China's Influence on Deforestation in Brazilian Amazonia: A Growing Force in the State of Mato Grosso

WORKING GROUP ON DEVELOPMENT AND ENVIRONMENT IN THE AMERICAS

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China influences deforestation in Brazilian Amazonia in a variety of ways, including the direct influence of Chinese enterprises. We examine these issues and present data on the growth of China's role in Brazil's soy and beef sectors, which are major drivers of deforestation in the country's Amazon region. We concentrate on the state of Mato Grosso, where soy and beef production are dominant forces and where China is the principal destination for exports. China also purchases other commodities from Brazilian Amazonia, such as iron ore and timber. Chinese financing is increasingly influencing and accelerating infrastructure development projects such as a planned railway that would connect Mato Grosso to ports on the Amazon River in order to facilitate soy exports.

We find that increases in Brazil's exports to China are significantly, positively associated with increasing deforestation rates. Nevertheless, deforestation has been declining in recent years, thanks to improved regulation, including a powerful new measure that disqualifies any operation with environmental irregularities from benefiting from public loans. However, the future of this policy is not secure. The influx of money from the booming Chinese export market is reshaping the Brazilian political landscape. The "ruralist" voting block representing large landowners has

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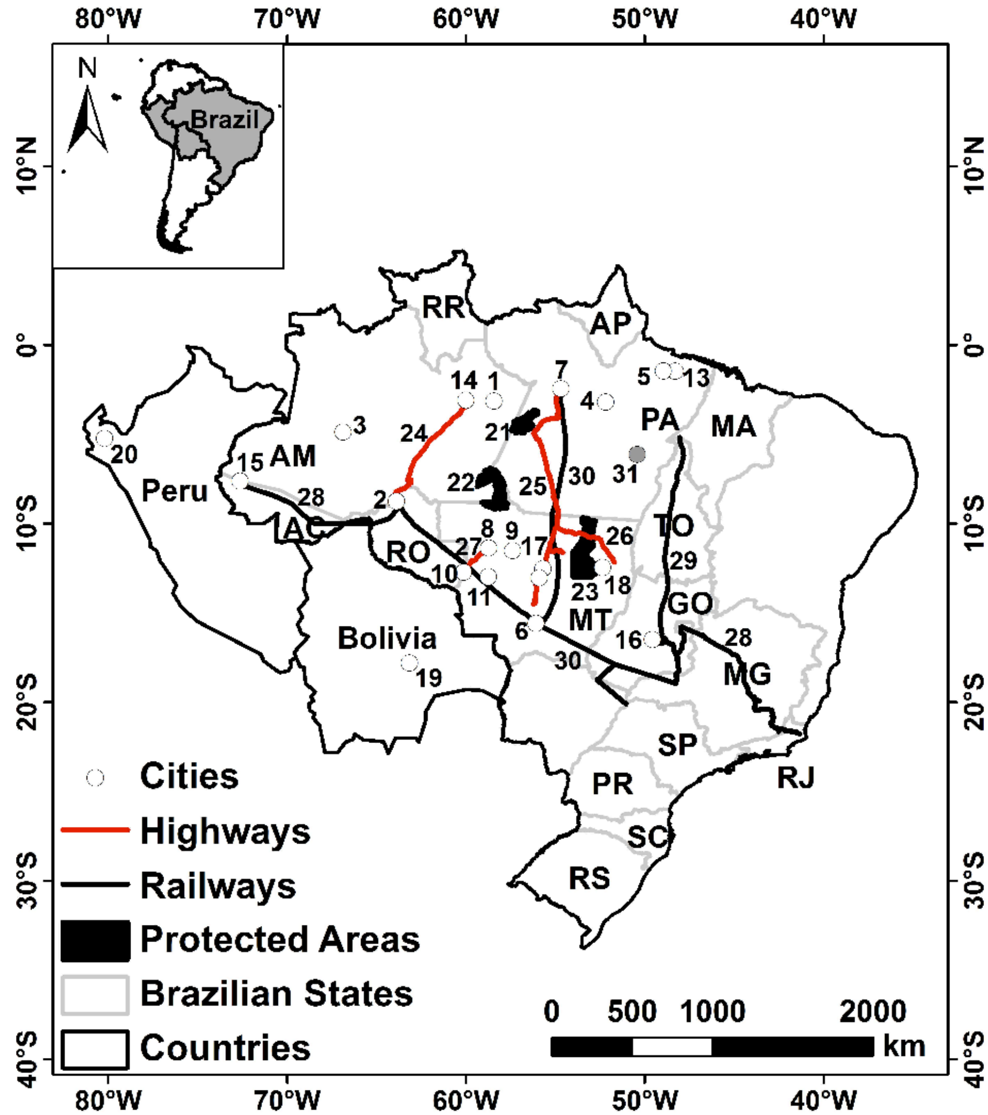
used its newfound influence to push for relaxing environmental regulation. If Brazil is to consolidate its gains against deforestation, especially during an agricultural export boom, it will need to hold fast to its regulatory progress and resist the call to sacrifice long-term conservation goals for short-term export revenue.

1. Introduction

As a country with vast natural resources, including agricultural land, timber, hydroelectric capacity and mineral deposits, Brazil is a logical source of imports to supply China's burgeoning demand. Brazil is also a logical destination for Chinese investment, particularly in the extraction or production of commodities and the transport infrastructure needed to facilitate export. Brazil's political stability and openness to foreign investment, combined with the financial power provided by China's strong economy, translate into the impressive growth and scale of China's presence in Brazil. China has become Brazil's largest trading partner and the greatest source of export surplus from agricultural goods (US$85 billion in 2011), contributing to Brazil's economic growth and to reducing the country's vulnerability to external economic crises (da Nóbrega, 2012). It should therefore not come as a surprise that China exerts multiple influences on events in Brazil, often to the detriment of Amazon forest.

