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Ranching and the new global range: Amazônia in the 21st century

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ABSTRACT

This paper seeks to understand how the Brazilian Amazon, which many thought unsuitable for agricultural development, has yielded to a dynamic cattle economy in only a few decades. It does so by embedding the Thunian model of location rents within the regime of capital accumulation that has driven the Brazilian economy since the mid-20th century. The paper addresses policies that have created location rents in Amazônia, the effect of these rents on land managers, and the spatial implications of their behavior on forests. Thus, the paper connects macro-processes and structures to agents on the ground, in providing a political ecological explanation relevant to land change science. The policy discussion focuses on reductions in transportation costs, improvements in animal health, and monetary and trade reforms. To illustrate the impact of policy, the paper presents data on the geography of Amazonian herd expansion, on the growth of Amazonian exports, and on the profitability of the region's cattle economy. It follows the empirical presentation with more abstract consideration of the spatial relations between cattle ranching and soy farming, and implications for deforestation. The paper concludes on a speculative note by considering the likelihood of forest transition in the region, given the transformation of Amazônia into a global resource frontier.

"How did this metamorphosis happen?" Eminem.
"...while the miser is merely a capitalist gone mad, the capitalist is a rational miser."
From *Capital: A Critique of Political Economy*, Vol 1. K. Marx.

1. Introduction

Loss of the Amazon forest is one of the most critical environmental problems of the present era and needs little introduction. Since roads began crisscrossing the region in the 1960s with the construction of the Belém-Brasília highway, regional populations have grown nearly 10-fold, from three to almost 23 million in the Brazilian portion of the basin, and huge tracts of forest have disappeared (Walker et al., 2007; Santos, 1980). Recent estimates in 2004 place the fraction of forest lost at 16.3% of the 4 million km^2 of closed moist forest that originally covered the Brazilian Amazon (Alves, 2007). This has involved large yearly conversions, which averaged 17,500 km^2 between 1989 and 2006 (http://www.obt.inpe.br/prodes).

Amazonian development is a controversial issue that arose when the first colonists and corporate ranchers took advantage of new infrastructure and government largesse, and started moving to the region in the early 1970s. Despite hopes that an agricultural economy based on agroforestry and extractive activities would take hold on the nutrient poor soils, ranching quickly emerged as the premier land use. As a consequence, Amazonian pastures today support a herd of over 70 million animals, about one third of Brazil's commercial stock; they also account for at least 80% of all deforested lands in the region.[1] Even with growing concerns about the penetration of Amazônia by soy, associated deforestation is small compared to ongoing pasture conversion, and mainly restricted to the shrub-lands and open forests of Mato Grosso and Rondônia (Brown et al., 2004, 2005; Morton et al., 2006). For the foreseeable future, pasture expansion will persist as the primary, proximate cause of Amazonian deforestation.

The present paper considers Amazonian ranching and particularly that in Brazil, which has suffered the most significant human

[1] Seventy seven percent of cleared lands were pasture in the 1995 agricultural census, and 9.9%, "abandoned". These abandoned lands were probably once pastures, in which case nearly 90% of Amazonian deforestation is probably accounted for by ranching.

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encroachments of all countries sharing parts of the Amazon River basin.[2] Our primary objective resides in understanding how a wet, forested region, which many thought unsuitable for ranching or much of any kind of agriculture, finally yielded to a cattle economy larger than that of Argentina in only a few decades. Never before has so much old-growth and primary forest been converted to human land uses so quickly, a metamorphosis that possesses significant implications for the global environment, not to mention the livelihoods of the Amazonian residents themselves.

The paper pursues its objective as follows. First, it embeds a Thunian model of location rents within the long-run regime of capital accumulation that has driven the Brazilian economy, as well as the policy process, since mid-20th century, and continues to this very day. The framework calls attention to both high-level governmental decision-making and to decentralized land managers. Consequently, the paper next addresses (1) select policies that have affected the region as a whole, and (2) the micro-economics of ranching in Amazônia's new cattle economy. Of particular interest to the policy discussion are reductions in transportation costs achieved through infrastructure investment, improvements in animal health, and monetary and trade reforms that have improved the market position of both Brazilian and Amazonian beef. These various policy interventions have had a profound impact on the productivity and profitability of ranching in the region. Following the discussions on policy and the new micro-economics of ranching, data are presented to document herd growth, and the recent explosion of exports that now sends Amazonian beef to the far corners of the world. The paper then places today's ranch economy within the Thunian framework elaborated at the outset. Of particular interest here is the relationship between soy and ranching, given the explosion of soy farming on the margins of Amazônia, and recent advances into the forest itself. Also considered are prospects for the future, including the likelihood of a forest transition in the region given expanding demand for Amazonian products. The paper concludes by calling attention to the destruction of the Amazon forest, a process that shows little sign of abating given global market integration and the world's insatiable demand for beef.

2. The political ecology of von Thünen

2.1. Structure and incentives

The present paper seeks to understand land cover change in the Amazon basin, particularly as it articulates with the advance of ranching. Discussions about Amazonian deforestation have mainly considered political economy, accessibility and demographic attributes of the spatial economy, and household characteristics. The political economy approach calls attention to the role of policy in assisting capital extract surplus from the Amazon basin either through subsidy capture or resource liquidation (e.g., Sawyer, 1984). Spatial economy explanations point to market access and the impact of growing population on the region's forests. These studies, typically econometric in methodology, link measures of deforestation to the penetration of roads, the growth rates of resident populations, and other variables thought to affect land use (e.g., Pfaff, 1999). Similarly, household studies often adopt econometric approaches to statistically describe patterns and rates of deforestation, but they do so at micro-scale (Caldas et al., 2007).

In this paper, we provide a synthetic explanation that links political economy to incentives and constraints faced by land managers responsible for the region's land cover change (cf. Blaikie and Brookfield, 1987). We seek to close the structure-agency binary (cf. Chowdhury and Turner, 2006) by appeal to the concept of locational bid-rents, which explain an individual's land use behavior as a function, in part, of social structure, specifically the component responsible for social overhead capital investments, in transportation for example (Walker and Solecki, 2004). This is tantamount to situating the proximate causes of land cover and land use change (LCLUC) – namely the incentives and constraints confronting land managers – within a social structure, interpretable as the underlying cause of LCLUC (Geist and Lambin, 2002). Our interest in Amazonian LCLUC is a compelling research interest of so-called land change science, an eclectic, multidisciplinary effort now underway to identify and explain the human drivers of changes on the earth's land surface, a phenomenon that contributes to myriad processes of environmental change more generally (Gutman et al., 2004; Turner et al., 2007). Thus, we seek to contribute an approach to land change science that allows for the integration of structural and behavioral explanation.

Our specific task involves a reconfiguration of the theory of von Thünen along two dimensions. The first is to embed it within the empirical context of social forces active over large-scale spatial domains, of much greater extent than that of individual cities. The second is to extract the land cover implications of the Thunian concept of rent. So reconfigured, the von Thünen model provides a political ecology of Amazonian deforestation by translating political economy into the specific ecological impact of interest, namely loss of tropical forest (cf. Walker, 2001; Walker and Solecki, 2004). It does so by describing (1) the policy processes that created location rents in the region and (2) the ground-level incentives faced by land managers stemming from the emergent rent structure. We refer to the land use outcome that arises by virtue of these hierarchical processes as Thunian structuration.

It is important to consider the manner in which von Thünen has been applied in both theoretical and empirical research. The tradition of regional science, of course, has developed spatial models of land use and urban structure based on the mathematical formalization of locational bid-rents, the seminal Thunian contribution (e.g., Fujita, 1989). More recently, the land change science community has addressed the importance of accessibility and transportation systems in driving land cover and land use change (e.g., Chomitz and Gray, 1996; Kaimowitz and Angelsen, 1998; Nelson and Hellerstein, 1997). Such research calls both explicit and implicit attention to von Thünen, and the role of rents in determining land use. A third application involves the deployment of Thunian rents to explain region- and even global-scale land uses in the context of political economy and historical change (Schlebecker, 1960; Peet, 1969; Katzman, 1977; Cronon, 1991; Walker, 2001; Walker and Solecki, 2004). The present analysis draws inspiration from the land change science and political economy traditions of Thunian application. It focuses on the role of accessibility in driving land cover change, but also considers the social and political forces that impact the degree of accessibility itself via government intervention. In addition, it addresses other phenomena, such as rising commodity prices, which extend the spatial distribution of rents.

