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Agricultural development and the industry life cycle on the Brazilian frontier

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ABSTRACT. The occupation of the last remaining tropical forests has been an initiative of many developing nations that is debated by the global community due to impacts on soil erosion, biodiversity loss and contributions to global climate change. Arguments against development range from the irreversible nature of tropical deforestation to the synergistic losses associated with environmental degradation and continued poverty. The focus of this paper is to determine if evidence of market advancements and growth can be found in an Amazonian settlement, thus providing counter-evidence for the boom–bust pattern of development that has been predicted for much of the Amazon. Using panel survey data (for four survey waves between 1996 and 2009), we find trends that are consistent with the industrial life cycle, suggesting a pattern that is more consistent with growth, development and consolidation.

1. Introduction

The removal of forested land in tropical regions affects both local and global communities through impacts on soil erosion, biodiversity loss and contributions to global climate change (Faminow, 1998; Laurance *et al.*, 2001). Conventional wisdom contends that inadequate management of tropical soils for monocultured crops and pasture can lead to the boom–bust cycle of land use and abandonment that has been extensively cited in the literature (Scott, 1999; Barbier, 2004; Rodrigues *et al.*, 2009). The end result is that both the environment and the individuals who inhabit these regions are made worse off as a result of occupation and inefficient resource use. Thus, the irreversibility of deforestation is expected to devastate inhabitants, leaving them with little choice but to become 'poorer, hungrier, less philoprogenitive, and more nomadic' (Goodland and Irwin, 1975). Similarly to predictions made by (Malthus, 1798), this deterministic view does not allow for ingenuity or adaptability by individuals. In contrast, the frontier expansion hypothesis as explained by Barbier (2005) considers the tendency of resource-dependent economies to display rapid rates of frontier land expansion that generate marginal returns due to underdevelopment rooted in the overuse and compaction of fragile soils. In this case, the cycle can be broken, but only through investment in human and physical capital. Thus, if appropriate investment in education and infrastructure does not accompany resource use, the boom–bust pattern is expected to continue. In this case, investments in capital can lead to systemic changes in markets that can transform subsistence-based economies into those that are more advanced, leaving behind an economy that is no longer resource dependent and growth that is decoupled from local resource use.

The industry life cycle, dating back to Schumpeter (1942), asserts that markets follow a specific pattern, with early stages characterized by growth and expansion followed by a relatively stable mature phase that is eventually succeeded by decline and extinction. In an agricultural context, this translates into a move from small family-owned farms to more mechanized large-scale operations. At first, the number of industry firms expands as extensive land use practices are utilized by primarily new and inexperienced farmers and then retracts over this life cycle through agglomeration, merger and the use of more efficient production strategies. This transition in economic growth transforms the agricultural sector and often promotes urbanization.

This paper examines the implications and inferences of these opposing trajectories for development within the context of agricultural production and farm merger. Our study region, located in a former frontier region in western Amazonia, has experienced substantial deforestation since its occupation and is characterized by a cattle industry predominately managed by relatively poor small-scale farmers. While this analysis cannot confirm long-term development, we contend that verification of trends in prices, output and ‘firm’ participation that are consistent with what the industrial life cycle would predict for agriculture can provide at least one part of the evidence necessary to verify market advancement. Thus, our focus is on determining if early evidence which is consistent with growth and consolidation can be found in this region (which remains largely unmechanized) to support the decoupling of the development and environment trajectories. To accomplish this, we present the theoretical underpinnings of the industrial life cycle as adapted to agriculture and test if the three concluding propositions are supported by changes in the study region over our 13-year study period. Using panel survey and geographical information systems (GIS) data (including property boundaries) matched at the household (for four survey waves between 1996 and 2009), we investigate firm mergers along with price and production rates of change to determine if this industry is following a trajectory of decline or early development.

2. Frontier development and the industry life cycle

One measureable sign of regional development is the growth of industry. Industry can advance through increases in the number of participating firms as well as through increases in market coverage. The industry life cycle suggests that developing markets follow a pattern in which the early stages are characterized by growth and expansion in the number of firms which is followed by a relatively stable mature phase in which the rate of change in the number of firms approaches zero, and a final stage that is characterized by decline (Londregan, 1990). Thus, the mere existence of an industry life cycle provides evidence of growth. These advancements, however, must be coupled with improvements in welfare and/or investments in public and human capital to also suggest development and imply that a 'bust' is not in the foreseeable future. Klepper and Graddy (1990) find trends in prices and output that fluctuate with the life cycle to indicate such 'healthy' development. Prices are found to change at decreasing percentage rates during both the growth and stabilization phases. As a result, only the firms that attain sufficiently low costs and/or high productivity remain during and after the decline, serving as the long term 'survivors' in the industry and the means to which the consolidated market continues. It is important to note that those among the first to enter the market often emerge as the industry leaders (Mueller, 1997). Thus, path dependence or initial asset holdings can drive future outcomes and success in the industry, indicating that these initial holdings can account for some of the persistent differences in performance across firms that exist throughout the life cycle.

The progression of industrial life cycles is often triggered by location economies. Industrial clusters can generate benefits including agglomeration resulting from greater access to inputs, greater opportunity for knowledge and information sharing, and improved access to social networks (Kukalis, 2009). Thus, cluster occupancy and the resulting externalities associated with spatial proximity have been found to lead to superior firm performance (Marshall, 1920; Krugman, 1991; Harrison, 1994; Storper, 1995). It is therefore possible for industrial clusters to accelerate and increase the life cycle.

Within the context of agriculture, most advanced nations have navigated through this cycle as part of the move from rural to urban societies (Johnston and Kilby, 1975; Scott, 1999). The evolution of farm management and land use decisions follows a general pattern of succession that can be interpreted as a movement from small-scale subsistence farming to larger commercial enterprises. In most cases, the implementation of more advanced management practices, including the use of new technology and more capital intensive processes (Griffin, 1979) completes these changes, eventually leading to specialization and a management plan focused solely on the cultivation of a single crop (mono-cropping) (Matson *et al*., 1997). Mechanization subsequently promotes the movement of many individuals to either urban areas or further into the frontier. This transition in farm management is evident in nearly every sector of US agriculture and other industrialized farming systems around the world (Cutter and Renwick, 2004) and has been described as containing several stages; from the privatization of land, the establishment of property rights, and the concentration and displacement of land owners, finally to the turnover of land and migration of former owners (Li, 2002). Others have described these development patterns on the individual level as movements from natural husbandry and subsistence farming, to more organized management of the land, and finally specialization (Gras, 1946).