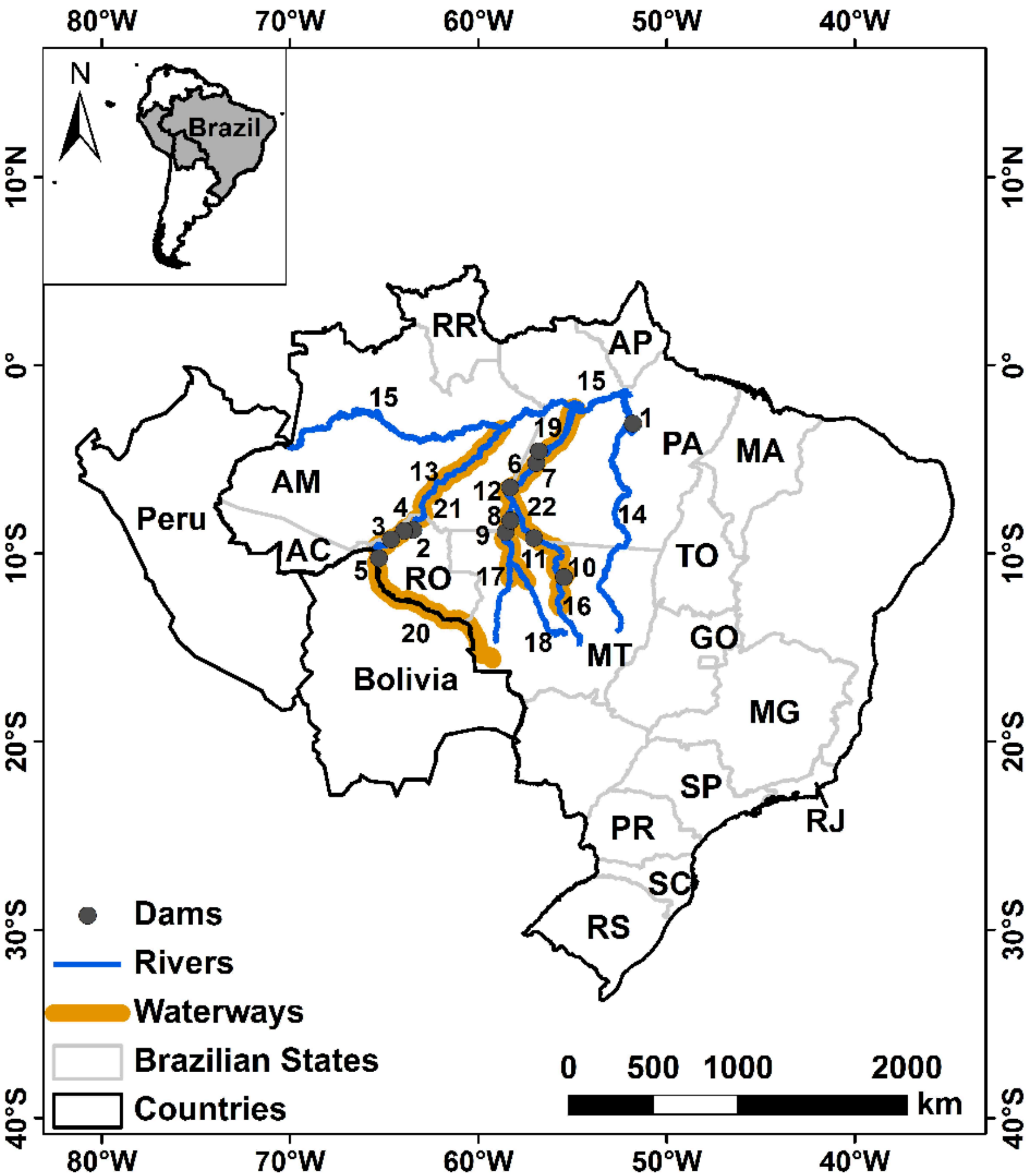
Brazil's state of Mato Grosso (Figures 1 and 2) is one of the main targets for Chinese investment and is the source of most of one of the major Brazilian exports: soybeans. Mato Grosso is twice the size of the US state of California and is one of the most important agricultural areas in South America and in the world. In the 2012-2013 agricultural year Mato Grosso's estimated production was 23.5 million tons of soybeans (29% of Brazil's production), with 7.0 million hectares planted and a productivity of 2959 Kg/ha (Brazil, IBGE, 2013). Improvements in transport infrastructure are expected to allow a much larger area to be planted with soy, especially in the northern part of the state. Chinese land purchases in Mato Grosso have been mostly for soy, but they also include some areas for cotton production.

Figure 1: Cities, highways, railways and protected areas mentioned in the text



Cities: 1 = Itacoatiara, 2 = Porto Velho, 3 = Carauarí, 4 = Altamira, 5= Barcarena, 6 = Cuiabá, 7 = Santarém, 8 = Juína, 9 = Porto dos Gaúchos, 10 = Vilhena, 11 = Sapezal, 12 = Lucas do Rio Verde, 13 = Belém, 14 = Manaus, 15 Cruzeiro do Sul, 16 = Anápolis, 17 = Sorriso, 18 = Querência, 19 = Santa Cruz, 20 = Piura. ***Protected areas:*** 21 = Amazonia National Park, 22 = Juruena National Park, 23 = Xingu Indigenous Park. ***Highways:*** 24 = BR-319, 25 = BR-163, 26 = MT-322, 27 = MT-319. ***Railways:*** 28 = Transcontinental Railway, 29 = North-South Railway, 39 = Ferronorte Railway. ***Other:*** 31 = Carajás Mine. ***Brazilian states:*** AC = Acre, AM = Amazonas, AP = Amapá, GO = Goiás, MA = Maranhão, MG = Minas Gerais, MT = Mato Grosso, PA = Pará, PR =Paraná, RJ = Rio de Janeiro, RO = Rondônia, RR = Roraima, RS = Rio Grande do Sul, SC = Santa Catarina, SP = São Paulo, TO = Tocantins.