Central to our approach is the concept of *frontier*, which we take as both spatial artifact created by social forces and as a field of constraints, and incentives, impacting the decisions of land managers. As an intellectual device, the frontier is open to considerable interpretation (Simmons et al., 2007; Browder et al., 2008), although, in general, frontiers are taken to possess both geographic and temporal dimensions. Thus, the frontier is a place, but a place that moves elsewhere, as one set of social relations gives way to another. Such spatiotemporal conceptualization had wide currency in early structuralist descriptions of the movement of capitalist production relations into Amazônia following the military government's development initiatives beginning in the 1960s.

Evidently, the advance occurred in stages, emanating from the centers of commerce and production in the south. A capitalist complex of social, institutional, and economic relations expanded and

[2] These include Bolivia, Peru, Ecuador, Colombia, and Venezuela.

contracted in waves, replacing the autarkic economies of Amazônia with modern modes of production, linking north and south in exploitive exchange relations, and laying waste to the environment by converting the dispersed patches of smallholder subsistence farming into empty pastures (Monbeig, 1957; Velho, 1972; Martins, 1975; Ianni, 1979; Mahar, 1979, 1989; Foweraker, 1981; Moran, 1983; Sawyer 1984; Schmink and Wood 1984, 1992; Wood, 1983; Branford and Glock, 1985; Hecht and Cockburn, 1989; Cleary, 1993).

We acknowledge the general validity of this structural interpretation of Amazonian frontier development, but we also seek to concretize its spatial representation in order to consider the environmental outcome with empirical detail. To this end, we adopt the notion of the agricultural frontier with its link to land rents and especially transportation costs. Such a conceptualization takes the frontier to be the *fringe* of market-oriented agriculture and ranching, which advances on subsistence farming or uncultivated wilderness, as the case may be, as a function of power relations and profit seeking behavior in the larger society (Walker, 2004; Walker and Solecki, 2004; Jepson, 2006).[3]

2.2. The margins of capital or the capital of margins?

It is useful at this point to consider *marginality*, and to specify our usage with respect to cattle ranching and to our concept of frontier. We argue that cattle possess a duality of margins that requires explication before we can advance an understanding of the forces driving pasture expansion into Amazônia, with deforestation, as a *frontier* phenomenon. On the one hand, they represent critical assets to often-itinerant peoples, living in marginalized environments, sporadically attached to markets. Here, cattle constitute a source of wealth and cultural value, fundamental to the social functioning of the herding households. They can be walked to market, liquidated for emergencies, exchanged at weddings, and milked and butchered to provide subsistence. In this rendition, cattle constitute a capital of margins, value-laden herbivores that make possible human habitation in difficult ecosystems, the drought-affected steppes and savannas, the shrub-lands largely forgotten by high input agricultural, much less urbanized, market-integrated settlement.

Alternatively, cattle may demonstrate an entirely different economic functionality involving tight market linkages and capitalization. Obviously, large quantities of cash change hands for beef and other cattle products worldwide, and consumer purchases create revenues for ranchers who provide the primary materials that source the markets. In such a situation, ranchers compete among themselves and other land managers to generate the highest rents possible, depending on their production systems for economic performance and little else. Such competitive activity possesses spatial implications, and creates the second margin of interest to our discussion. In the Thunian representation, land-demanding agricultural systems are found far from market centers because of their low location rents. Ranching, of course, generates the lowest values in this regard by virtue of its extensive nature; it therefore lies at great distance from intensive farming, butting up against lands that are valueless in economic terms due to high transportation costs. As a component of the commercial land use system so described, ranching thus constitutes the spatial margin of capital, or the extensive frontier of market-integrated land use (Jepson, 2006; Simmons et al., 2007).

These statements, of an abstract nature, have concrete meaning in today's Amazon. As has already been pointed out, the vast majority of cleared lands in the region are covered by pastures. This aggregate picture is consistent with field-based ethnography that has established an overwhelming movement toward pasture-dominated farming systems in active frontiers, even among small-holders (Walker et al., 2000; Walker, 2003; Browder et al., 2008). The cattle trend affects both the upper and lower basin, and colonist populations as well as traditional peoples originally focused on extractive activities (Salisbury and Schmink, 2007). Moreover, statistical studies addressing land use in Amazônia point strongly to the importance of accessibility in driving Amazonian land cover change, a finding robust in both aggregate and household-level analysis (e.g., Ozório de Almeida, 1992; Reis and Guzmán, 1994; Jones et al., 1995; Pichón, 1997; Pfaff, 1999; Walker et al., 2002; Anderson et al., 2002; Pan et al., 2004; Pfaff et al., 2007; Caldas et al., 2007). Thus, to assert a link between road-building and the Amazon's emergent cattle economy is hardly controversial. The present paper seeks to solidify this link in theoretical terms by appeal to the Thunian rent concept.

3. The policy framework

Our Thunian-based political ecology framework calls attention to both (1) social forces affecting high-level governmental decisions about Amazonian policy, and (2) incentives at ground-level influencing the decisions of land managers to opt for cattle. In this section, the policy framework is considered, with a special emphasis on road infrastructure, animal health, and monetary and trade reform. The following section, Section 4, considers how these investments have affected the profitability of ranching at ground level.

The explosive growth of the Amazon cattle sector did not occur in an historic vacuum, and involved extensive government intervention. Beginning as early as 1946 and on to the turn of the 21st century, federal policy aggressively promoted development efforts to integrate the Amazon region into the national economy. It also followed and implemented economic policies aimed at furthering the nation's participation in global trade. Much has been written about early development efforts, prosecuted under the auspices of the military regime that took power in 1964, and surrendered to a democratic groundswell in 1985 (Hall, 1987, 1989; Woodward, 1988; Browder, 1988; Mahar, 1989; Santana et al., 1997; Margulis, 2003). Consequently, we focus our efforts on explicating policy interventions that have come later, or persisted beyond the early focus on capital subsidies. These include efforts to reduce transportation costs and improve product quality. We also consider monetary reform and trade liberalization, both of which have helped open global markets to Amazonian cattle products.

3.1. The expansion of Amazonian highways

Development of highway infrastructure began with the military government, and has persisted as an important component of Amazonian planning ever since. In 1968, the federal highway system in Amazônia covered a scant 400 km, a number that grew by 1999 to 56,654 km (Walker, 2008b). The federal expansion has sparked both state and municipal governments to also build roads, which now exceed the lineal extent of the federal system by orders of magnitude (Arima et al., 2005). The upshot of this multi-scale investment process has been a precipitous decline in transportation costs, as documented by Fig. 1. This figure, developed with a GIS application (See Appendix), shows hours of travel time, by road, from Amazonian locations to São Paulo in the south. São Paulo has long dominated Brazil's economy as the premier internal market and international trans-shipment point (Romeu de Vasconcelos and Augusto de Oliveira, 2006).

[3] Logging and mining are often in evidence beyond the agricultural frontier (Foweraker, 1981; Browder, 1988; Schneider, 1995; Walker and Homma, 1996). Extractive activities are usually short-lived, however.