The early occupation of frontier land settlements is primarily focused on subsistence farming and the need for food security at the individual household level (Walker, 2003). At this stage in development, management practices tend to be minimal, as the abundance of land provides disincentives for the implementation of careful management plans (Gras, 1946). Given the many similarities, it is interesting to place what is occurring in western Brazilian settlements in the context of development of agriculture in the US. For comparison, the migration of rural households to the American West encouraged by the passing of the Homestead Act of 1862 resembles aspects of the Brazilian settlements in the 'west'. In both cases, landlessness coupled with poor regional economic conditions helped to persuade farmers to abandon their homes and seek new arable lands (Lee, 1979; Hong, 1987; Johnson, 2009). The process of land degradation and lot abandonment is characteristic of this initial stage in agricultural development and is often correlated with non-mechanized agricultural practices and the lack of well-developed economic markets.

As colonization intensifies, frontiers traditionally experience changes in several important developmental factors, including a growth in population, improvements in infrastructure and the emergence of economic markets. All of these socio-economic changes contribute to the development of a frontier settlement and are critical to the success of a region. The establishment of well-defined markets significantly changes agricultural behavior as household farm decisions begin to diverge from subsistence management practices (Walker, 2003). This transition in farm management represents a movement towards commercial production and reflects a shift in household agricultural ideology. Improvements in infrastructure also help shape household decision making as these changes facilitate access to markets and increase the efficiency with which goods and services can be exchanged. Regardless of the relational causality between these socio-economic changes, population, infrastructure and markets all experience periods of intensification and help to advance development in the frontier settlement. However, industrial and market advancements that lead to urbanization do not necessarily result in welfare improvements. Actually, the traditional assumption that rural–urban population shifts correspond to development has long been debated in the literatures on urban informality, social marginalization and social exclusion. These frameworks focus on the inequalities that can be introduced by urbanization through social spatial segregation (Kudva, 2009; Roy, 2011), labor market and social inequalities (Wu, 2004; Amoroso, 2007; du Toit, 2008), as well as the complete delinking of these populations from local and regional markets (McGregor and McConnachie, 1995; Teraji, 2011). Thus, regional growth that leads to urbanization can result in inequalities that unequally transform welfare. Improvements in social welfare can only proliferate through a population if growth is accompanied with homogeneous investments in human capital and infrastructure.

The colonization of the Brazilian state of Rondônia included the development of several Amazonian frontier towns beginning in the early 1970s along the federal highway BR-364. Several of the settlements within this state exhibit evidence of a transition from subsistence level farming to more commercially driven enterprises. As such, farmers have been systematically abandoning traditional crop cultivation and converting their properties into ranches for the primary purpose of cattle grazing (Caviglia-Harris, 2005). This transition in agricultural practices demonstrates a movement towards intensive specialization and suggests the establishment of a defined market structure and significant changes in the landscape. Much of the state was forested at the beginning of the federal settlement campaign and two decades later (by 1990) only 3 per cent of the original forest cover had been cleared. It was not until the beef and dairy industries became accessible to the small farmers in the region that deforestation rates became relatively high. By 2010, the state was over 40 per cent deforested with levels over 90 per cent for several of the municipalities located along the major interstate highway, BR-364 (INPE, 2011).

The industrial life cycle therefore provides a framework from which to gauge the development that has eluded evaluation in previous studies due to the short time frame for which the region has been settled (Schneider, 1995). Actually, early studies in this same study region suggest that the population was relatively stable over 15 years ago as little lot abandonment was noted (Jones *et al*., 1995), and that the region was relatively successful as yield increases for various agricultural crops were noted as early as 20 years ago (de Almeida and Campari, 1995). It is the continued success and growth of the region that has yet to be tested.

The industrial life cycle dynamics that are predicated by this framework are therefore consistent with growth and later consolidation, and in direct contrast to boom–bust cycles. The ecological foundation for boom–bust cycles is the unsustainable use of an exhaustible resource (i.e., poor tropical soils) that is expected (over time) to translate into significant declines in agricultural productivity and household income. The larger framework at play here is a modernization framework in which economic development corresponds to a host of changes tied to input, labor, land and product markets that are decoupled (or uncorrelated) with resource use. In this case, the mechanisms for growth and consolidation that support the industrial life cycle framework are not singular. Consolidation likely results either from the crowding out of unproductive or less efficient landowners, or speculative behavior that is motivated by productive soils, the ability to provide inputs to poor soils or the conversion of agricultural income into human, physical and other forms of capital. Independently of the mechanism at work, the life cycle framework suggests that consolidation (and the avoidance of these busts via consolidation) is the result of a developing economy rather than an inevitable decline.

3. Conceptual model

Drawing on Klepper and Graddy (1990), we provide the theoretical foundation for our empirical findings within the context of frontier agriculture. Our goal is to determine if trends that are consistent with an agricultural or industrial life cycle can be identified within the study region.

We hypothesize that phases within the life cycle mimic those of the industrial (or product) life cycle founded within the field of industrial organization. Here the behavior of profit maximizing agents is extended to utility maximizing households, thus serving to motivate the patterns of the 'agricultural' life cycle, although drawing from a different source of motivation. In this model, P_t, is price, $Q_{t.}$ is industry output, $N_{t.}$ is the number of firms in the industry, E_t is the number of entrants, X_{t-1} is the number of firms to exit (in the previous time period) and N_t is the number of incumbents in the industry; all at time t. The product is introduced in period 0, so $N_{t=0} = 0$. Therefore, the number of firms in the market at any time t is:

$$N_t = N_{t-1} + E_{t-1} - X_{t-1} \tag{1}$$

The model assumes a constant-cost competitive market in which there are a finite number of potential entrants. It is assumed that there is a lump-sum cost associated with entry that can be interpreted here as the cost of migrating to the frontier. It is assumed that, in each period, potential entrants differ in the average costs entailed if they entered the industry. The costs of entry are therefore driven by the opportunity costs of labor while the costs of remaining in the industry are driven by economic rents as represented by the productive capability of the land and/or soil quality. These market characteristics adequately fit the study region as the milk market and related agricultural markets are competitive, a majority of the households participate in these markets, there are a number of supply outlets and there is evidence of equilibrium prices (Caviglia-Harris, 2004). Land markets, on the other hand, are less competitive. Even so, this does not invalidate the assumptions of the model as the cost of land used for agriculture is essentially the cost of household labor, as the property size far exceeds the amount used in agriculture at any point in time.

In the model, the key factors driving the evolutionary process are the number of potential entrants in each period, the rates at which firms grow in each period, and the ease of imitation of rivals. While the number of potential entrants and the growth rates of incumbents in each period will be endogenously determined, there are no doubt exogenous factors that cause them and the ease of limitation differs across industries. Based on the assumptions and the conditions above, Klepper and Graddy (1990) determine three propositions that characterize the industry life cycle:

Proposition 1. *There exists a period T such that for all periods* $t < T$, $p_t > p_{t-1}$ *and* $Q_t > Q_{t-1}$, *and for all periods* $t \geq T$, $p_t = p_{t-1}$ *and* $Q_t = Q_{t-1}$.

Therefore, according to this proposition, the time period before T, or the growth phase, is characterized by increasing prices and output, and the time period after T, or the decline phase, is characterized by constant prices and output.