Figure 2: Dams, rivers and waterways mentioned in the text

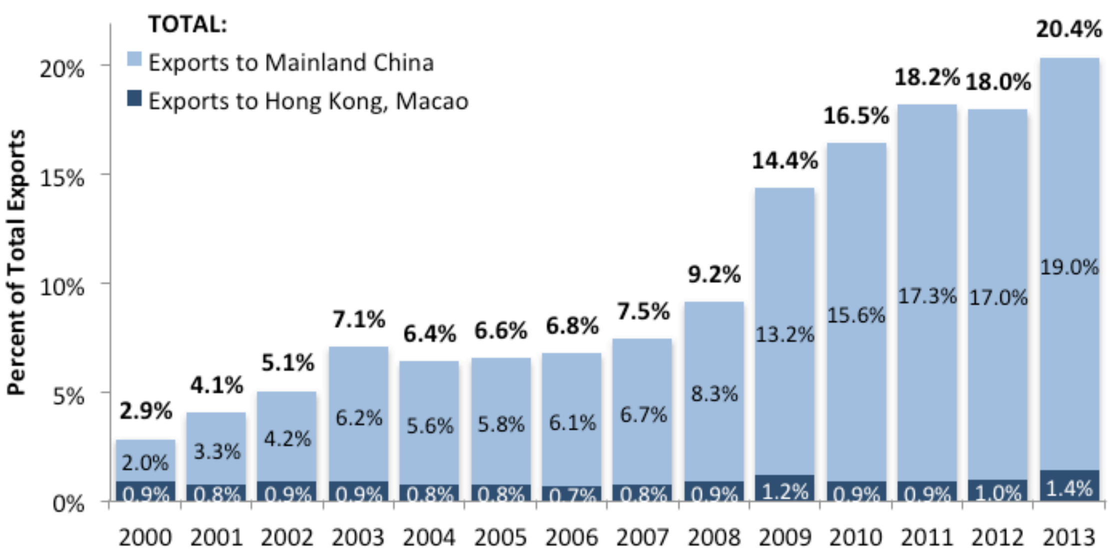


Dams: 1 = Belo Monte Dam, 2 = Samuel Dam. 3 = Jirau Dam, 4 = Santo Antônio Dam, 5 = Guajará Mirim (Cachoeira Riberão) Dam, 6 = São Luiz do Tapajós Dam, 7 = Jatobá Dam, 8 = São Simão Alto Dam, 9 = Salto Augusto Baixo Dam, 10 = Sinop Dam, 11 = São Manoel Dam, 12 = Chacorão Dam. ***Rivers:*** 13 = Madeira River, 14 = Xingu River, 15 = Amazon River, 16 = Teles Pires River, 17 = Juruena River. 18 = Arinos River, 19 = Tapajós River. ***Waterways:*** 20 = Guaporé Waterway, 21 = Madeira Waterway, 22 = Tapajós Waterway. ***Brazilian states:*** AC = Acre, AM = Amazonas, AP = Amapá, GO = Goiás, MA = Maranhão, MG = Minas Gerais, MT = Mato Grosso, PA = Pará, PR =Paraná, RJ = Rio de Janeiro, RO = Rondônia, RR = Roraima, RS = Rio Grande do Sul, SC = Santa Catarina, SP = São Paulo, TO = Tocantins.

2. Brazil's Exports to China and the World

Brazil's exports to the world, including China, increased dramatically over the 2003-2008 period. The annual mean growth rate of Brazilian exports in the 1990-2002 period was 5.6%, but the annual rate jumped to 22% for the 2003-2008 period (Bittencourt et al., 2012, p. 102). The global economic downturn then led to a fall in total Brazilian exports in 2009, but economic recovery was followed by a new export record in 2010. Exports bound for China grew much faster than the trend for Brazilian exports in general: over the 2000-2008 period exports to China grew at an average annual rate of 40.4%. They even grew by 23.1% in 2009 when Brazil's total exports fell by 22.2% (Bittencourt et al., 2012, p. 103). The percentage of Brazil's exports represented by China grew from only 2% (or 2.8% including Hong Kong and Macao) in 2000 to 19% (or 20.4% including Hong Kong and Macao) in 2012, making China Brazil's number one individual market, as shown in Figure 3 (UN Comtrade, 2013). This percentage doubled in the 2008-2012 period. The increased exports to China were mirrored by decreases in exports to the United States and the European Union.

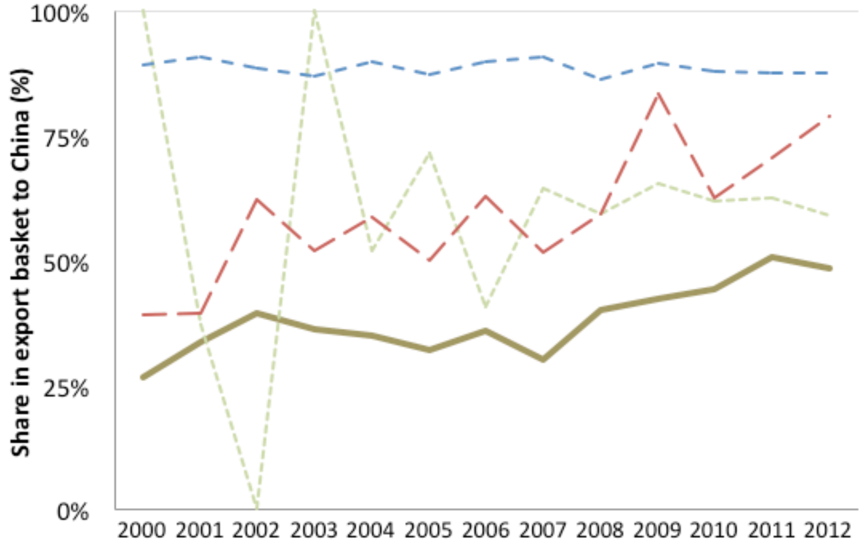
Figure 3: Brazil's Exports to China as a Share of All Brazilian Exports, 2000-2012.



Source: UN Comtrade (2014).

The nature of what was being exported also changed, with primary commodities increasing from 38.9% in 2000 to 44.9% in 2008 and 51.0% in 2009, when China became dominant (Bittencourt et al., 2012, p. 106). The increasing role of China is an important factor in this shift. In 2000, Brazil accounted for 27% of Latin America's primary and resource-based products (PRBP) exports to China, but that share grew to 48% in 2012, after a peak of 51% in 2011, as shown in Figure 4 (UN Comtrade, 2013). For soybeans and other seeds this percentage grew from 39% in 2000 to 79% in 2012, after a peak of 83% in 2009 (SITC Revision 3, 222). For iron ore and iron concentrate the percentage each year was always between 87 and 91% (SITC Revision 3, 281). For crude petroleum, after some variation in the 2000-2003 period, the percentage stabilized between 59 and 65% after 2007 (SITC Revision 3, 333). All of these products have significant impact on the environment. Unfortunately, cross-national studies indicate that export of primary commodities is associated with the least gains in indicators of human wellbeing in the exporting countries (Carmignani & Avom, 2010).

Figure 4. Share of Brazil in 2000-2012 Latin American exports to China, by type



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
All primary, resource-based products	27%	33%	39%	36%	35%	32%	36%	30%	40%	42%	44%	51%	48%
Crude Petroleum	100%	37%	0%	100%	52%	71%	40%	64%	59%	65%	62%	63%	59%
Iron ore, concentrates	89%	91%	88%	87%	90%	87%	90%	91%	86%	89%	88%	88%	88%
Soybean, other oilseeds	39%	39%	62%	52%	58%	50%	63%	51%	59%	83%	63%	70%	79%

Notes: Commodities are defined using SITC Rev.3. Soybeans and other seeds corresponde to 222, iron ore and concentrates to 281, and crude petroleum to 333. Source: UN Comtrade (2013).