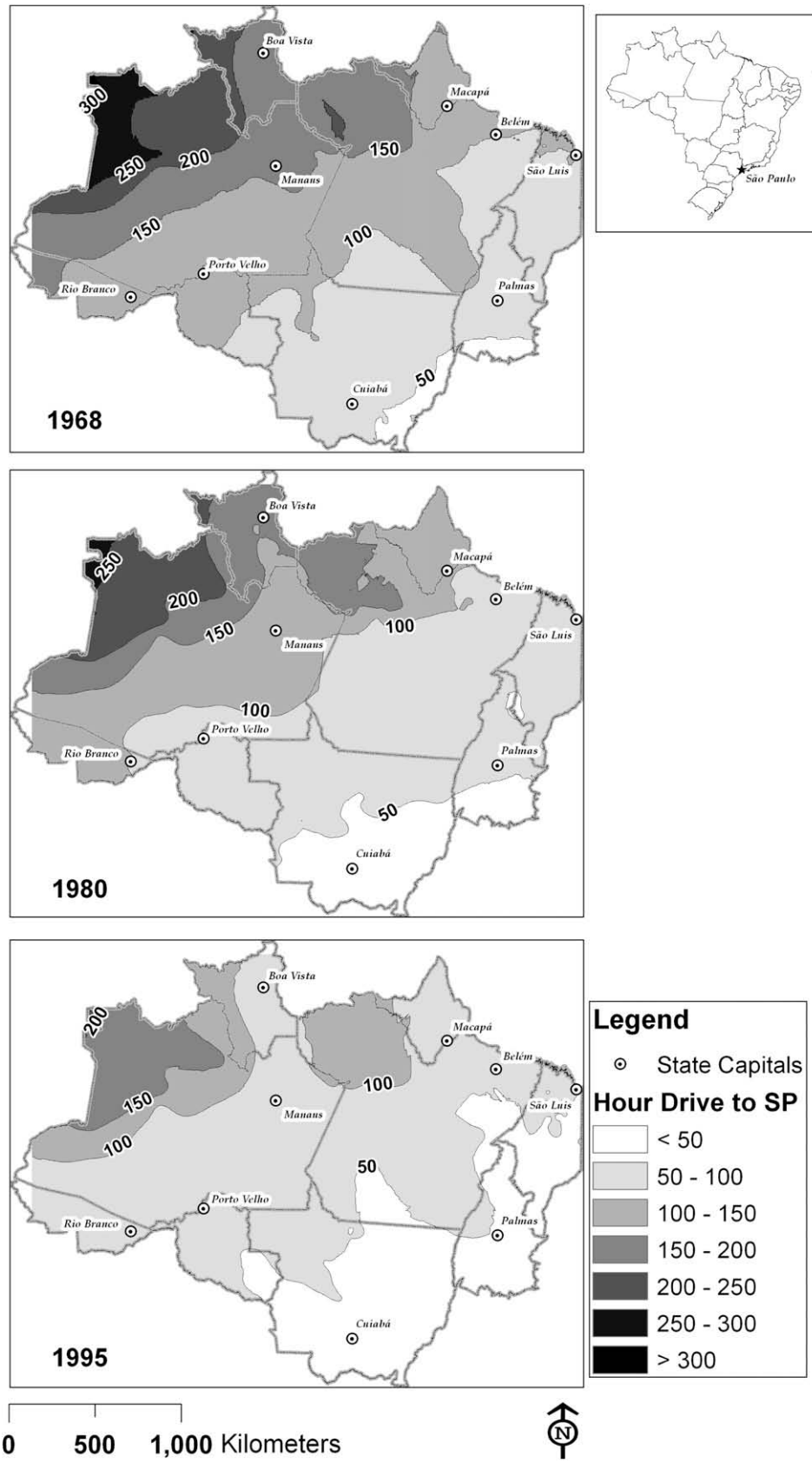

Fig. 1. Ground Travel Times to Sao Paulo, in Hours.

By 1968, the Belém-Brasília Highway had been completed (Valderde and Dias, 1967). Although this highway only passed through a small section of Amazônia, it reached the region's largest city, Belém, in which case the travel times in the upper panel of the Figure (1968) already reflect a certain degree of spatial integration. Be this as it may, Amazônia remained significantly isolated. Travel

times from Belém were about 100 h, and from Manaus they exceeded 150 h. Even Cuiabá, an important city on the so-called Soy Highway, BR-163, was far removed from the economic core of Brazil, and trips south required more than 2 days of ground travel. As the lower panel of Fig. 1 shows, this all changed radically by 1995. Of particular note is that the tongue of travel times of less than 50 h almost reaches Belém, and covers a large portion of southeastern Rondônia. Cuiabá, of course, was fully connected to the south by 1995, and a wedge of short travel times (<50 h) cut far into southwestern Pará state, along BR-163. Even Manaus and Boa Vista have access in 1995 comparable to Cuiabá's in 1968. By 1995, about a third of the basin, to the south and east, lay within 50 h of São Paulo by ground, whereas less than 30 years before only a thin sliver in the far southeast had this degree of access.

3.2. Foot-and-mouth disease control

Although transportation infrastructure has certainly played a role in reducing costs of Amazonian beef products, improved animal health, particularly with respect to foot-and-mouth disease (FMD), have made them much more desirable to both domestic and global markets. FMD has a long history in Brazil, beginning with its apparent importation from Europe in 1895, after appearing in Argentina and Uruguay (Astudillo, 1992). Serious efforts to resolve the problem did not arise until the 1950s, however, with the implementation of credit programs for ranchers and vaccine production following the first national conference to control FMD in 1950 (Ministério da Agricultura, 1950, 1964). These efforts continued somewhat haphazardly until the 1990s, when the Brazilian government shifted its entire approach under the National Eradication Program, or PNEFA, in 1992. This shift reflected Brazil's growing interest in export, together with rising international standards promulgated, in large part, by World Organization for Animal Health, formerly known as the Office International des Epizooties, and still referred to by its old acronym, OIE.

Prior to PNEFA, the federal emphasis was on control through a sometimes slow-moving centralized bureaucracy. After 1992, the government sought disease eradication, not control, and pursued this vigorously through a multi-pronged strategy that both regionalized and decentralized FMD efforts. Regionalization involved the creation of cattle circuits (*circuitos pecuários*), large contiguous parts of the country that could be managed effectively as units in the battle against FMD (Lyra and Cortes, 2002). PNEFA also called explicitly for the direct participation of civil society and individual Brazilian states in decentralizing FMD eradication. Specific components of PNEFA promoted vaccination campaigns, strengthening of the Department of Animal Health, and control of animal movements between circuits through *rastreamento*, or animal tracking.

The impact of PNEFA has been dramatic, as indicated by Table 1, which shows decadal totals of reported cases of FMD, as well as years of maximum and minimum numbers of cases. As can be seen, incidents of FMD have declined since the 1970s by several orders of magnitude, from nearly 70,000 to 89, midway through the first decade of the 21st century. The decisive years appear to fall in the 1990s, which is consistent with the creation of PNEFA. Although the decadal total is 7550, the maximum number of cases (2093) was reported early in the decade, and the minimum number (35), late. Given the program's start date in 1992, impacts would most likely be observable after mid-decade, given animal growth rates.

Table 1
Herd affected by foot-and-mouth disease in Brazil.

Decade	Number of cases	Year	Number of cases	
			Maximum	Minimum
1970	66,114	1976	10,295	
		1970		2529
1980	25,248	1980	7850	
		1988		1314
1990	7550	1994	2093	
		1998		35
2000–2004	89	2000	47	
		2002		0

Note: In 2004 there were five cases in Brazil.
Source: Boletim de Defesa Sanitaria Animal, Ministerio da Agricultura, Brasil.

The fall-off in FMD cases has had significant spatial implications for the cattle economy in Brazil and Amazônia. Even in the late 1990s, FMD was widespread throughout the country, and only two states in the far south (Rio Grande do Sul and Santa Catarina) were cleared for international export by the OIE, with Paraná functioning as a barrier between the northern infected states, which amounted to the rest of the country, and the disease-free southern tip. By 2005, almost all of southern and central Brazil were cleared by OIE for export, including the Amazonian states of Acre, Rondônia, Mato Grosso, and Tocantins. In 2007, the extent of OIE-certified clear areas regressed with FMD outbreaks in Mato Grosso do Sul and Paraná; this impacted the entire central part of the country, up into Amazônia. Nevertheless, the situation is extremely dynamic, as attested by the opening of the southern part of the State of Pará in Amazônia that same year. As for Amazonian certification for export, this begins as early as 2001 with Mato Grosso and Tocantins, and expands in 2005. Mato Grosso and Tocantins were affected by the FMD outbreaks in 2007, although southern Pará was added to the list of Amazonian exporters, together with Acre and Rondônia, two states that did not lose their OIE status (Ministério da Agricultura, 2007). Clearly, then, advances in FMD eradication in Amazônia paved the way for the expansion of beef exports to be discussed.