Proposition 2. *There exist periods* $t_1 \leq t_2 < T$ *such that: (i) if* $t < t_1$ *, then* $N_{t+1} - N_t \geq 0$; *(ii) if* $t_2 \leq t < T$, *then* $N_{t+1} - N_t \leq 0$; *and (iii) if* $t \geq T$, *then* $N_{t+1} - N_t = 0$.

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Therefore, according to this proposition, in the initial years of the evolution of the industry the number of firms will grow; later the number of firms will decline, and following this period, the number of firms will stabilize.

Proposition 3. *For all* $t < T$, $p_{t-1-}p_t/p_{t-1} > p_{t-}p_{t+1}/p_t$ *and* $Q_{t-}Q_{t-1}/Q_{t-1} > Q_{t+1-}Q_t/Q_t$.

Finally, according to this proposition, the price and output rate changes over time. This is suggested because, if the demand curve for the new good is not increasing over time, the price and output paths must be linked. Thus, if the price elasticity of the demand curve does not change systematically over time, then the changes in growth in output must account for any percentage fall in price. Therefore, both the percentage decrease in price and the growth of output must decline over time.

The analysis to follow therefore aims to first determine if there is support for these three propositions. We test for such evidence by tracking trends in prices, output and the number of participating households over the study period (1996–2009). We then estimate the determinants of farm merger to place these changes within the context of the boom–bust framework. The supposition is that, if the market growth that mimics the industrial lifecycle is combined with welfare improvements, then a 'bust' would not be expected in the foreseeable future and in place a development consolidation trend might more accurately reflect these changes over time.

4. Study site

The development policies of the Amazon (including the creation of roads and the establishment of colonies) have been controversial since the creation of the National Integration Program (PIN) in 1970, with researchers predicting the imminent collapse of both the ecosystem and livelihoods of the migratory frontier residents as they were relocated to one of the 'wettest and most aseasonal places on earth' (Goodland and Irwin, 1975). It was widely believed (and later shown; see Pfaff, 1999) that the Amazonian highway system would lead to more environmental degradation than the highways themselves as spontaneous settlements and road creation continued from this nucleus. This is in part due to the sheer number of migrants these highways facilitated; millions of people migrated into the Amazon interior post 1960 (Andersen *et al*., 2002; Browder *et al*., 2004). The individuals who migrated to these new government settlements are generally characterized as low-income sharecroppers with minimal formal education (Pedlowski *et al*., 1997; Andersen *et al*., 2002). Thus, the lack of capital combined with the relative infertility of the soil resulted in many unsuccessful settlements, characterizing the boom–bust pattern often associated with such regions (Browder, 1994).

The state of Rondônia lies in the southwestern region of the Brazilian Amazon, bordering Bolivia, and is bisected by federal highway BR-364 (figure 1). In contrast to these unsuccessful areas, Rondônia represents one of the relatively 'successful' Amazonian states, where such success can be

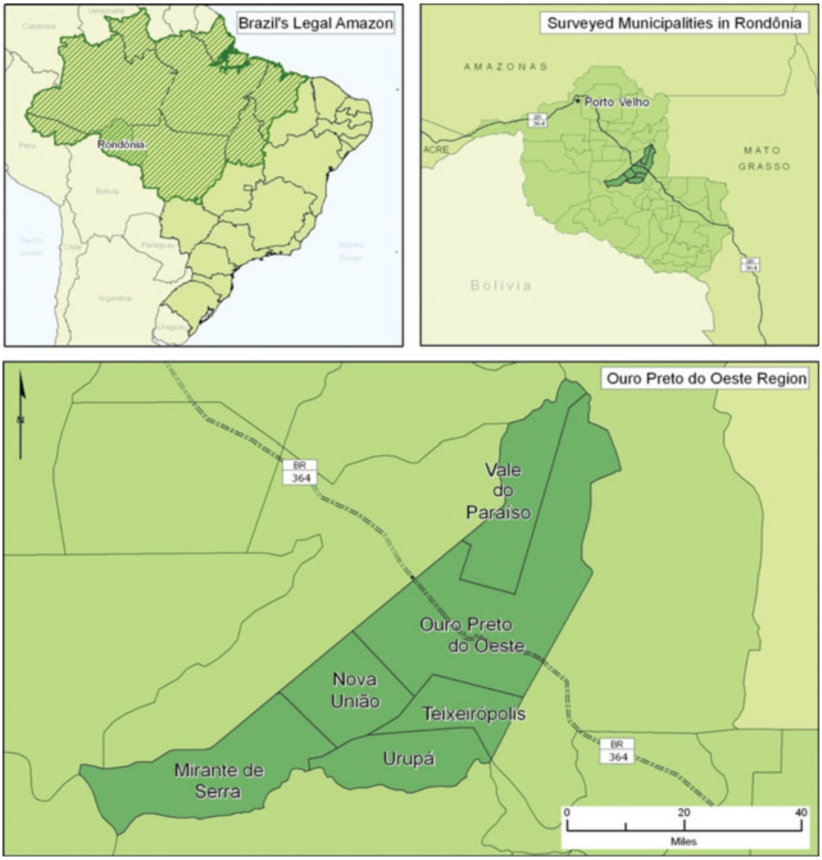

Figure 1. *Map of the survey region*

attributed to higher levels of relative soil fertility as well as greater personal wealth of the migrants (Caviglia-Harris, 2004; Sills *et al*., 2009). As a result of these advantageous conditions, the state has experienced significant changes in agricultural development including the advancement of cattle and dairy markets. Even so, with respect to welfare and income, the state is not significantly different from others within the Amazon (see table A1 in the online appendix, available at http://journals.cambridge.org/EDE). For example, according to data on literacy, income per capita, the Gini index and the cattle herd from the 1991, 2000 and 2010 censuses, Rondônia values are relatively close to the regional averages with levels that are neither the highest nor the lowest in any category.

The study area, Ouro Preto do Oeste, includes six municipalities located in the south-central portion of the state (figure 1). The population of this region has experienced significant growth since the promotion of government-sponsored settlement programs. From 1971 to 1985, the state population grew at an annual rate of 16 per cent, increasing from 111,000 to 1,122,800 (Browder *et al*., 2008). During this time, the study area experienced continued growth as well as significant levels of deforestation. By 2003, the estimated population reached 1.4 million with 23.5 per cent of the natural vegetation cleared for agriculture (Browder *et al*., 2008). The intense colonization of this region has transformed the natural environment, converting tropical forest cover into developed urban centers and pastures for grazing cattle. From 1970 to 1995 the cattle population in Rondônia increased tremendously from 23,000 to 3,937,000. Since then, the annual growth rate has continued to far exceed that of other settlement regions, at 23 per cent compared to an average of 7 per cent for the remainder of the Amazonian states (Andersen *et al*., 2002; IBGE, 2010).