3. China and deforestation in the state of Mato Grosso

Some of the main drivers of Amazon deforestation include roads, agribusiness development (cattle pasture, soybean production, logging and agro-industrial expansion), fire and mining (Brown, 2004; Fearnside, 2005a, 2008a). Hargrave & Kis-Katos (2011) analyzed the economic causes of deforestation in the Brazilian Amazon with a regression method. They investigated the deforested area using the theoretical model of Angelsen (1999), who argued that deforestation can be explained by the expected profits from land use, but that liberalization and macroeconomic issues may also be relevant. Angelsen and Kaimowitz (1999) showed that agricultural and forestry exports may lead to more deforestation. In general, the literature points to such deforestation causes as the area of soybeans harvested, the area of cattle pastures, the prices of these commodities, roads, population density, cattle herd size, geographical variables related to climate and soil, rural credit policies and economic growth (Morton et al., 2006; Barona et al., 2010; Martins & Pereira, 2012). Hargrave and Kis-Katos (2011) estimated deforestation as a function of these possible causes for each municipality (county) in the Legal Amazon (this 5-million km^2 administrative region includes the states of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins). They show soybean prices and environmental fines to be factors influencing deforestation. Their findings, however, did not explicitly take into account the exports to China as the main consumer of Amazonian soybeans. An econometric study of deforestation in Mato Grosso using municipality-level data from 2001 to 2010 shows the strong role of soy, beef and wood exports (Moreira, 2013). Moreira (2013) did not separate exports to China from those bound for other destinations, but as the largest purchaser of these commodities, particularly for soybeans, China's role is clear. Even before the recent surge of exports to China, Nepstad et al. (2006) argued that China's demand for Brazilian soybeans has stimulated production and also deforestation in Mato Grosso, the biggest Brazilian producer.

We concentrate our attention on Mato Grosso, where the effect of soybeans is paramount, rather than timber, beef and minerals (which are also exported to China). Soybeans are a major force in clearing of the *cerrado* (central-Brazilian savanna) and in Amazonian deforestation both in areas that are climatically and topographically appropriate for planting soy and in areas that are not good for soy but where deforesters gain access using soy-related transportation infrastructure (Fearnside, 2001a, 2007). The expansion of soy into pasture areas in Mato Grosso also leads to displaced deforestation for cattle in Pará, the state bordering Mato Grosso to the north (Arima et al., 2011). In addition to its impact on deforestation, the migration of ranchers to Pará and the expansion of pasture there can exacerbate land-tenure conflicts, usually at the expense of small farmers and traditional peoples (e.g., Fearnside, 2001b).

The rapid rise in exports of products such soy and beef to China have consequences for Amazonian deforestation that, while they may appear obvious, are nevertheless complex to quantify and interpret. This direct impact of commodity exports is only the tip of the iceberg of Chinese influence on Amazonia. Money earned from this trade is strengthening Brazilian agribusiness interests, with profound effects on domestic politics that are reflected in legislative and administrative changes weakening environmental protection. Impacts can also be expected from Chinese financing under negotiation for infrastructure such as a railway linking the state of Mato Grosso to a port on the Amazon River. Mato Grosso is a major focus of expansion of soy, cotton and intensified cattle production. Chinese purchases of land for agriculture and timber imply an increasing direct role in commodity production. Other impacts come from exports from mining and from the processing of minerals, especially the demands for charcoal for pig-iron smelters and for electricity from hydroelectric dams for aluminum smelters.

4. Brazil's exports to China

4.1 Interpreting export data

Data on exports by product, origin and destination (for quantities as well as value in US dollars) are provided by the Aliceweb system (Online Information System for Analysis of Foreign Trade) of the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC). Chinese demand for Brazilian exports reached approximately US$30 billion in 2010, having increased tremendously since 2000, with annual geometric rates from 2000 to 2010 of about 44% for non-agricultural products and 34% for agricultural products in values FOB[3]. Exports from the Legal Amazon to China have also increased at an impressive rate of 52% yearly from 2000 to 2010,

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[3] "Free on board," or the value at the port of shipment net of all domestic transportation and loading costs

increasing from US$104 million in 2000 to US$6631 million in 2010 (research data based on Brazil, MDIC, 2012).

Exports to China from the Brazilian Legal Amazon rose from an average of 13% of total Brazilian exports to China in the 2000-2004 period to an average of 23% in the 2005-2010 period. The change occurred abruptly from 14.6% in 2004 to 23.3% in 2005 and then kept stable. Almost half of the change in the 2004-2005 period can be attributed to FOB price increases, but for the 2009-2010 period (when FOB prices were lower) the physical quantities explain most of the increase in value (research data based on Brazil, MDIC, 2012).

An interesting point to observe is that the share of export value represented by a soybean composite (soy grain, soy oil and other vegetable oil) decreased from a high of 66.3% in 2003 to 34.4% in 2010, with an average of 47.7% over the last five years. Iron and manganese now represent a large share of Brazilian exports to China, reaching 63.1% in 2010 (49.8% as a 5-year average). In 2010 about 83% of the Legal Amazon's exports were from the states of Pará (52% - iron) and Mato Grosso (31% - soybeans). The share of iron plus soybeans in these two states decreased from 79% in 2006 to 72% in 2008, but then rebounded to high levels: 89% in 2009 and 83% in 2010 (research data based on Brazil, MDIC, 2012).

Figure 5 graphs the exports of soybeans from Mato Grosso and of iron from Pará. The impressive increase is apparent. The value of iron from Pará and of soybeans from Mato Grosso totaled US$5.5 billion in 2010 (research data based on Brazil, MDIC, 2012).

Figure 5. Value of exports, soybeans from Mato Grosso and iron from Pará

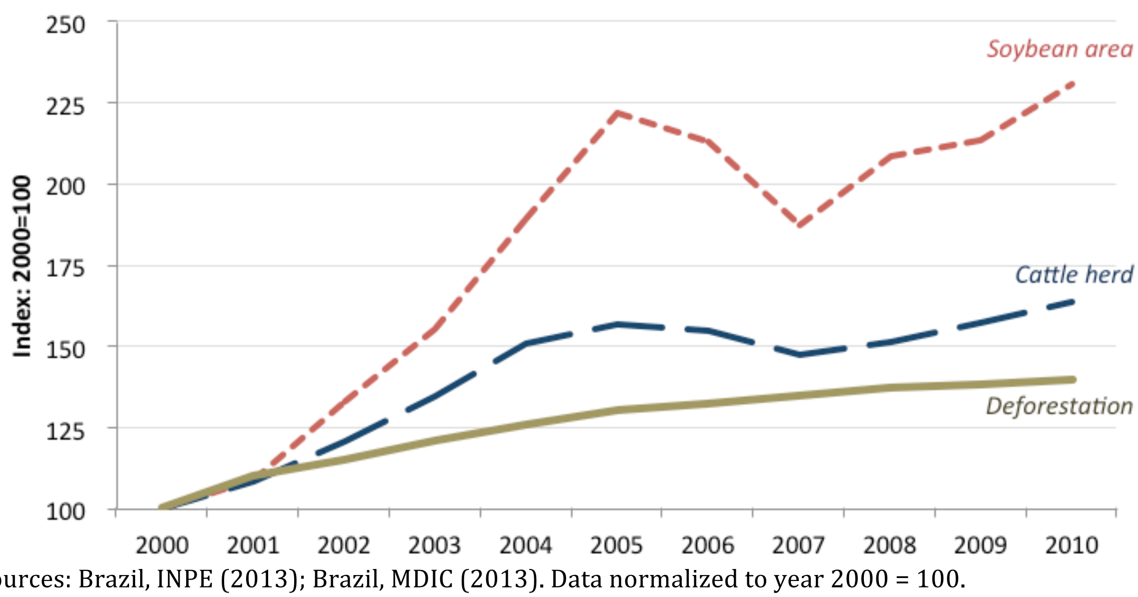
Note: Values are shown in USD, on an FOB basis. Source: Brazil, MDIC (2013).