3.3. Market reforms

Also improving prospects for Amazonian production, in addition to reduced transportation costs and sanitary improvements, have been monetary and trade reforms. Although the dolarization of the Brazilian currency, the Real, under the *Plano Real* in 1994, initially over-priced livestock and increased the costs of commercial credit (Homen de Melo, 1999; Helfand and Rezende, 2004), conditions changed once free-floating exchange rates devalued the Real, making Brazilian commodities competitive in world markets (Peck, 2003; ABIEC, 2004). The Real has grown strong again, but not enough to dampen the upsurge in agricultural exports that resulted, and President Lula da Silva's government continues to support the currency policies of earlier administrations.

Brazil's trade policy has also changed since the protectionism of the 1970s and 1980s with the elimination of export taxes on agricultural commodities and the formation of a regional trading bloc, Mercosul, involving Argentina, Brazil, Chile, and Uruguay (Ornelas, 2001; Ponciano and Campos, 2003; Helfand, 2001). To date, Mercosul has failed to fully integrate markets for agricultural products (Mohanty et al., 1998), and has widened regional economic disparities within Brazil (Sá Porto, 2002; Montoya and Guilhoto, 2001). Nevertheless, it has also increased value-added to the livestock sector, the only agricultural commodity in Brazil to benefit significantly from the multi-lateral partnership (Ferreira Filho, 1999).

3.4. Policy impacts overall

Although the principal driver of cattle industry expansion in Amazônia has been private investment, it is important to consider the larger political economy in which this investment is made. Specifically, Brazilian policies have enabled investors to capture the

rents created on frontier pastures by virtue of public sector spending on transportation infrastructure and animal sanitation, and by virtue of monetary policies favoring export production. The long history of fiscal incentives targeting the region stimulated considerable sectoral expansion via cheap capital, with total subsidized credits to agriculture in Brazil exceeding US$ 40 billion between 1969 and 1990 (Helfand, 2001). As for monetary policy, the *Plano Real* has had great impact by making Brazilian exports, meat and otherwise, affordable throughout the world. Strategic efforts to lower prices by trade policy have accentuated the salubrious effects of currency stabilization, as have the cost reducing impacts of infrastructure investment, particularly in transportation. These investments have created tens of thousands of kilometers of roads in the region, and enabled producers to serve both national and international markets. Finally, efforts to improve the health of the herd, and in particular the control of FMD, have made cattle products from Brazil and a growing section of Amazônia desirable to discriminating markets throughout the world. In sum, the supply-side of the Amazonian cattle economy was well poised to exploit growing world demand for beef, particularly after the outbreak of Bovine Spongiform Encephalopathy (BSE, or "mad cow disease") in the United Kingdom in the early 1990s, and its subsequent spread (Galvão de Miranda, 2001).

4. The new ranch economy

Given the vitality of the Amazônia's cattle economy, it is perhaps ironic that the critical discourse on Amazonian development held for many years that agriculture, and ranching in particular, offered little promise of success and that private investment could only be secured with substantial government subsidies to investors (Hecht, 1985). As was pointed out

> "...the costs of raising cattle were rarely met by the selling price...livestock in the Amazon is not profitable without subsidies or speculation...pastures do not remain productive for very long...(they) are degraded and frequently abandoned in just ten years, and these degraded lands are exceedingly difficult to recuperate. Clearing for pasture in the end often condemns land to waste, and more than 50% of the cleared lands have been abandoned..." Hecht and Cockburn (1989, pp. 149–152).

Indeed, early analyses did demonstrate that some ranch operations, particularly larger corporate ventures receiving federal subsidies, were "irrational" in the absence of such subsidies; in so doing, they led to sharp criticism of subsidized credit programs and corporate tax breaks that encouraged speculative land acquisition and forest conversion to pastures in the 1970s and 1980s (e.g., Browder, 1988). It is important to point out that such programs did not cover all ranching activity in the basin, which perhaps explains the fact that a large herd had formed by 1990. In 1980, fiscal incentives provided by the Superintendência de Desenvolvimento da Amazônia (SUDAM) and Fundo de Investimento da Amazônia (FINAM) went to 0.2% of ranching enterprises in the region. In that they were large, these accounted for 17% of the region's herd. By 1985, the numbers had changed to 0.4% of enterprises and 25% of the herd (Schneider, 1995, p. 3).

We argue in the present paper that economic conditions at ground level have changed appreciably since the first explosion of corporate ranching on the primary forests of Amazônia. Before describing these changes, we note that in the present context the term "rationality" carries connotations about the economy, the environment, and social welfare in general. Our intention is not to deconstruct *rationality* per se, which we freely admit is a highly contested concept in discussions about Amazônia. Instead, we merely wish to point out that "rational" economic decisions can easily visit undesirable effects on the environment, to the point that costs ultimately outweigh benefits as has been long recognized (Pigou, 1962). In such a situation, these very decisions become globally irrational, even in economic terms. However, since the intent of the paper is to understand how the Amazonian cattle herd grew from the wild colonial stocks of Marajó Island to its present size of over 70 million animals, we limit our usage of the term to its rather narrow micro-economic meaning. Thus, to say that ranching is rational is not to say that it is right, or even makes sense when viewed from a distant window. The irrationality of capital is of course highly rational in this regard.

The present paper does not take issue with early forecasts about the likely doom of agriculture and ranching in the Amazon basin. Moreover, we remain agnostic about long-run prospects for the region and agree that (1) some early ranching relied on subsidies, and that (2) speculation – often masquerading as an agricultural venture – drove a component of the region's early penetration. Be this as it may, frontier development typically involves significant government investment, the anticipation of which drives speculative frenzies in land markets (Cronon, 1991; Walker and Solecki, 2004).

Although Amazonian ranching began as a low productivity venture focused on Marajó Island and the floodplains of the Amazon River, it migrated to higher ground on *terra firme*, and modernized in the process. A consequence is that ranching here often shows higher profits than elsewhere in Brazil, as established in a recent study conducted by Arima et al. (2005) for the Instituto do Homem e Meio Ambiente da Amazônia (IMAZON). Certain results of this study, which analyzed the profitability of ranching at select locations across Brazil, are presented in Tables 2a–c. The profitability of Amazonian locations is due to qualities of the resource base and the price of land. As for the resource base, Amazonian soils are mostly low fertility Latosols, but not much worse than in other parts of Brazil (Falesi, 1976; Fearnside, 1980; Adámoli et al., 1985); low fertility, in turn, is compensated by moisture, insolation, and a frost-free climate (Arima et al., 2005; Anualpec, 2003; Arima and Uhl, 1997). These conditions lead to appreciably higher rates of animal growth than in the southern part of the country, where land prices are also higher (Tables 2a–c). With productivity and land cost advantages, Amazonian ranchers earn higher returns on investment than their competitors, as shown in Tables 2b and 2c.

It is important to note that this economic success is still limited, given constraints on the region. FMD continues to restrict Amazonian involvement in international markets, and relegates many producers to the support role of satisfying domestic demands while their southern counterparts participate in a growing global trade (Kaimowitz et al., 2004; Balanza, 2005). But the situation is changing, as discussed. The natural incidence of foot-and-mouth disease, as well as Brucelosis and ecotoparasites, are lower in key Amazonian cattle areas than the south and central regions of Brazil (Arima and Uhl, 1997).