While the colonization projects administered throughout the Amazonian states of Rondônia, Pará and Mato Grosso were similar in many respects, there are some marked differences in regard to federal support, the development of infrastructure, soil quality and property size. First, many of the small-scale farming settlements were focused in Rondônia and Pará, while Mato Grosso contains a greater number of large-scale cattle operations (although there is a broad distribution of property sizes in each of the states; see Aldrich *et al*., 2006 for Para, and Bell, 2011a for Rondônia). The soils are of significantly higher quality in Rondônia (Jones *et al*., 1995); even so, small-scale farming has been found to be economically viable in this and other regions (de Almeida and Campari, 1995; Walker *et al*., 2002; Walker, 2003). Along with these advances, there has been a notable trend in land consolidation throughout the Amazon. This has been occurring at the same time as household landholdings are split due to population increases and the movement of second-generation migrants to new homesteads (D'Antona *et al*., 2006). In fact, a fairly recent study actually found land aggregation to be almost completely offset by simultaneous disaggregation of comparable properties (Aldrich *et al*., 2006), while another found properties to be declining in size (Bell, 2011b). Thus, this study advances this line of inquiry first by adding a more expansive panel to the analysis of land consolidation and placing this within the context of market development and growth.

5. Data

The survey panel used in this analysis consists of data collected in four waves, including a stratified random sample of 1,330 observations divided between 171 households surveyed in 1996, 170 in 2000, 371 in 2005 and 608 in 2009. The sample of farmers was originally drawn in 1996 on a systematic random stratified basis, using colonization agency maps (i.e., Instituto Nacional de Colonizacao e Reforma Agraria) as a sampling frame for each municipality. A longitudinal sample was maintained in 2000 by revisiting each of the original lots, and expanded in 2005 and 2009 by revisiting these same lots, tracking households who had moved within the study region, and expanding the original sampling frame to ensure representation of the population and new settlements within the survey region. The sampling methodology and survey design are consistent between each of the waves (Caviglia-Harris *et al*., 2009). The survey data provide full information on farm production outputs and purchased inputs, hectares reported in different land uses (including forest, pasture, annual crops, and agroforestry and perennial crops), different measures of wealth, and a standard set of socio-economic characteristics. Data indicate that the rural population of small farm families has remained fairly stable over this study period (1996–2009), exhibiting a relatively low 5 per cent annual attrition rate. Property rights are well established and recognized by local, regional and state level government agencies with over 99 per cent of the sample holding legal tenure.

Socio-economic and price data (table 1) suggest that the age of the average household head has remained fairly constant over the survey time frame, while education has risen and family size has fallen. These changes likely occur due to developmental advances in education and health care, as younger household heads have attended a greater number of years of schooling and birth rates have fallen. Other measurements of human welfare including income and wealth have also shown signs of continuing growth. On average, income more than doubled over the survey time frame with similar increases in household ownership of durable goods. The cattle herd has increased from 71 head per household in 1996 to over 136 by 2009, while absentee ownership has exhibited an increasing trend, rising from about 5 per cent of the population in 1996 to about 24 per cent by 2009, suggesting that more households are acquiring urban properties and living in the municipality city centers. It also appears that more intensive management practices and those more consistent with a movement towards commercialization are occurring in the survey region as the cattle herd per ha of pasture has increased from 1.6 in 1996 to over 2.7 by 2009.

Other notable trends are that the pricing of agricultural goods related to cattle and pasture has steadily increased over time, while the number of rural properties owned per household has also been increasing. The total property owned per household actually peaked in 2005 and fell by 2009. Although there is no significant difference[1] between these latter two survey years, this is interesting to note because it appears that the global real estate boom impacted this region as well (with further details to follow). This also implies that, similarly to the literature presented earlier, this region is experiencing both the subdivision and merging of properties by different landowners, raising the question as to whether it is the subdivision or accumulation of land that is dominating the region.

If one divides the 2009 sample of property owners between those in the original sample (in 1996) and those added since the first survey wave (table A2 in the online appendix), there is evidence that the households in the original sample who remained on the same property throughout this 13-year time period are less likely to be absentee owners, as almost 80 per cent of these households live on the rural properties that they own as compared to almost 75 per cent of the remaining sample. And, as noted above, income (inflation adjusted) has risen steadily over the survey time period along with the ownership of durable goods. These increases are even greater for those households which remain in the sample for the entire

[1] This and all other significance values are based on t-tests.

Table 1. *Descriptive statistics for all survey years, mean and standard deviation (in parentheses)*

		1996 ($n = 171$)	*2000* ($n = 170$)	*2005* ($n = 371$)	*2009* ($n = 608$)
Household characteristics					
Age	Average age of the household heads (years)	46.36	49.11	46.59	49.31
		(12.94)	(12.47)	(14.62)	(14.72)
Education	Average education level of the household heads (years)	2.5	2.49	3.17	3.81
		(2.47)	(1.62)	(2.19)	(3.03)
Family	Number of household members living on the property	8.42	7.4	5.24	4.77
		(6.02)	(5.78)	(3.35)	(3.33)
Southern origin	=1 if the origin of the household head is the south or southeast census regions of Brazil; 0 otherwise	0.68	0.68	0.60	0.59
		(0.47)	(0.47)	(0.49)	(0.49)
Year migrate	Year the household migrated to Rondônia	1979	1980	1980	1981
		(5.87)	(6.79)	(6.33)	(7.23)
Owner type	=1 if the owner lives on and uses property for production; 0 if an absentee owner	0.05	0.28	0.41	0.62
		(0.22)	(0.59)	(0.85)	(1.04)
Wealth and welfare measurements					
Cattle	Number of cattle owned (head)	71.44	97.21	161.26	136.42
		(83.73)	(94.57)	(289.09)	(236.34)
Cattle per ha	Number of cattle owned per ha of pasture (head)	1.64	2.40	2.64	2.72
		(1.12)	(1.40)	(2.68)	(1.87)
Income	Revenues from annual and perennial crops, milk, off-farm labor and livestock (2000; US\$1 = *R*\$1)	7,021	14,702	12,917	15,616
		(8,579)	(15,537)	(22,131)	(20,531)
Durables[a]	Count of all durable assets	3.22	4.68	5.17	5.95
		(2.79)	(3.7)	(3.55)	(3.53)

(*continued*).

