 geometric

[f]Some firms on the new frontier had only circular saws. The maximum number of band saws on the new frontier was 1

Referring to Table 1, both stumpage and land prices on the old frontier are significantly higher than on the intermediate frontiers, at a 0.05 level of significance. This is expected. Higher land prices are indicative of a scarce supply of land, which would hold true for older more densely populated areas. Land prices on new frontiers, as expected, appear to be lower than both intermediate and old frontiers. Also a rental ratio (equivalent to a return on investment in land) is calculated, showing an acceptable range of returns (8–11%). Harvest volume shows no significant difference for the intermediate and old frontiers, which is somewhat surprising because harvesting on intermediate frontiers is limited to higher value logs, which have a lower per hectare representation given there are less species in that category. One explanation for this is that the harvest volume limits are technological, and a thus similar volume can be harvested irrespective of log quality or category. The result for the new frontier of a slightly higher volume also holds to the idea that harvest volume is largely determined by technology.

In the absence of technology adoption, one would expect costs of logging to increase over time because, with all of the easy to access regions already harvested, logging will now occur on more challenging (hilly or waterlogged) terrain. On the other hand, if firms manage the forest well and adopt reduced impact management practices for long-term forest use, then the costs of harvesting should decline over time as firms make use of permanent infrastructure and capture efficiency derived from these technologically more advanced logging improvements and planning. Here, we see that harvest costs in our data equal R$53 on the old frontier and are significantly higher than the cost of R$37 on the intermediate frontier. Furthermore, the costs are only R$30 on new frontiers. This suggests that, in general, firms are not adopting improved harvest technologies on the old frontiers; interestingly, this is true despite that the first Reduced Impact Logging training programme (the Fundação Floresta Tropical est. 1995) was in the Municipality of Paragominas in the State of Pará, and 58% of all FSC certified areas in Brazil come from the State of Pará (235,395 ha of a total 405,937 ha in 2003 (Lentini et al., 2003)). Moreover, reduced impact technologies are known to reduce logging costs at the margin (Holmes et al., 2002).

Looking at investment in harvesting technology, one would expect old frontiers to have newer equipment overall and also to have additional investments in skidders (which will increase logging productivity) made over time. In fact, we do find that loggers on old frontiers have relatively more bulldozers (1.48 compared to 1.16), and their bulldozers are younger (11 vs 14 years) than on intermediate frontiers. There is, however, no statistically significant difference in skidder adoption between the two frontiers. We suspect that skidder adoption has been delayed for two reasons. First, skidders are very expensive investments and serve only one purpose, whereas bulldozers can be used for building roads and also have alternate rental markets in the wet (non-logging) season. Secondly, bulldozers are the traditional machinery of choice among loggers, and information about the benefits of skidders specific to harvesting is only slowly diffusing through the industry. The trends on the new frontiers also appear to confirm this result. Thus, although we would expect greater adoption of skidders on old frontiers, without a critical mass of information, the risk associated with the large financial investment in skidders is probably a deterrent to their adoption on both old and intermediate frontiers.

We find, however, that mills on all frontiers tend to subcontract their logging and purchase logs. Forty two percent of mills on the intermediate frontier do their own

logging, whereas 33% of mills on the old frontier have their own logging operations, and only 30% on new frontiers. This suggests that firms favour subcontracting logging operations and purchasing logs at the mill gate. This result is supported by results from recent studies that suggest firms subcontract logging activities mainly to avoid costly government bureaucracy (Lima and Merry, 2003). The subcontracting occurs at a significantly lesser extent on intermediate frontiers, however, which may imply a different production strategy. Indeed, many intermediate frontiers have high populations of smallholders, who occupy large areas of land and forest and firms may need to adopt different practices – such as owning a flexible logging operation – to access that supply. But, that said, the purchase of logs is commonplace on all frontiers with 82% of firms purchasing logs on old frontiers, 85% on intermediate and 95% on new.