5. Amazonian herd growth and exports

Ranching has a long Amazonian history, but when the military regime began its push to open the north the region accounted for only about 8% of Brazilian stock (Arima and Uhl, 1997). Forty years and a continuous series of policy interventions have changed this scenario dramatically, as indicated by Table 3, showing herd sizes disaggregated by state, from 1990 to 2005. These data are published by the Instituto Brasileiro de Geografia e Estatística, or IBGE (1990, 2005). As can be observed, by 1990 the Amazonian herd had already reached about 20 million animals, but by 2005 it added another 50 million head, growing to over 70 million animals dispersed widely across the basin.

Table 2a
Beef cattle productivity in planted pastures in Amazônia and other Brazilian states.

System	Average productivity (@/ha/year)		Median productivity	
	Amazon	Other states	Amazon	Other states
Calving	4.11	3.72	4.41	3.88
Fattening	3.85	3.50	4.10	3.68
Calving and fattening	5.45	4.93	5.55	4.77

Source: Anualpec (2003) and Arima et al. (2005).
Obs1: Main producing regions in Amazon include Barra do Garças, Alta Floresta, and Pontes e Lacerda in Mato Grosso; Redenção and Paragominas in Pará, Ariquemes in Rondônia; Gurupi and Araguaína in Tocantins. Main producing regions in other states of Brasil include 14 municípios.
Obs2: The symbol @ refers to the weight unit "arroba", equal to 15 kg (33 lb).

Table 2b
Profitability and land prices in Amazônia and São Paulo.

Municipality/state	Net income (R$/year)	Land price (R$/ha)	IRR internal rate of
Alta Floresta/MT	139	1200	14.5
Ji-Paraná/RO	133	1250	11.5
Paragominas/PA	103	1250	11.0
Redenção/PA	66	1300	9.1
Santana do Araguaia/PA	96	2000	14.7
Tupã/SP	65	3300	3.8

Source: Barros (2002).
MT is Mato Grosso; RO is Rondônia; PA is Pará; SP is São Paulo.

Table 2c
Pasture prices and return on investment in cattle ranching in Amazônia and other producing regions in Brazil.

	Mean values	
	Amazon	Other states
Pasture price (R$/ha)	954	1918
Annual return	5.01	3.37

Sources: Anualpec (2003) and Arima et al. (2005).
Note: Annual return is the annual net income as a percentage of capital assets used in production.

Table 3
Amazonian cattle herd, by state and year.

State	Years			
	1990	1995	2000	2005
Rondônia	1,718,697	3,928,027	5,664,320	11,349,452
Acre	400,085	471,434	1,033,311	2,313,185
Amazonas	637,299	805,804	843,254	1,197,171
Roraima	0	282,049	480,400	507,000
Pará	6,182,090	8,058,029	10,271,409	18,063,669
Amapá	69,619	93,349	82,822	96,599
Tocantins	4,309,160	5,528,370	6,122,256	7,961,926
Maranhão	3,565,267	3,829,430	3,788,819	5,895,265
Mato Grosso	9,041,258	14,153,541	18,924,532	26,651,500
Total	25,923,475	37,150,033	47,211,123	74,035,767

Source: IBGE, Pesquisa Pecuária Municipal (http://www.sidra.ibge.gov.br/bda/pecua/default.asp) Maranhão includes only counties in Legal Amazônia.

Fig. 2 depicts the expansion of the cattle frontier by disaggregating the IBGE data to county level, calculating density using county areas, and plotting the densities using municipal boundary files for the Amazon region. In addition, highway data are overlaid on the density chloropleths to demonstrate spatial correspondence between ranching and transportation infrastructure. The highway data were derived using paper maps produced by the *Department Nacional de Estradas de Rodagem*, *Ministerio dos Transportes*, or DNER. Attributes of the paper maps provided information for correcting a digital file of Amazonian roads shared by IMAZON, and originally produced by IBGE. The map in the figure represents key elements of the federal system as of 1999, as well as state roads that are implicated in cattle expansion.

As can be observed, ranching starts out in the savanna, or *cerrado*, parts of the basin to the south and east.[4] Notable are cattle herds in southern Mato Grosso, in a strip running north and south through Tocantins (the Belém-Brasília Highway; BR-010), in central Rondônia (along BR-364), and throughout the southeastern part of Pará state (mostly along PA-150). By 2005, however, the frontier has penetrated large parts of the basin's forest. From the east, stocking densities have filled in through southern Pará, and a strip of ranching now stretches east and west along the Transamazon Highway. Cattle have also moved into Mato Grosso's most extensive area of closed forest near the border with Pará. Similarly, ranching has dispersed widely through Rondônia following BR-364, and a large herd has even emerged in the state of Acre, which possessed few cattle in 1990. The fundamental change between 1990 and 2005 is the coalescence of a continuous swath of counties displaying sizeable cattle herds. This area is largely coterminous with the so-called "arc of deforestation", and runs from the mouth of the Amazon River in Pará state, south and west, linking up over thousands of kilometers herds grazing in Maranhão, Tocantins, Mato Gross, Rondônia, and Acre.

5.1. Growth of exports

Expansion of the Amazonian herd across the arc of deforestation is largely contemporaneous with expanding Brazilian exports, depicted in Fig. 3 in value terms. As can be seen, the balance in payments remains in equilibrium until the decade of the 1980s, when exports begin their climb above imports, generating a yearly surplus of nearly 10 billion US$ by the end of the 1980s. This changes abruptly with economic difficulties spanning the military regime and transition to democracy, such that exports dip below imports through much of the 1990s, a trade imbalance that only turns the corner in 1998. Then, exports surge dramatically, posting growth that creates a 50 billion US$ surplus by 2006. The export explosion ramifies into market dispositions of Amazonian producers, who initially supplied the frontier's growing urban populations and regional demands (Faminow, 1997). This has all changed, with demand expanding first to national, then to international, markets. Presently, Amazonian beef continues to supply the region, but also markets in the southern part of the country and overseas (Arima, 2007). In only a few years, Amazônia has evolved as a major supplier for other parts of Brazil, and nearly 90% of its production left for domestic consumption in the early 2000s, primarily in the northeast and south (Arima, 2007). More notably, growth in Amazônia's share of Brazilian export has quadrupled in only six years, from about 5% in 2000 to over 20% in 2006 of beef *in natura* (Table 4).[5] These export products satisfy demands around the world, with markets in Latin America, the European Union, the Middle East, and Asia, including China (Arima et al., 2005).

6. Discussion

6.1. Agricultural expansion and deforestation

We have argued that frontier expansion in the Amazon, with associated land cover change, is a process driven by increasing

[4] Brazilians use the term cerrado, which is a fairly shrubby savanna and can even include seasonal forests.

[5] In natura refers to boneless meat, exportable following adherence to the OIE guidelines. The main OIE recommendations are that carcasses (from certified slaughterhouses) be boneless and the major lymphatic glands, removed. Carcasses must also be submitted to maturation via heat within 24 h following slaughter (OIE, 2007). Bones and lymph nodes are the main source of FMD contamination.