Table 1. *Continued*

		1996 ($n = 171$)	2000 ($n = 170$)	2005 ($n = 371$)	2009 ($n = 608$)
Annual milk	Number of liters of milk produced in a year	19,048 (19,732)	34,873 (31,367)	28,571 (27,095)	33,141 (31,158)
Market prices (inflation adjusted)					
Price of milk	Price for gate pick up, in inflation adjusted Reais/liter (2000; US$1 = R$1)	0.19 (0.02)	0.23 (0.04)	0.26 (0.03)	0.27 (0.04)
Price of beef[b]	Price per head cattle, in inflation adjusted Reais (2000; US$1 = R$1)	248.00 (0)	275.43 (72.21)	286.60 (95.15)	370.66 (137.79)
Price of calves	Price per head calf, in inflation adjusted Reais (2000; US$1 = R$1)	124.00 (0)	142.33 (42.54)	137.76 (32.30)	182.63 (71.10)
Property ownership and merger					
Properties	Number of rural properties owned	1.1 (0.63)	1.29 (0.57)	1.34 (0.95)	1.38 (0.79)
Property size	Total rural property owned (ha)	83.15 (70.66)	84.81 (69.61)	102.74 (227.23)	97.38 (174.72)

Notes: [a]Durable goods include appliances, bicycles, phones, vehicles and satellite dishes.
[b]Average collected at beef markets.

survey time frame. These households also have greater cattle herds and produce significantly more milk on an annual basis. Finally, as mentioned earlier, property ownership has increased over time. The amount of property owned by these original households is also significantly greater; however, the number of properties is not significantly different between these groups, suggesting that newer migrants are accumulating properties at similar rates, but that many of these are smaller, on average. Thus, the aggregate impacts of these opposing pulls on landownership that are driven by original landowners (or early entrants) and the impacts by new migrants (to smaller properties) are the focus of the empirical analysis.

6. The industrial life cycle on the frontier: output, price and farm participation rates

We begin examining evidence for the industrial life cycle with a description of land ownership changes that occur over the survey time frame. As seen in table A3 of the online appendix, the average size of rural properties has declined from 71 ha in 1996 to about 61 ha by 2009. This reduction is expected as the original lots distributed to migrants were far greater, at 100 ha, than those in the more recently settled regions of our study area which range from 10–50 ha and because subdivisions are occurring as second-generation migrants split properties for homesteads. However, since the number of rural properties owned has increased from about one to approximately 1.4 over this same time period, the total rural property owned by households increased by approximately 17 per cent. The total value and value per ha of the property owned also increased over this time period (exhibiting a peak in 2005). Urban property ownership followed similar patterns, with increases in the amount and value of properties and a peak in value in 2005. These peaks in value, or dips afterwards, correlate closely to the global land boom that occurred at the same time.

These data suggest that there has been significant change in the region over the sample time frame both in terms of the socio-economic indicators and market conditions. Income, wealth and education all exhibit positive trends, with no indication of decline. At the same time, the prices of major agricultural goods (including beef, calves and milk) have increased throughout each survey year. Participation in these markets differs, with 73 per cent of households selling milk in any given year and only 37 per cent and 24 per cent for the beef and calf markets, respectively. It is this highly participatory market that exhibits the greatest signs of commercialization for these small-scale operations, as the number of famers selling refrigerated milk to processing plants increased from none in 1996 to about 40 per cent (of all milk producers) by 2009. Prior to the use of refrigerated tanks, the farm gate pick-up of milk by processing plants was for warm milk and used for manufacturing cheese products. Given its greater versatility, the price for cold milk is found to be approximately 9 per cent higher than that of warm milk.

Returning to the three propositions set forth in the industrial life cycle, according to the first proposition the cycle is divided into two phases: the growth phase is characterized by increasing prices and output, while the decline phase is characterized by constant prices and output. The data provided in table 1 suggest a growth phase, as all prices related to the cattle industry have increased over the survey time frame. Output can be represented by trends in cattle herds (for the calf and cattle trade) and milk production. While cattle herds have increased over the time period of study, the trends in milk production have largely been driven by a severe drought, experienced throughout the Amazon in 2005 (Aragão *et al*., 2008).

The second proposition defines three phases in relation to firm participation. According to this proposition, in the first phase the number of firms within an industry will grow; in the second phase the number of firms will decline; and in the final phase the number of firms will stabilize. The number of property owners is extrapolated for the entire survey region to interpret this proposition for participation in cattle markets. Admittedly, these are not 'firms' in the traditional sense, as they are utility-maximizing households. However, calculating the number of these participating households provides one way to gauge market participation. In this case a GIS is used to calculate the total number of lots in the survey region in each year. These totals are combined with census data on the rural population and survey data on the number of properties owned per household to estimate the total number of property owners per year for each municipality in the survey region (table A4 in the online appendix). Similar to what the industrial life cycle would predict, the number of households involved in rural production has increased over time as migrants have been attracted to the region (in part due to increasing milk, beef and calf prices) and additional properties have been settled. However, at the same time as the number of properties owned have increased, the merging or accumulation of additional properties has tended to dominate in later years, resulting

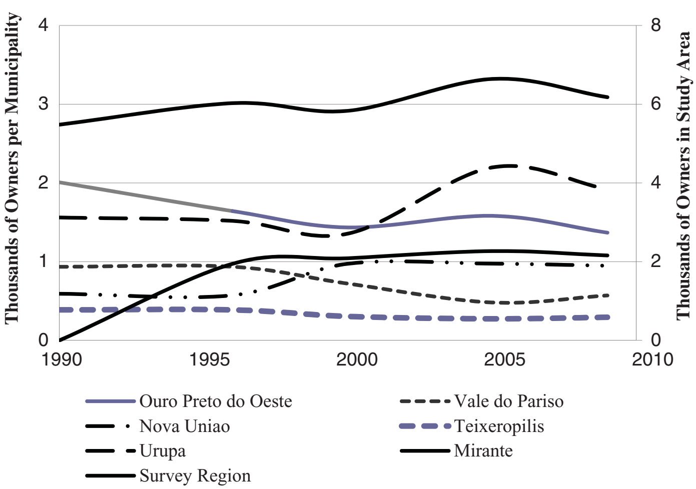

Figure 2. *Number of property owners in survey region by year (1990–2009)**
**Survey data extrapolated to the entire survey region.*

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in an increase and then decline in the number of land-owning households (figure 2).

Finally, the third proposition asserts that price and output rate changes should decline over time. This is certainly the case with milk production (if one ignores the 2005 drought), as production nearly doubled between the first survey waves and was then followed by (significantly) no growth by the last survey wave in 2009. This is also the case for milk prices. In comparison to the beef and cattle trade, this market also shows the greatest signs of pricing stability as the rate of price changes increased more rapidly in the initial survey periods and approaches zero by 2009 (figure A1 in the online appendix).

Thus, anecdotal evidence suggests trends in output, market participation and prices that are consistent with market growth and commercialization. We have already noted that technological advances are being adopted for milk production, that prices in the related markets are increasing, and that rural land holdings are increasing for households, especially those with first-mover advantage (or those who moved to the region in the more distant past). Although it is premature to suggest that support could be found for the 'industrial life cycle', there is significant evidence that the region is developing and markets are not in decline. Such advances lend themselves to both a boom–bust *or* continued growth. The following analysis is therefore devoted to determining if a bust is expected to follow this noted growth or if continued growth can be expected. We therefore continue by estimating the determinants of farm mergers and land accumulation to draw conclusions about welfare relating to the boom–bust cycle that is predicted for settlements in the Amazon.