4.2 Interpreting deforestation data

Data on the area planted in soybeans and the size of the cattle herd were obtained from IBGE (Brazilian Institute of Geography and Statistics). Data on area deforested in the Brazilian Amazon are available from the Prodes project of the National Institute for Space Research (Brazil, INPE, 2013). The database reports deforested area in hectares at the municipal level for 2000-2010. Note that these data only report the clearing of forest, not the clearing of *cerrado* (central Brazilian savanna) that represents much of the soybean area in the state of Mato Grosso. We note that in the past there have been significant problems with Brazilian deforestation data (e.g., Fearnside, 1997a), but that transparency and reporting have been greatly improved for the years covered in our quantitative analysis.

Looking at deforestation in the Legal Amazon and comparing it to exports to China, to soybean planted area and to cattle herd size, Figure 6 exhibits an interesting behavior. In Figure 6, based on Brazil, INPE (2013) deforestation data and on Brazil, IBGE (2012) agricultural data, the cumulative area may give a misleading interpretation because this area is not the increase in deforestation. Cumulative deforested area clearly has a positive relationship with area of soybeans, size of the cattle herd and value of exports, but for each year there is a different value for exports and soybean area, while deforested area is a cumulative value. One point to be observed is that recent expansion of soybeans in Mato Grosso is taking place in preexisting pastures that represent areas deforested at some time in the past. Advance of soybeans into pasture areas in Mato Grosso has long been believed to displace ranching activity into forest areas such as those in Pará, contributing to deforestation there (Fearnside, 2001a; Fargione et al., 2008). Recently this effect has been demonstrated statistically (Arima et al., 2011). Brazilian diplomats currently deny this effect, and in March 2014 they were successful in getting mention of it deleted from the summary for policy makers of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Garcia, 2014).

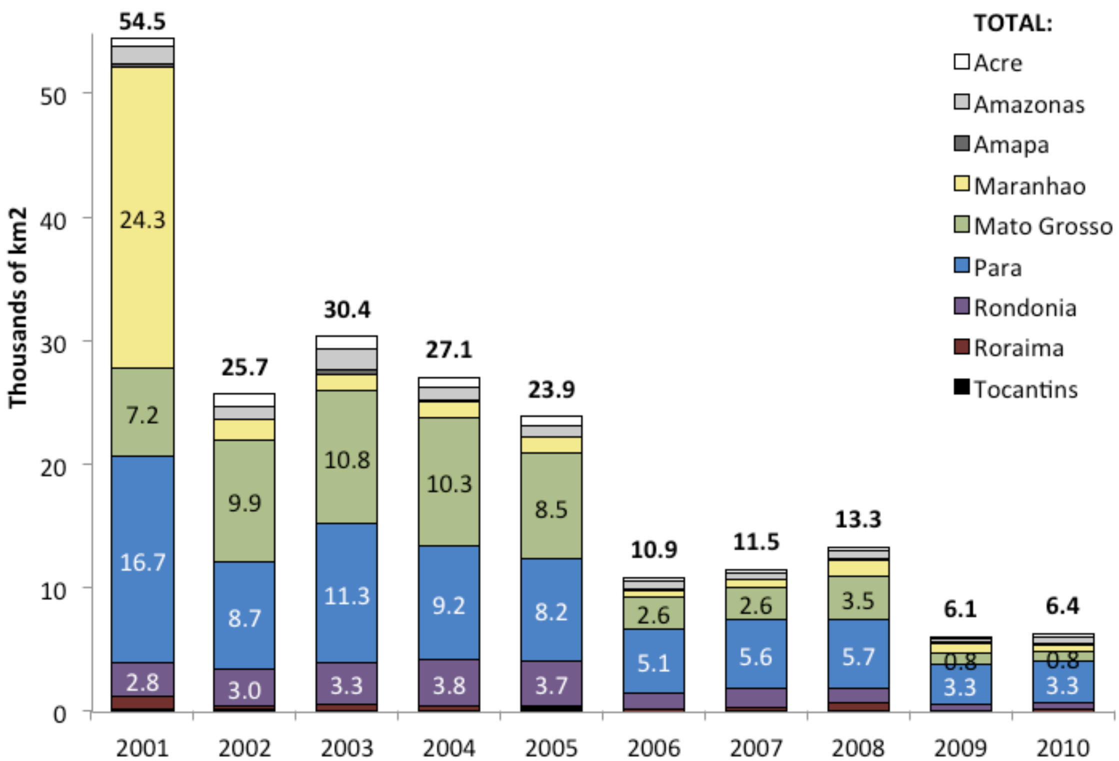
Figure 6. Cumulative area of deforestation (km²), Soybean planted area (ha), Cattle herd (head) in the Brazilian Legal Amazon, 2000-2010.



Sources: Brazil, INPE (2013); Brazil, MDIC (2013). Data normalized to year 2000 = 100.

In Figure 7, increase in deforested area is depicted for each state in the Legal Amazon using Brazil, INPE (2013) data. It can be observed that deforestation rate has declined since 2001, staying below 10,000 km² in 2009-2010. The state of Pará had the largest increase in deforested area (almost 3400 km²), or 52.6% of the total increase in 2010. Mato Grosso was an important state up to 2008 with a rapid expansion in agriculture and cattle raising, but there was a significant reduction in 2009-2010: Mato Grosso accounted for only 12% of the total increase in 2010.