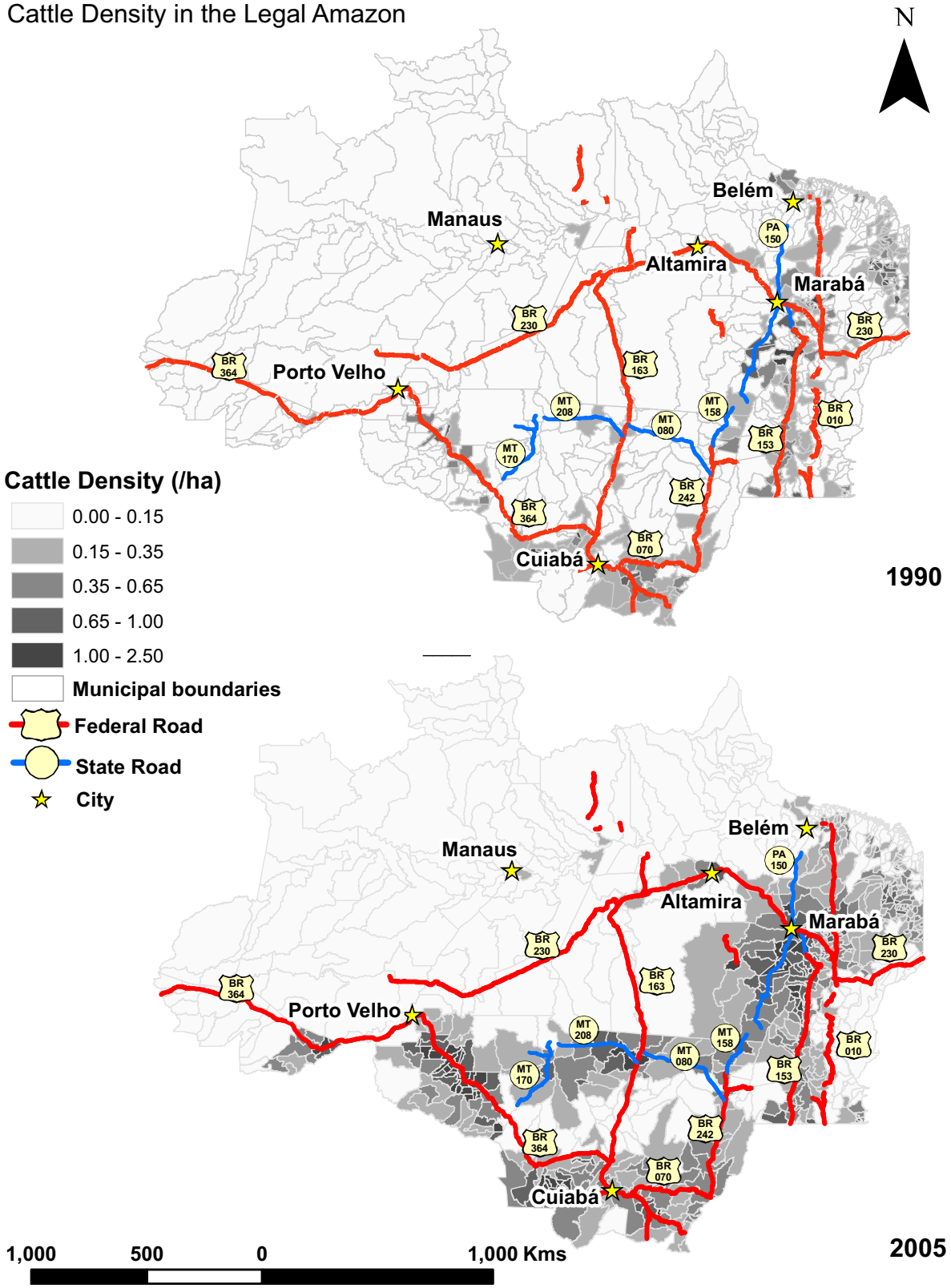

Fig. 2. Cattle Density in the Legal Amazon, 1990 and 2005.

location rents (Walker, 2004). These rents were originally created by investments in transportation infrastructure and by subsidies to capital. They were later augmented by product quality enhancements focused on animal health, by changes in monetary and trade policy inside Brazil, and by growing international demand for Amazonian agricultural products, particularly beef. It would be problematic to disentangle and isolate the effects associated with these rent-creating factors individually, given their complex inter-

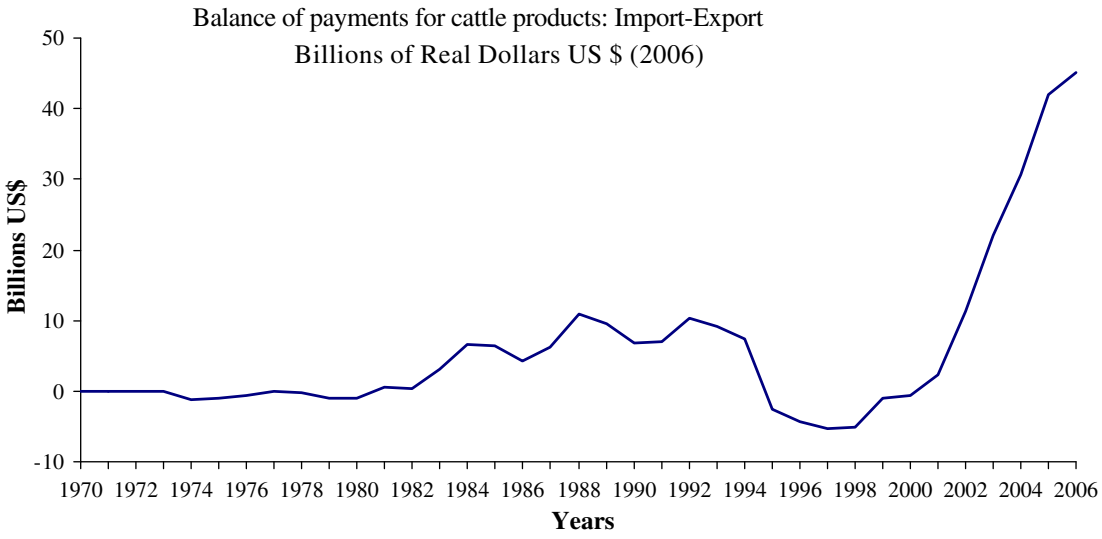

Fig. 3. Balance of Payments for Cattle Products, 1970–2006.

Table 4
Brazilian and Amazonian boneless beef exports between 2000 and 2006.

	2000	2001	2002	2003	2004	2005	2006
Brazil (metric tons)	188646.22	368237.40	430175.37	620088.71	925018.20	1085569.95	1225393.47
Amazon (metric tons)	10000.35	25427.04	29977.83	44676.15	53139.20	106185.44	263787.70
Amazon/Brazil (%)	5.30	6.91	6.97	7.20	5.74	9.78	21.53

Source: Ministry of Development, Industry and Foreign Trade – MDIC, Aliceweb System: http://www.desenvolvimento.gov.br. Carnes Desossadas, de bovino, frescas ou refrigeradas e congeladas (*in natura*).

actions and synergies. But this is unnecessary to our purposes, which focuses on the behavioral significance of rent. Specifically, the Thunian concept is that land managers engage in the land use that generates the highest rent at any particular location, irrespective of how that rent was created.

In the Brazilian case, this means that cattle ranching occupies the most remote locations, such as found in Amazônia, but also in other parts of the country. "Behind" ranching, understood spatially to be the general space of greater accessibility to large urban markets, is found the domain of mechanized agriculture, for example soy farming. In the Thunian formulation, deforestation is the immediate consequence of land use encroachment, happening at the instant labor and capital flow to capture the rents that materialize with improving infrastructure or market conditions (Chomitz and Gray, 1996; Walker and Solecki, 2004). In Amazônia, again, the implication is that deforestation typically occurs when ranchers identify new rents created by altered economic conditions, and cut the forest to capture them.

Two issues must be addressed before we finally place Amazonian deforestation within a Thunian construct. The first involves agricultural intensification, or the adoption of new farming practices and technologies that augment land productivity. Intensification reduces the demand for land, *ceteris paribus*, and consequently has been held out as a potential solution to the problem of Amazonian deforestation. The second issue relates to the mechanisms of forest encroachment under a multi-crop Thunian system, and specifically the role of soy expansion and ranching as partners to deforestation impulses reaching through the basin.

Regarding intensification, it is often imposed by virtue of land scarcity, as the historical record shows (Boserup, 1965). Farmers and ranchers are unlikely to intensify in the Amazon given abundant land, even with new technology. Nor should it be forgotten that intensive systems promote deforestation if they generate higher rents than non-intensive ones (White et al., 2001; Arima et al., 2005). Thus, we do not consider intensification in our conceptual efforts, and assume an unchanging technology for both ranching and mechanized agriculture. Moreover, we do not interpret the replacement of pasture by mechanized agriculture as intensification per se, and deploy the term only to describe increasing productivity of specific land uses arising from technical interventions. Thus, ranching intensifies if new technologies yield higher, unit-area beef production or stocking densities.