7. Empirical models and results

The amount of land owned by each household is estimated with fixed, random and mixed effects models using data collected in four survey waves. These estimations include variables that are recognized as important in identifying the industrial life cycle such as household characteristics (to indicate initial and current capital holdings), wealth and market prices; however, these are determined by a dynamic version of the household production model, which represents households as unified production and consumption units, maximizing utility subject to input and endowment constraints (Singh *et al*., 1986; Sadoulet and de Janvry, 1995; Sadoulet *et al*., 1998; Shively, 2001). In this context, deforested land is used as an input to production. We estimate the area of land owned in a given year (L_{it}) according to the equation below:

$$L_{it} = \beta x_{it} + \gamma Z_i + \mu_i + \varepsilon_{it} \quad (2)$$

where L_{it} is the dependent variable, varying over the individual and time, x_{it} is a $1 \times k$ vector of variables that also vary over individual and time, β is the vector of coefficients on x, z_i is a $1 \times p$ vector of time-invariant variables (where p is the exogenous grouping of these indicators) that vary by individuals, is the $p \times 1$ vector of coefficients on z, μ_i is the individual-level effect and ε_{it} is the disturbance term. The variables included in the estimations to follow are therefore those found in the household's derived demand for the quasi-fixed input of cleared land (L), which is a function of all exogenous factors including household characteristics (Singh *et al.*, 1986). x_{it} therefore includes age and education of the household heads, family size (to indicate household labor), and year and location of origin (to account for initial capital holdings). Income, cattle and the number of durable goods owned are used to measure the impacts of welfare on land accumulation and prices are included to determine impact on input demand. Finally, z_i includes the ownership type (i.e., whether the owner is a resident or not).

There are several panel methods that can be used to estimate (1), including (but not limited to) fixed, random and mixed effects, the choice of which depends on the correlation assumption for μ_i and any clustering of the data. The random effects (RE) model assumes that μ_i is uncorrelated with x_{it}, z_i and ε_{it} (and the individual-level effects are parameterized as additional random disturbances), the fixed effects (FE) model assumes that μ_i is correlated with x_{it} and $z_{i,}$, and the mixed model (including both FE and RE) assumes correlation for z_i only (Baum, 2006). An FE estimation implies that each individual serves as his or her own control. Comparisons are made within individuals and any between-observation variation is ignored. Nonetheless, discarding the between-observation variation can yield standard errors that are considerably higher than those produced by methods that utilize both within- and between-observation variations. Instead of considering the individual-specific intercept as in the FE model, the RE model specifies the individual effect as a random draw that is uncorrelated with the regressors and the overall disturbance term. Rewritten, this equation is:

$$L_{it} = \beta_k x_{it} + \gamma Z_i + (\mu_i + \varepsilon_{it}) \tag{3}$$

where $(\mu_i + \varepsilon_i)$ is the composite error term and the μ_i are the individual effects (Baum, 2006). The mixed model combines the virtues of the FE and RE models, allowing for the estimation of FE for the time-varying parameters and RE for the time-invariant predictors (Allison, 2010). Thus, in cases where the FE assumption is supported (i.e., with a Hausman test) the mixed model allows the estimation of time-invariant policy variables that differ by observation but not over time (i.e., ownership type). To date, these models are more commonly applied in the physical, biological and other social sciences outside of economics. However, the model is particularly useful for representing clustered data such as that representing cohorts or other homogenous subgroups (Fox, 2002). This is because mixed-effects models recognize correlations within sample subgroups, thus providing an alternative to ignoring data groups entirely and fitting each group with a separate model (Raudenbush and Bryk, 2001). The benefits of the mixed model over other models that include components of both fixed and random models (such as the Hausman–Taylor method) is that instrumental variables are not required to estimate . In this case, the FE are the coefficients from a standard linear regression ($\hat{\gamma}$) and the RE are summarized by their variance components (Gutierrez, 2008). Rewriting (2) in this format, we have

$$L_{it} = \beta_k x_{it} + \hat{\gamma} Z_i + (\mu_i + \varepsilon_{it}) \tag{4}$$

Therefore, instead of the values being differenced out as they would be in an FE model, the estimates from a linear regression ($\hat{\gamma}$) are represented in this estimation, allowing one to calculate the impact of time-invariant parameters.

L_{it} is measured in two ways: (1) the amount of rural property owned (in ha) and (2) the number of properties owned with fixed, random and mixed effects methods (tables 2 and 3). A Hausman test is used to test the fit of the FE and RE models, while a test of clustering effects is used to test the validity of the mixed model. The mixed model includes owner type (dummy indicating if an owner lives on the property or is an 'absentee' owner that manages the land for cattle only) as the grouping variable. The sum of all rural property owned is discussed first, while the number of properties owned follows. Given that property ownership and buying and selling of land is an investment that typically involves a long transaction time, all time relevant variables (including household demographics and income) are lagged in each of these estimations, reducing the sample to 422 observations. These estimations are first made with an unbalanced panel (table 2) with a robustness check that includes the same estimation with only the balanced panel (table 3).

The FE model (table 2, Model 1) suggests that the amount of rural property owned is impacted most significantly by the price of milk. The limitations of this estimation are obvious, as one of the variables of interest, ownership type, is time-invariant and therefore differenced out of the equation.[2] We therefore turn to the RE results (Model 2) which provide greater explanatory power (i.e., a higher R-squared) as well as various different significant determinants including milk prices, wealth and income. Even so, a Hausman test of the difference between the more efficient RE coefficients and the less efficient but consistent FE coefficients suggests the FE model is the preferred choice. We therefore turn to the mixed effects model (Model 3) to draw conclusions on the impact of absentee ownership. This model suggests that the price of milk is a marginally significant determinant while prior wealth in the form of cattle ownership and durable goods are significant determinants of property owned. In addition, ownership type is found to be a significant group determinant. Results suggest that there is a significant difference in the slope as related to owner type (i.e., the group residuals are significant). The between-property owner variance (group constant variance) is estimated at 1,038, and the within-type between-household (group residuals variance) is significantly

[2] Southern ownership is not differenced out in cases where the household heads (as defined by the households themselves) change over time due to the death or retirement of the original household head. In this case we do not consider the household to be different; however, the new owner (or head of the household) in these cases is younger and more likely to be born in the Amazon region (and not in the origin state of the parents).