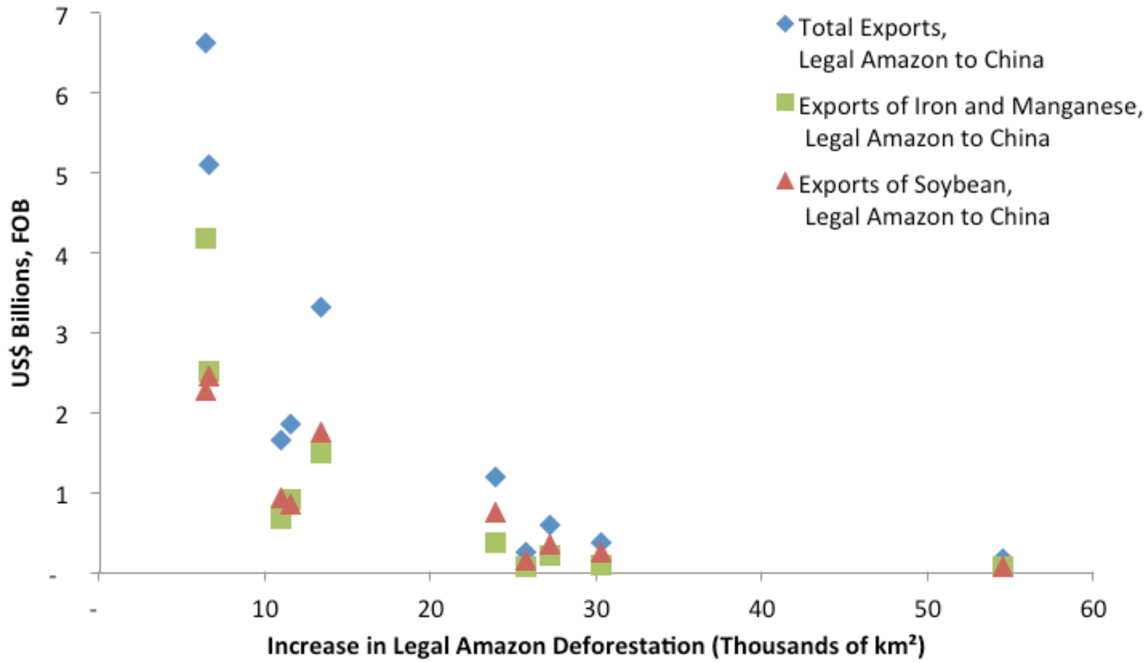
Figure 7. Annual increase in deforested area (km²) in each state in the Brazilian Legal Amazon, 2001-2010.



Source: Brazil, INPE (2013).

Data from Brazil, INPE (2013) and Brazil, MDIC (2012) exhibit a strict positive relationship between cumulative deforestation and the Legal Amazon's exports, with a high correlation (0.82). A different pattern is seen if increase in deforestation is plotted against the value of exports. This shows an inverted relationship with a negative correlation of -0.72 with total exports (Figure 8).

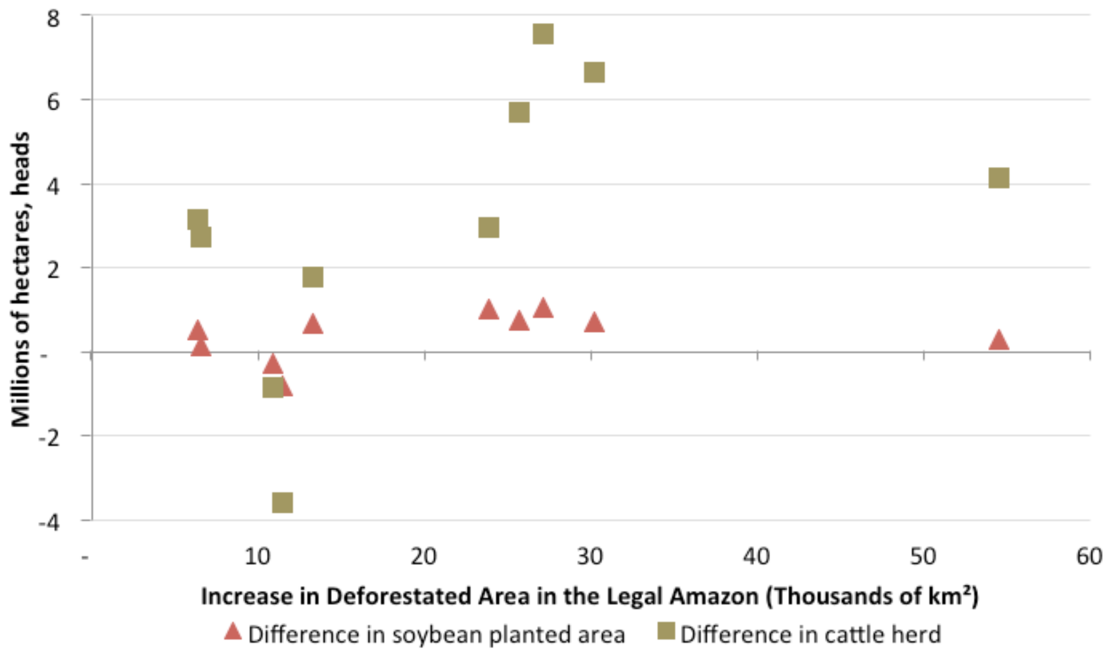
Figure 8. Increase in deforested area (km^2) in the Brazilian Legal Amazon against the value of exports to China, 2001-2010.



Sources: Brazil, INPE (2013); Brazil, MDIC (2013).

Looking at the data in this way, exports to China are not a driving force of deforestation directly, and more detailed observation is needed. Soy is a major product in total exports to China, but what is its relationship to the increase in deforestation? Figure 6 indicates a pattern associating cumulative deforestation with soybean area and cattle herd size. Figure 8 shows the increase in deforestation against these two variables using Brazil, INPE (2013) and Brazil, IBGE (2012) data.

Figure 9. Increase in deforested area (km²) in the Brazilian Legal Amazon against the difference in soybean planted area and in cattle herd size, 2001-2010.



Sources: Brazil, IBGE (2012); Brazil, MDIC (2013).

According to Figure 9, the increase in deforested area is accompanied by increases in either the cattle herd or the soybean area. However, the regression line had non-significant parameters and the correlations with the increase in deforestation were only 0.3 for soybeans and 0.5 for cattle. On the other hand, there is a strong positive correlation (0.85) between the differences in soybean area and in cattle herd size. The same pattern was found by Marta and Figueiredo (2008). A regression was performed for the entire Legal Amazon, aggregating the data from the nine states in the region. The deforestation process is quite complex, leading us to use a systems approach[4]. This approach allowed us to relate explanatory variables to both a deforestation equation and an exports equation. Here we will discuss some results of this system.