With technology adoption, one would also expect transportation costs to decline over time, and therefore these costs should be lower on older frontiers. Stone (1998) reports that investment in larger trucks reduced the logging costs in Paragomias between 1990 and 1995. Our results suggest that transport costs are indeed significantly different on old and intermediate frontiers. For example, average hauling distances are 98 km (17 km of which are asphalt) on old frontiers, 84 km on intermediate (8 km of which are asphalt) and 73 km on new (0 km asphalted); total transport costs are R$28 on old and R$35 on intermediate frontiers respectively; and logging costs per m^3 per kilometre are R$0.32, 0.54, and 0.57 on old, intermediate, and new frontiers, respectively. The significant differences confirm there is a pattern of investment in transportation technology as a logging frontier matures.

One of the important levers in the process of forest sector industrialisation is a scarcity signal to the industry, i.e. increases in log prices. In the Amazon timber industry, logs are classified loosely into three defined categories: ‘noble’, or high value; ‘red’, or medium value; and ‘white’, or low value. In our results, we find only the high value category shows a significant difference in log prices across frontiers. This corresponds with the reality that high value species are the first to be harvested, and these would therefore be the first to show scarcity signals. In the future, as medium value species become relatively scarce on the old frontier, we would expect prices for these species to show the same signal. But it is apparent that this has not yet happened, and so the industry faces a limited set of scarcity signals. The end result of this is to dampen any incentives for technology adoption.

Stepping forward to the processing phase of wood production, we see that although firms are larger on old frontiers, they are not significantly older when compared to intermediate frontiers. Firms have an average age of about 7 years on intermediate and old frontiers; about 2.5 on new. This suggests that, while the new frontiers are a case apart, the market for sawnwood is dynamic and always in flux, with mills entering and exiting, on old as well as intermediate frontiers, as demand and prices and costs fluctuate. The precise reasons for the rapid entry and exit of firms are as yet unclear, but migration to new frontiers, although a common perception, is not the sole determinant given our (surprising) finding that relatively young mills are present on the old frontiers. Furthermore, equipment age (band saws) is not significantly different across firms in the different frontiers. This supports the discussion above of a strong market for second-hand equipment, which serves to increase the opportunity costs of new technology adoption. Although, in our data, the value of the mills is not significantly different on old frontiers, they are larger and process more logs, according to the results. However, milling costs

are not significantly different, showing no adoption of processing technologies in the old frontier that could reduce costs. A better market for residuals, reflecting a higher use percentage or improved use and training of labour, can explain the significantly higher yield shown in our results.

Finally, one would expect that better training and technology adoption on old frontiers would result in more skilled labour and higher wages. This is not the case, however, as we see significantly lower wages on old frontiers; possibly explained by the more difficult working conditions and labour scarcity on intermediate and new frontiers. This also suggests the absence of technology that increases labour productivity, which would reduce costs and increase wages.

4 Conclusion and policy recommendations

The theory of forest sector industrialisation provides for a scenario in which the harvest of old growth forest and some deforestation is logical along the path of development. Tied to this process, however, is a series of conditions that must be met in order to attain sustainable economic development on forested frontiers. Among these conditions, scarcity, efficiency, and unburdened markets are key factors. Our objective here was to ask, and hopefully answer, the question of whether the timber sector can emerge from its current cycle of 'boom and bust' to become a sustainable engine of growth on emerging frontiers in the Amazon. An affirmation of this hypothesis requires there to be evidence that the timber sector behaves rationally. Or, in other words, that the forest industry comprises profit maximising economic agents who respond according to theory and follow a rational path set forth by the theory of forest sector industrialisation. Both secondary and primary data, collected through a survey of 499 mills, was used to examine this hypothesis.