Table 2. *Estimations of farm mergers with unbalanced panel*

	Property size (ha) (n = 422)			*Number of properties owned (n = 422)*			
	Model 1 (Fixed)	*Model 2 (Random)*	*Model 3 (Mixed)*	*Model 4 (Fixed)*	*Model 5 (Random)*	*Model 6 (Mixed)*	*Model 7 (Tobit/Random)*
Constant	2409.422	−89.0519	−1.576	−9.2291	0.484	0.9223	0.4886
	(2761.39)	(95.8)	(97.44)	(15.3833)	(0.5995)	(0.5867)	(0.5896)
Age[a]	−0.2339	0.4245	0.44	−0.0048	−0.001	−0.0014	−0.001
	(0.79)	(0.49)	(0.49)	(0.0044)	(0.003)	(0.003)	(0.0029)
Education	1.0142	0.5486	0.7899	−0.0086	0.0006	0.0071	0.0009
	(4.43)	(3.05)	(3.11)	(0.0244)	(0.0185)	(0.019)	(0.0183)
Family	0.7871	0.583	0.296	−0.0019	−0.0036	−0.0079	−0.0037
	(1.4)	(1.1)	(1.13)	(0.0076)	(0.0065)	(0.0069)	(0.0065)
Southern origin	6.4255	17.0404	16.6779	0.0328	0.1382*	0.1575**	0.1391*
	(32.68)	(12.64)	(11.96)	(0.1825)	(0.0805)	(0.0732)	(0.0791)
Year migrate	−1.262	0.0221	0.0196	0.0052	0.0002	0.0001	0.0002
	(1.4)	(0.04)	(0.04)	(0.0078)	(0.0003)	(0.0002)	(0.0002)
Price of milk	619.2932***	−37.0557	−124.9255	4.2741***	1.974***	1.3784	1.9414***
	(220.85)	(137.19)	(143.58)	(1.2321)	(0.8317)	(0.8792)	(0.8328)
Price of beef	0.1204	0.1047	0.1341	−0.0016	−0.0009	−0.0008	−0.0009
	(0.2)	(0.13)	(0.13)	(0.0011)	(0.0008)	(0.0008)	(0.0008)
Income (thousand Reais)	0.1	1.1	1.2	0***	0***	0***	0***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)

Cattle (hundreds)	−0.91	11.7***	15.46***	−0.06***	0.04***	0.09***	0.04*
	(4)	(3)	(3)	(−0.02)	(0.08)	(0.14)	(0.08)
Durables	−1.0053	0.0193	−0.1189***	−0.0171	−0.0071	−0.0077	−0.0071
	(2.7)	(1.78)	(1.8)	(0.015)	(0.0109)	(0.011)	(0.0107)
Owner type		50.4426***			0.2213*		0.2211*
		(20.46)			(0.1305)		(0.1278)
Group constant (variance)			1037.553			0.0139	
			(1743.639)			(0.0299)	
Group residuals (variance)			12324.78***			0.4641***	
			(862.907)			(0.0324)	
R-squared Wald χ^2	0.00	0.15	3.44**	0.00	0.11	0.86	35.34***
Hausman	37.10***			101.18***			

Notes: Coefficients presented in the table; SE in parentheses.
*,**,*** represent significance at the 10%, 5% and 1% levels, respectively.
[a] All variables are lagged with the exception of southern origin, year of migration and ownership type.

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Table 3. *Estimations of farm mergers with balanced panel*

	Property size (ha) (n = 253)			*Number of properties owned (n = 253)*			
	Model 1 (Fixed)	*Model 2 (Random)*	*Model 3 (Mixed)*	*Model 4 (Fixed)*	*Model 5 (Random)*	*Model 6 (Mixed)*	*Model 7 (Tobit/Random)*
Constant	−0.4699	−0.2026	0.2689	−7.2472	−7.2589	−3.8274	−7.4512
	(0.58)	(0.54)	(0.66)	(15.7171)	(14.5283)	(15.9377)	(13.7564)
Age	3.6157	4.5262	5.7674	−0.001	−0.0018	−0.0027	−0.0016
	(3.22)	(3.05)	(3.91)	(0.0052)	(0.0047)	(0.0049)	(0.0044)
Education	1.9163	1.8911	1.217	0.0357	0.0323	0.031	0.033
	(0.98)	(0.93)	(1.22)	(0.028)	(0.0262)	(0.029)	(0.0247)
Family	0.1242**	−0.9631**	2.7643	0.0066	0.0015	−0.005	0.0027
	(20.04)	(15.79)	(15.12)	(0.0083)	(0.008)	(0.009)	(0.0076)
Southern origin	0.2883	0.2785	0.0651	0.0235	0.0713	0.1222	0.0625
	(0.9)	(0.85)	(1.08)	(0.1773)	(0.1251)	(0.1128)	(0.1239)
Year migrate	240.7494	120.3038	−213.1926	0.0042	0.0044	0.0027	0.0044
	(152.45)	(150.38)	(222.41)	(0.0079)	(0.0074)	(0.0081)	(0.007)
Price of milk	0.2953	0.3486	0.5324	3.2432**	1.8551	0.1052	2.1428
	(0.14)	(0.14)	(0.19)	(1.3471)	(1.347)	(1.6592)	(1.2731)
Price of beef	0.988**	1.2***	0.0017***	−0.0017	−0.0015	−0.0012	−0.0016
	(0)	(0)	(0)	(0.0012)	(0.0012)	(0.0014)	(0.0011)
Income (thousand Reais)	1.628*	3.87***	0.1022***	0.00***	0.00***	0.00***	0.00***
	(0.02)	(0.02)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)

Cattle	−1.0359	−1.1972*	−1.6226***	−0.05***	−0.02	0.04	−0.02
(hundreds)	(1.77)	(1.68)	(2.2)	(0.02)	(0.02)	(0.02)	(0.02)
Durables				−0.0204	−0.02	−0.0169	−0.0202
				(0.0155)	(0.0146)	(0.0164)	(0.0137)
Owner type		75.0001			−0.1702		−0.1348
		(78.68)			(0.5366)		(0.5645)
Group constant (variance)			0.00			0.00	
			(0.00)			(0.00)	
Group residuals (variance)			7708.016***			0.4293***	
			(817.0481)			(0.0324)	
R-squared Wald χ^2	0.14	0.19	0.00	0.04	0.11	29.84***	24.55***
Hausman	34.24***			111.92***			

Notes: Coefficients presented in the table; SE in parentheses.
*,**,*** represent significance at the 10%, 5% and 1% levels, respectively.
All variables are lagged with the exception of southern origin, year of migration, and ownership type.

higher at 12,325. The variance participant coefficient (VPC) is therefore $1,038/12,325 = 0.08$, which suggests that 8 per cent of the variance in property holdings can be attributed to differences between owner types, with absentee owners holding higher levels.