The second issue concerns the identification of the underlying forces driving a frontier land use into so-called, "uncultivated wilderness", the original terminology employed by von Thünen (Walker, 1999). In a one-commodity world, as with simply beef, this devolves to identifying conditions leading to increased rents for ranching. For example, price rises for beef bring lands into production that did not generate rents before; transportation costs reductions lead to the same outcome. Two goods complicate the picture. Letting soy be the crop located "behind" the cattle frontier, at least two possibilities arise. The first is that economic conditions improve for beef, either through price rises or production cost reduction with infrastructure investments. In such a situation, we continue to observe an advancing cattle frontier. Alternatively, economic conditions might favor soy, in which case soy encroaches on pastures until all are exhausted, at which point the soy frontier becomes the proximate cause of deforestation.[6]

The circumstances described do not match the Amazonian case, as the market situation has sustained prices for both beef and soy. In such a situation, soy farming potentially affects Amazonian forests by two mechanisms. First, soy may be "pushing" cattle deeper into forest by occupying pastures, thereby forcing displaced ranch-

[6] The real world is of course more complicated, and more than soy crops are grown in the Amazon (e.g., rice, sorghum, sugarcane). However, simplification helps make the conceptual point.

ers to cheaper lands. Alternatively, when the price situation sharply favors soy, it may "leap-frog" into primary forest ahead of ranching. Such "leap-frogging" occurs by the same mechanism as when sprawl overwhelms agriculture on the urban fringe, and begins converting natural areas to residential land use (Walker and Solecki, 2004). Specific conditions for both of these phenomena have been described for the Thunian model elaborated by Walker (2001).[7]

6.2. The current situation in Amazônia

Over the past several decades, pasture expansion has been the primary proximate cause of Amazonian deforestation by the single-crop mechanism described above. But the mechanisms are themselves subject to change, and questions have arisen about the role of soy in current and future land cover dynamics in the region. Moreover, the ultimate fate of the forest invites speculation about the possibility of an Amazonian forest transition (Perz and Skole, 2003). As for the role of soy, we speculate, in the absence of sufficient research on the topic, that it has shown both "pushing" and "leap-frogging" effects in relation to the Thunian linkage with pasture encroachment just considered. Having said this, recent remote sensing analyses suggest an intensification of soy impacts on the region. Morton et al. (2006) report that, between 2001 and 2004, 12–14% of directly converted forests in northern Mato Grosso were put in croplands, not pasture. The amount peaks at over 20% in 2003, when the price of soy was high, which is consistent with a Thunian "leap-frogging" of soy farming into forests, ahead of pasture. A similar pattern is observed in eastern Rondônia. Here, the majority of cropland growth occurs on previously-cleared land, but a large amount (on the order of 20%) directly encroached on forest between 1996 and 2001 (Brown et al., 2005).

At basin-scale, however, the overall fraction of direct soy conversion is small and localized relative to that of pasture, and can be expected to remain so at least over the near- to mid-term, given the continuing strong demand for cattle products, the productivity of Amazonian pastures, the limits to soy expansion posed by high yearly rainfall, and the need of mechanized equipment for flat terrains. That pasture represents the primary proximate cause of Amazonian deforestation should not be interpreted to suggest that soy has no or little impact on the forest. Even in the absence of direct conversions, the demand for land by mechanized agriculture is surely an important distal factor that "pushes" compensatory deforestation by Thunian displacement. Given that market conditions for Amazonian cattle products have been strong, much of the pasture taken by soy has no doubt been recovered by new acts of deforestation for frontier pastures. Thus, sizeable fractions of past and current deforestation are probably accounted for by the Thunian "pushing" effect, as described. The exact size of these fractions remains an important empirical question.[8]

6.3. An Amazonian forest transition?

The preceding analysis has described Amazonian deforestation as primarily a direct conversion of forest for pastures, producing for expanding markets. In this sense, it is best interpreted as a response to domestic and global demands for the region's agricultural output, mainly beef, but also soybeans and other products. Of course, the ability to respond derives from the capital-driven structuring of the supply-side in the first place, via extended investments in infrastructure and other interventions designed to create and capture location rents. These investment strategies have translated at micro-level into strong profit maximizing incentives throwing fuel on the fire of regional pasture conversion.

A question naturally arises regarding the final implication of such demands, and the incentives driving ranchers ever deeper into wild parts of the Amazon basin. Research on many forests worldwide suggests the existence of a point of landscape turnaround, or forest transition, whereby forests expand their domains against agriculture, following prolonged periods of deforestation lasting decades and even centuries (Mather, 1990, 1992; Walker, 1993). Forest transitions have been explained by agricultural intensification, the shifting of energy sources from wood to fossil fuels, rural out-migration following urban-based industrialization, and the development of societal preferences for natural landscapes (Mather, 1992; Walker, 1993). A key issue that has emerged within forest transition scholarship is the likelihood of such spatial dynamics in tropical parts of the world, since forest recoveries have most often been observed in relatively wealthy, temperate countries (Walker, 1993; Rudel et al., 2002; Chomitz, 2006; Perz, 2007).

By econometric accounts, Brazil could be experiencing or about to experience a forest transition at aggregate scale based on income studies that establish a link between rates of deforestation and per-capita income. Latin American countries appear to experience reduced deforestation at per-capita GDP of about $6300 (in 1996 US dollars). Brazil's per-capita GDP of $6900 in 2000 (in 1996 dollars) is clearly adequate to have put a drag on the rate of forest loss in that country, if not provoking outright transition.[9]

In fact, localized transitions have been observed in parts of the Ecuadorian Amazon, as well as in Brazil's Atlantic rainforests to the south (Rudel et al., 2002; Baptista and Rudel, 2006). Moreover, much previously-cleared land in the Brazilian portion of the basin shows signs of forest regrowth (Moran et al., 1996; Perz and Skole, 2003), and Perz and Skole (2003) suggest that Amazônia might enjoy an "early" transition at regional scale given indications of strong forest recovery already underway in older frontiers.

However, as is well known, secondary forest and fallow need not necessarily indicate long-term forest abandonment in frontier areas, given the use of rotational systems (Perz and Walker, 2002; Walker, 2003). Thus, observation of secondary growth cannot automatically be interpreted as heralding the onset of forest transition (Walker, 2008a). Although long-term forest regrowth may be occurring in certain Amazonian localities, net forest loss in the region has shown remarkable persistence, and through the mid-1990s it increased from an early decadal dip to its currently high levels, even in the face of rural *out-migration* (Perz, 2002). Nor do demand projections for Amazônia's agricultural production provide any hopeful antidote to this observation. Considering beef, a reasonable aggregate projection for 2020 will require an addition of 400,000,000 animals to the global herd.[10] Certainly, some of these cattle will graze on Amazonian pastures, given supply constraints in Brazil and other parts of the world. Add to this expanding global demands for Brazilian soy as well as the importance of Ama-

[7] For example, if frontier producers of a specific crop dominate a market (inelastic demand), then prices rise as land shifts to uses encroaching from "behind". But price increases also elevate rents on the extensive margin, which expands existing land uses there, like pasture, to bring more land into production. In the Amazonian case, this results in deforestation.

[8] Answering this question will require extensive remote sensing analysis. In addition, specifying the dynamic relationship between soy and cattle ranching will require detailed ethnographic accounts of farm system choices in both forest frontier and settled areas of pasture displacement. See Walker et al. (2002) for farming system choices in the Amazonian forest frontier.

[9] Barbier (2001, p. 164) reports the turnaround point for maximum deforestation in Latin America at $4946 in 1987 US$. This converts to $6354 in 1996 US$, using the price deflator from the US Department of Commerce. In 2000, Brazilin GDP per capita was $7400, which converts to $6915 in 1996 US$.