From our results, we identify several trends that can help determine the plausibility of a rational sector. Firstly, based on secondary data (IBGE), it appears that the industry follows general trends determined by the market and is strongly influenced by government policy incentives. Our results show a massive growth in production during the late 1980s and early 1990s – when government land development policies were strongest in the Amazon – followed by a strong general industry decline. This follows theory, but accentuates the effects and has dampened incentives for technology adoption. Thus, instead of becoming competitive, the industry is slowly being replaced by other land uses or economic activity. We do note a shifting of production from old to new frontiers, but the relative volumes remain small (only 4% of the total volume is produced on new frontiers).

Secondly, we find that the larger production centres on old frontiers – the ones most affected by early incentives and principal examples of boom-and-bust – appear to be less efficient than other production centres. This suggests that these centres were unable to overcome the inertia of early policies that determined their model of development. An important caveat, however, is the result that intermediate frontiers produce relatively more for export than older frontiers. This means that the development strategy for old frontiers is based more on the domestic market, which does not demand higher quality, or value added processing, which in turn requires less investment in technology.

Thirdly, based on our recent survey of processors, we show that intermediate frontiers – which, based on time as the only distinguishing factor, are assumed to essentially be an earlier stage of industrialisation than old frontiers – differ from old frontiers to the extent that they are on a slightly different technology adoption path. These frontiers may be less affected by the boom-and-bust phenomenon. This different path is probably a result of early government policies distorting the old frontiers, rather than an industry that does not fit into the theory of industrialisation. We support this assertion by identifying critical matching and deviating trends between the intermediate and old frontiers.

The trend most closely matching the economic theory of industrialisation is investment in transportation; firms on older frontiers have clearly reduced per kilometre costs of wood transport per cubic meter. For harvest technology, we do not find this to be the case. Instead, we see that although there is more investment in machinery on the old frontiers, a critical deviation from theory is that harvest volumes are no different across frontiers. Moreover, harvest costs per cubic meter appear higher on old frontiers. According to the theory, we would therefore expect higher volumes and lower costs on old frontiers. In fact, on older frontiers, firms are divesting themselves of logging operations, and only 33% conduct their own logging operations We also see interesting matches in log prices, where scarcity signals, vital for incentives to adopt new technology, are apparent, but only for the highest valued species. In mill processing, we find a consistent deviation from theory. The only matching trend is that firms are larger on old frontiers (assuming that larger firms would indicate the presence of economies of scale).

We also argued that deviations from the theory in our data could largely be attributed to the influence of poor policies implemented during the early stages of industry development. These led to an industry that has not been able to complete the cycle of industrialisation, because it could not compete successfully with other land use options as they became relatively more valuable. Instead, there has been a progressive decline in forest processing where new technology has been adopted slowly, or not at all. If firms are to compete and thrive financially while maintaining a productive forest cover, then our results suggest that policies must be put in place that encourage technology adoption in both harvesting and processing phases. Barring that, the industry will continue to decline as windfall profits from old growth are gradually exhausted and wood saving technologies are not put in place as possible relief. Finally, our research suggests that, although not entirely different, intermediate frontiers are sufficiently different, in key issues, to suggest that they require different policies and should not be entirely directed by what has happened on old frontiers. The pre-conception of ‘boom-and-bust’ should not be held as a universal truth or inevitable outcome for the industry.

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Notes

[1] Part of the 'boom-and-bust' of the old frontier industry may be the result of moving Municipal boundaries: the Municipality of Paragominas has been divided twice – exacerbating the shrinking effect – once in 1991 to create the municipality of Dom Eliseu and again in 1993 to add the Municipality of Ulianopolis.

[2] Interestingly, firms located on the floodplains, the oldest of frontiers, in production for more than 300 years (Lentini et al., 2005), generated approximately the same volume as the new frontiers, 12% of the total volume, but did so with 25% of the firms.

[3] We choose a comparison of old and intermediate rather than new frontiers because the objective is to examine the process of change between stages, for which intermediate to old is acceptable.