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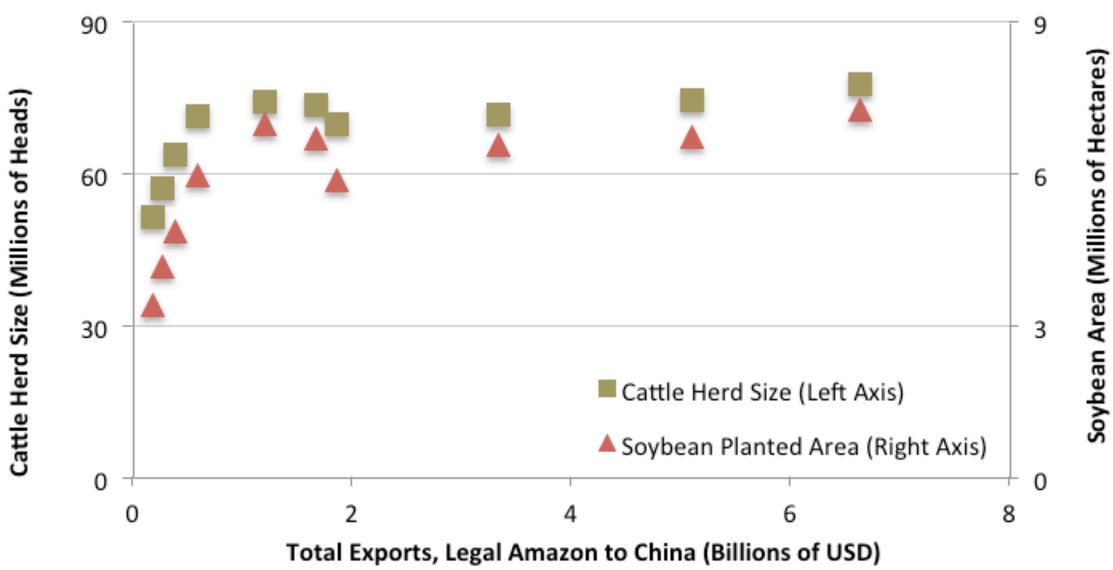
[4] The details for the system of equations as well as its results are provided in the Technical Appendix.

Deforestation rates throughout Brazilian Amazonia have declined substantially since 2004, with a statistically significant negative trend. The decline through 2008 is explained by falling international prices of soy and beef in the 2004-2006 period, together with a worsening exchange rate of the Brazilian real against other currencies from the point of view of exporters, but deforestation continued to decline after 2008 despite a recovery in commodity prices (Assunção et al., 2012).

Figure 10 shows the relation of exports to soybeans and cattle according to Brazil, MDIC (2012) and Brazil, IBGE (2012) data. The two dispersion plots in Figure 8 present essentially the same information: a positive correlation between the exports to China and the sizes of the herd and the crop. The correlation is 0.69 for soybean area and 0.67 for cattle herd.

Figure 10. Total exports from the Brazilian Legal Amazon to China against the soybean planted area and cattle herd, 2001-2010.



Sources: Brazil, IBGE (2012); Brazil, MDIC (2013).
Note: Total exports from Legal Amazon to China in FOB US$ billion. Soybean planted area in 10^3 hectares. Cattle herd in millions of head.

The idea is that soybeans are planted in already-existing cattle pastures (Marta & Figueiredo, 2008). The soybeans are then exported and there is a kind of learning process where exports lead to an effect on the next period's exports. The preceding period's exports and cattle herd size, as well as current soybean planted area, soybean price and beef price explained the change in deforestation in the current period.

On the other side, the soybean plantations are occupying previous pastures. The persistence of cattle herds occupying land is a restriction on soybean cultivation and exports. The land-use shift from old degraded pasture into soybean cropping can, in some way, have a positive effect on exports. The problem is that expansion in soybean area leads to increase in deforestation. Increasing cattle herd size also has a statistical impact on the increase in deforestation, similar to other studies that have found a strong effect of cattle herd size on deforestation (e.g., Alencar et al., 2004; Kaimowitz et al., 2004; Arima et al., 2005). Nevertheless, increasing the herd size appeared to reduce exports to China and this reduction would lead to a decrease in deforestation.

Two factors can help explain the relationship between cattle and deforestation in Mato Grosso. First, is the recent spread of techniques for improving pasture productivity (or pasture stocking), particularly in Mato Grosso, as well as the growth of feedlots. Feedlot holding capacity in Mato Grosso grew from 668,000 head in 2009 to 883,000 in 2014; interviews with ranchers conducted by the Mato Grosso state government indicate a dramatic surge of intention to hold cattle in feedlots in the northern part of the state, where plans for this practice doubled from 2013 to 2014 (IMEA, 2014). These feedlot meats are mainly for high-quality beef exports. Although our analysis is at the level of the Legal Amazon for all variables, the effect of intensification would probably be substantially less important in other Amazonian states such as Pará.

A second factor is that China only recently permitted the importation of Brazilian beef. Until that point, the increase in herds represented a restriction on products that could be exported to China, namely soy, leading to more deforestation for pasture. For example, reducing soybean exports would lead to pasture and herd increases. Prices of soybeans and beef also impact deforestation rates, with soybean price as a direct effect and beef price having an indirect negative effect on deforestation rates. Now that China has authorized imports of Brazilian beef, it is expected to exert pressure on the Brazilian beef market, competing with the Brazilian soybean exports.

Even though states like Mato Grosso and Pará exhibited increases in cattle herd size after 2010, the herd in 2010 was about the same size as in 2005 for Pará, and Mato Grosso. The herd remained constant over the 2005-2008 period and had remarkable increases of more than 5% annually in 2009 and 2010. Mato Grosso had small increases in deforestation in 2009 and 2010, although it was one of the states with the largest increases in deforestation between 2000 and 2008, clearing land for herd expansion in the following years.

The relations of soybeans and cattle to deforestation over the 2000-2010 period were complicated by other factors that influenced the deforestation process to differing degrees in each year. The efforts of environmental authorities to control illegal deforestation through inspections and fines have varied substantially (Nepstad et al., 2014). Increased efforts to control deforestation appear to have had a significant effect from 2008 onwards, whereas before 2008 deforestation rates track soy and beef prices closely (Barreto et al., 2011; Assunção et al., 2012). In addition, the periods immediately preceding elections are normally characterized by deforestation increases both as a result of political pressure to relax environmental enforcement (especially at the state level) and as a result of anticipation by deforesters that election results will bring relaxed enforcement and/or amnesties forgiving past violations (see Fearnside, 2003).