[10] Calculated as follows: Current world consumption (2005) is 60 million Metric Tons (FAO data:. http://www.faostat.fao.org.faostat Retrieved: April 28, 2006) and projected World Consumption (2020) is taken as 86 million Metric Tons (Mt), yielding an increment in world production between 2005 and 2020 of 26 million Mt (Delgado, 2005). This means 118,000,000 more animals will have to be butchered per year, at .22 Mt per animal. With a 30% off-take rate, an additional 393,000,000 animals will be added to the global herd.

zonian agriculture to internal Brazilian markets (Pfaff and Walker, 2008), and it is difficult to imagine that aggregate deforestation will lose its momentum in the short- to mid-run. The prospect of an Amazonian forest transition remains on the distant time horizon, beguiling but elusive, at least for now.

7. Concluding remarks

The Amazon basin has been a stage on which the winds of capitalism have twice blown strongly. During the rubber boom, which lasted five decades, great riches came to the region, and the first taste of its economic potential (Weinstein, 1983). The boom went bust of course, leaving behind an impoverished population, and rusting grillwork in the European Baroque plazas of the commercial capitals of Belém and Manaus. Since then, a new economy has emerged, once again raising hopes, and incomes, although as of yet not to the levels of the great rubber era (Walker et al. 2007). But cattle and associated activities have also brought people, in numbers far beyond those who paddled the lonely *igarapés* in search of trees to tap, and the Amazon region now boasts a population once thought improbable, topping 20 million and growing by virtue of internal birth rates, not in-migration (Perz, 2002). Also unlike the rubber boom, this new economy, with cattle at its heart, is by its very nature land-demanding, and so has leveled vast tracts of forest with environmental consequences that cannot yet be fully comprehended.

To recapitulate the objectives of the paper, we set out to explicate this regional metamorphosis, now on the verge of starting its own fifth decade. Unlike the rubber boom, all indications are that the cattle economy will continue its expansion, and therefore, its encroachment on the world's largest remaining tropical forest, pushed on by mechanized agriculture at its rear. To account for this ongoing and seemingly irresistible advance, we have used Thunian land use theory, based on location rents, as a heuristic in providing political ecological explanation. In so doing, we have treated political ecology as unproblematic despite a wide-ranging discussion about its meaning, its applications, and its values (Walker, 2005, 2007). Our specific deployment seeks to link land managers, in this case ranchers, with governmental decision-makers far removed from the forest frontiers, and acting in response to a regime of capitalist accumulation targeting the capture of potential rents (Walker and Solecki, 2004). Thus, we advance what might be referred to as a "first generation", structural approach, drawing inspiration from Blaikie and Brookfield (1987).

The focus of our efforts is an environmental change process of great ecological consequence, namely the destruction of the Amazon rainforest. The argument and analysis may therefore be regarded as an application in the spirit of "putting the ecology" back into political ecology (Walker, 2005). Given the specific ecological issue in question is a form of land cover change, we suggest that our efforts may also be interpreted as expanding the theoretical base of land change science in the direction of political ecology (Gutman et al., 2004; Turner et al., 2007).

In developing our explanation of Amazonian deforestation, we have revived the old work-horse, von Thünen, not to lay out an *a priori* configuration of the Amazonian landscape, but as a way to understand how choices are made about land use, and how these choices are themselves structured by policy, pursuant to political and social processes. Specifically, Thunian thinking provides a heuristic for explaining how the advance of ranching into Amazônia results from the creation of location rents by the state, via transportation cost reductions, product quality enhancements, and demand stimulation through monetary and trade policy. In some quarters, the model of von Thünen represents an antiquated first wave of economic geography, particularly for those pursuing the pathways of social theory (Page and Walker, 1994; Barnes, 2001). We agree, to the extent that the criticism aims its sites at deductive mathematical modeling. But we also argue – to the contrary – that the rent theory of von Thünen can be deployed in a manner embracing economic rationality *and* political economy, both of which are necessary to explicating land cover and land use change (LCLUC), the conjoined social processes that, in the Amazonian case, destroy the forest.

Although we draw inspiration from the tidy conceptual world of von Thünen, we recognize the role that politics play as a mediating force on the dynamics of Amazonian deforestation (Peet and Watts, 1993). We resist a linear explication that runs directly from the high-finance capitalists of São Paulo and Rio de Janeiro, down to the frontier ranchers, responding blindly to incentives. Of course, providing descriptions of the federal political process over four decades, not to mention the localized reactions by civil society to top-down policy impositions, would be a daunting task outside our immediate competency. We do wish to note, however, what we identify as an *historical block* on the issue of Amazonian development (Gramsci, 1992). In this regard, the constellation of social and political forces in Brazil appears to have struck a surprising equilibrium across the political spectrum. Lula da Silva, a populist president who resisted the military regime as a young metal worker, now pursues a neoliberal policy designed by his predecessor, Cardoso, who lived in exile from the same regime. Further, first Cardoso and then Lula da Silva adopted much of the developmentalist thinking of their former military foes, who ruled the country until 1985. The worker's party administration of president Lula da Silva has certainly helped the Brazilian poor with its distributive policies. But the point more central to our concerns is that successive presidential administrations, even with widely varying ideological perspectives and performances, have shown surprising uniformity in their designs for Amazônia.

We conclude by disclosing that our motivation for writing this paper is a deep concern for the Amazonian environment, and its dependent human populations. The forest is disappearing at a vertiginous rate, which has all the appearance of an ineluctable force, a manifest destiny. Thus, it is worth remembering that markets are institutions, that profit maximization occurs in social context, and that environmental problems, even of this magnitude, are human constructs that can be resisted. Conservation of Amazônia remains a critical global project, all the more so given the apparent inevitability of its transformation into humid pasture.

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Appendix

The base data used to produce the travel times are from the website managed by the Institute of Applied Economics Research, or IPEA (http://www.ipeadata.gov.br). They are located in the file, "Custos de Transporte da Sede Municipal ate São Paulo", and were retrieved on December 5, 2005. The IPEA data contain transportation costs, in the form of a cost index, from 2485 counties to São Paulo in 1968, 1980, and 1995. Certain Amazonian counties in Tocantins and Para are not covered, and were interpolated using

1540 points from all the other Amazonian states, as well as from counties within Tocantins and Para. Following Simmons et al. (2007), the interpolation is done as follows. First, the cost index, c_i, for some arbitrary county, i, is transformed by the log function

$$z_i = \log(c_i).$$

The log function is then fit to a surface, where x_i and y_i are the coordinates of county i as

$$z_i = b_0 + b_1 x_i + b_2 y_i + u_i,$$

where (x_i, y_i) is the coordinate of county i. Values of $\hat{u}_i$ predicted from estimation are next used in Kriging, and the final prediction for the counties without data is accomplished additively using the trend surface.

Kriging finds an estimate for a spatial variable with unknown value, like $\hat{u}_j$, as a weighted linear combination of nearby known $\hat{u}$'s at locations, s_i. Using the notation of Bailey and Gatrell (1995)

$$\hat{u}_j(s_j) = \sum_i^n \lambda_i(s)\hat{u}_i(s_i),$$

where the λ_i's are weights, determined as a function of the covariance between adjacent points. In vector notation

$$\lambda(\boldsymbol{s}) = C^{-1}\boldsymbol{c}(\boldsymbol{s}),$$

where C is the $(n \times n)$ covariance matrix between all pairs of n sample points, and $\boldsymbol{c}$ is a vector of covariance between the prediction point and the n sample points. Matrix C can be found by using a semivariogram

$$C(h) = \sigma^2 - \gamma(h),$$

where σ^2 is the overall variance (the sill), h is an index of distance between points, and γ is the semivariogram, which was specified using an exponential model (see, Simmons et al., 2007).

The kriging application just described produces a surface of effective distances from points to São Paulo, interpreted as distance over a paved road in good condition. In this paper, these distances were dived by 60 km/h, taken as an average velocity for trucks with freight, in order to produce travel times in hours.

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