The estimation results for the number of rural properties owned are provided in table 2 as Models 4–7. The FE model (Model 4) suggests that amount of rural property owned is impacted most significantly by the price of milk, the cattle herd owned in the prior time period as well as prior income (although the coefficient is relatively low). In addition, those households which originate from the wealthier southern region of the country are also found to have acquired a greater number of properties. Again, the limits of this estimation include ownership type being differenced out of the equation. We therefore turn to the RE results (Model 5), which provide greater explanatory power (i.e., a higher R-squared) and similar significant determinants in addition to owner type. Again, a Hausman test suggests the FE model is the preferred choice. The impacts of owner type are further supported by the mixed model (Model 6). This model confirms the findings of the FE model, as the significance and sign of the independent variables remain the same and again ownership type is found to be a significant group determinant. Again, results suggest that there is a significant difference in the slope as related to owner type (i.e., the group constant and residuals are significant). The between-property owner variance (group constant variance) is estimated at 0.01, and the within-type between-household (group residuals variance) is significantly higher at 0.46. The VPC is therefore 0.02, which indicates that 2 per cent of the variance in the number of property holdings can be attributed to difference between owner types. Finally, since the number of properties owned may be censored due to the large number of households with one to two properties, a Tobit panel model is estimated (Model 7). The results indicate that no observations are censored, although the sign and significance of the variables are consistent with the other panel models.

Finally, the same estimations are made with the balanced sample (table 3). These households are a sub-sample of the unbalanced panel included in table 2. Thus, this selected group likely represents a 'biased' sample where any source of bias would be related to how and why these households were available in each of the four years. Since we did return to households that were not home at the time of the initial interview multiple times, the exclusion from the sample in any given year only occurred due to extended absence from the property. Even so, the results are similar for these estimations as compared to the unbalanced panel. Again, the Hausman model rejects the RE model for each of the dependent variables, the mixed model supports a significant effect for owner type, and the sign and significance of many of the independent variables is similar. The price of beef is, however, significant in these models instead of the price of milk, and the number of family members is positively linked to the total property holdings according to the FE and RE models. However, results are also similar for the impact of previous wealth and income on future property holdings. One can therefore conclude that the findings that are most relevant to the lack of support for a 'bust' are similar for these estimations.

In sum, results suggest that the main drivers of property mergers and/or the accumulation of rural properties are the prior ownership of cattle, previous levels of wealth, and income earned in the previous period. These findings are largely consistent with developing markets that are not likely to 'bust' in the near future, since here growth is highly correlated with successful land use practices. The past period's milk prices are also found to be a significant (and positive) determinant, suggesting that this market is largely driving property decisions and the degree of market participation. Finally, absentee owners are accumulating significantly more land, both in absolute terms and in the number of properties, although a significant amount of variation can be noted within the ownership category. This suggests movements towards mechanization as greater amounts of properties are used for production alone (rather than homesteads) over time.

8. Conclusions

The occupation of the last remaining tropical forests has been an initiative of many developing nations that is debated by the global community due to the expected irreversible nature of both agricultural land use and colonization (Fearnside, 2002; Schwartzman *et al*., 2009; Gibbs *et al*., 2010). Arguments against development range from the loss of biodiversity and ecosystems services to the synergistic losses associated with environmental degradation and continued poverty. This article is focused on the latter through an investigation of development within an Amazonian state that was settled over 30 years ago. The survey region (representative of many in the state) is by no means advanced, as many health and education services are limited, roads remain impassible in the rainy season, and income and human development remain lower than the national average. However, there appears to be evidence of progress that we contend can be in part measured by the existence of advancing markets. Thus, we test for evidence of growth and expansion, a leveling out or mature phase, and a final decline stage within the markets related to cattle (i.e., milk, beef and calves), using the framework provided by the industry life cycle.

According to the propositions discussed, these stages are represented by various changes in price, output and the number of firms, including: (1) a growth phase that is characterized by increasing prices and output and a decline phase that is characterized by constant prices and output; (2) early growth, decline and stabilization in the number of new firms and in the market; and (3) the percentage fall in price and growth over time. With household survey data spanning over a decade that is matched with GIS data, we are able to investigate price changes, land accumulation and the number of property owners and find evidence of advancing markets and a move from subsistence farming to a more commercially based structure. Milk, beef and calf (inflation adjusted) prices are all found to increase over the survey period and to increase at rates that suggest a stabilizing milk market and beef and calf markets that continue to advance.

We also find the determinants of farm mergers and land accumulation to be time-lagged wealth and income (along with market prices), suggesting that these farms are not being abandoned due to failure but rather accumulated due to success. Additionally, we find owners who have taken up residence in urban centers to be accumulating significantly more land, suggesting there is a transition in the use of rural properties for production rather than as homesteads. Finally, the number of owners of rural properties is found to increase and later decline over time, suggesting a movement towards a more mature phase in this agricultural life cycle.

In sum, there appears to be ample evidence of what we call the agricultural life cycle – or a trajectory of growth and consolidation. This suggests that the region is on a development path, with the households remaining likely to benefit from such progress. This result is in contrast to the boom–bust cycles that may be linked to past trends, while providing the context to explain the 'contemporary' Amazon that may be more likely to experience booms followed by consolidation. The economic growth of Brazil and the social welfare programs that have reached all states and regions within the nation are potential sources of this shift. Brazil is currently ranked the eighth largest economy in the world with average growth rates that have been impressive over the last 10 years (CIA, 2012). Previously one of the world's leaders in income inequality, the nation has now fallen to 13th in the world (Lustig *et al*., 2011), with much of these gains attributed to social welfare programs that many households in our study region (as well as throughout Amazonia) benefit from (Rocha, 2009).

Admittedly, these results are too premature to support the development of a true industrial life cycle; however, they do support the growing number of studies that have found agriculture and small-scale ranching to be ecologically and economically stable (de Almeida and Campari, 1995; Walker *et al*., 2002; Aldrich *et al*., 2006; Cochrane and Cochrane, 2006; Pacheco, 2009). Equally, there remain exogenous factors that may affect future prospects for landholders, notably: (1) the growing global demand for regional products; (2) the rising probability of future droughts; and (3) climate change impacts on regional ecosystems. The first will tend to sustain growth and intensification over time, thus ensuring against busts in the foreseeable future; however, the last two have the potential to undermine productive capability, thus impacting the demand for farmland. Evidence of lower primary productivity in the Amazon during the 2005 drought is noted in this study (with regard to milk production) and for the Amazon region for this and other severe drought years (Betts *et al*., 2008; Phillips *et al*., 2009; Lewis *et al*., 2011). Furthermore, through reciprocal impacts of climate change, forest clearing is expected to contribute to the destabilization of ecological processes, a decline in rainfall, increased fire risk, canopy mortality and possible 'worst-case' consequences including widespread 'savannization' and forest dieback (Shukla *et al*., 1990; IPCC, 2007; Betts *et al*., 2008; Malhi *et al*., 2008; Nepstad *et al*., 2008), which of course have the potential to change the game with regard to growth, investment and productivity. Thus, outside of these future unknowns, the predictions of a lose–lose scenario that is associated with occupation and the boom–bust pattern of development, at least to date, is not a reality. However, similarly to the parallels made relative to the industrialization of the US, this has not come without a cost, as the region is over 90 per cent deforested.

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