A key change that occurred in 2008 was a decision by Brazil's Central Bank that no public bank loans could be given to operations with environmental irregularities reported by agencies such as IBAMA (BACEN Resolution 3.545/2008). Unlike fines given by IBAMA and other agencies, which can be circumvented with a seemingly endless sequence of appeals, the restriction on bank loans has real teeth and an immediate effect. The credit restriction greatly increases the impact of the environmental inspection programs, even if the programs themselves do not change substantially in scale and even in the face of the inability of agencies like IBAMA to collect most of the fines. This recent change in bank policy was not included in our model, and its effect remains as a suggestion for further study. Increased exports were possible at a time of decreasing deforestation due to rising per-hectare soy yields, clearing in non-forest vegetation types (i.e., *cerrado*), and soy expansion in former cattle pastures (the indirect effects of which would be displaced beyond the borders of Mato Grosso to increase pasture in Pará).

4.3 Other commodities exported from Brazilian Amazonia

4.3.1 Timber

China has cut almost all of its natural forests and, despite large-scale plantations of fast-growing trees, the country has a tremendous demand for timber such as that from Brazil's Amazon forest. Unlike European and North-American markets, China is willing to buy wood from almost any species of tropical tree. An example of this occurred when timber was sold prior to the 1988 flooding the Samuel Dam in the state of Rondônia (Fearnside. 2005b). Export of raw logs from Brazil has been prohibited since 1965, but an exception was opened to allow logs from Samuel to be exported (Nogueira, 1988). From 1987 through 1989, a continuous chain of barges arrived in the Amazon River port of Itacoatiara with logs for loading on ships, and one ship loaded with logs departed for China every two weeks during this period. The exception opened for the relatively small Samuel reservoir area had allowed logs to be illegally exported from vast areas in western Amazonia.

Chinese companies purchased several bankrupt sawmills in Manaus in 1996, thereby gaining the forestland holdings of the sawmill companies. Together with Malaysia, land purchases totaled 4.5 million hectares in the state of Amazonas (*Amazonas em Tempo*, 1996). Most of the forestland bought by Chinese companies was in the municipality of Carauarí. A major increase in logging activity was expected at the time, but this did not occur (presumably due to the substantial bureaucratic barriers to obtaining approval of forestry management plans). Other countries have been satisfying most of the world's demand for tropical timber, including the demands of China. However, Brazil has by far the largest stock of remaining tropical forest, and the pressure of this demand is bound to focus on Brazil once available stocks elsewhere are exhausted (Fearnside, 1989a).

4.3.2 Alumina, aluminum and iron

Chinese companies have interests in alumina (Al_2O_3: the precursor of primary aluminum) in Barcarena, Pará, where Alumina Brasil-China (ABC) and Aluminum Corporation of China Limited (Chalco) have a joint venture with the Brazilian mining company Vale (Vale, 2009). The power demand for this electricity-intensive industry contributes to Brazil's push for a massive increase in building hydroelectric dams in Amazonia over the next decade. Brazil's 2011-2020 ten-year energy-expansion plan (Brazil, MME, 2011) calls for 30 large dams to be built in the Legal Amazon by 2020, a rate of one dam every four months. The Chinese-Brazilian alumina plant will be an important beneficiary of the Belo Monte Dam, now under construction on the Xingu River, near Altamira, Pará. Belo Monte has environmental and social impacts that extend far beyond the areas that will be directly flooded, and the dam is likely to justify much larger upstream reservoirs to regulate the river's flow (Fearnside, 2006). The dam has functioned as a "spearhead" in creating precedents that weaken Brazil's environmental licensing system and prepare the way for the many dams proposed under the energy-expansion plan (Fearnside, 2012). In February 2014 a consortium led by Chinese State Grid won the bidding for the R$5 billion (US$2 billion) contract to build the transmission line for Belo Monte. The expansion of Amazonian dams also receives a boost from China's equipment sales, as in the case of the turbines from Dong Fang Electric Corporation International and Dong Fang Electric Machinery for the Jirau Dam now under construction on the Madeira River. The influence of both Brazil and China in expanding carbon credit for hydroelectric projects under the Kyoto Protocol's Clean Development Mechanism has further increased the profitability of dams (Fearnside, 2013a,b).

Iron from Brazil is now largely exported to China (Soares, 2012) (and previously shown in the introduction of this chapter). The Chinese market has eclipsed the European purchasers that dominated exports from the Carajás Mine, in Pará, when the mine was opened in the 1980s. Processing of part of the ore for export as pig-iron consumes charcoal, providing a longstanding source of pressure on the forests of eastern Amazonia and a challenge to environmental and labor authorities (Fearnside, 1989b). The environmental and social impacts of charcoal production made European iron imports from Amazonia a target for criticism from non-governmental organizations (e.g., Sutton, 1994), but this is no longer evident now that exports have shifted to China. Brazil's export of iron alloys, although representing far smaller quantities than iron in the form of ore or pig-iron, is the fastest-growing category of exports to China, tripling from 4000 to 12,000 tons between 2013 and 2014 (CEBC, 2014). Producing iron alloys consumes a tremendous amount of electricity and creates a miniscule amount of employment in Brazil: 1.1 jobs per GWh of electricity consumed, or even less than primary aluminum, which creates only 2.7 jobs per GWh (Bermann & Martins, 2000, p. 90).

5. China and political shifts in Brazil

The political influence of the "ruralist" voting block that represents large landholders in Brazil's National Congress is has increased markedly due to the large amounts of money entering Brazil from the export of soybeans, China being the number one source of these earnings. The shift of Brazil's economy towards agricultural commodity exports (strengthening the influence of large landowners) and away from manufacturing (weakening the influence of industrialists and labor unions) is affecting virtually every aspect of Brazil's politics (e.g., ISA, 2014). Effects include the positions of the current presidential administration on environmental issues (Santilli, 2014; Smeraldi, 2014). The "ruralist" block is currently trying to revert the Brazilian Central Bank's resolution blocking loans for agriculture and ranching from the Banco do Brasil (BB), Caixa Econômica Federal (CEF) and Banco da Amazônia (BASA) for properties with pending fines for environmental violations.

China's influence on this transition extends beyond the boost to "ruralist" influence from soy income: China's exports of cheap manufactured goods to Brazilian manufacturers' former export markets has cut deeply into Brazil's exports from this sector, and China's direct export of manufactured goods to Brazil further displaces Brazilian manufacturing and reduces the political influence of this sector within Brazil. Brazil has maintained an approximate balance in terms of monetary value between exports to and imports from China (Figure 11). This balance may be influenced by trade negotiations between the two countries in which the Chinese interest in maximizing its exports could help explain the close parallel between the increasing monetary flows in the two directions. Unlike countries that have little domestic manufacturing to lose, the effect in Brazil is significant. The increasing exports of agricultural commodities and imports of manufactured goods contribute to a shift in political influence in Brazil from the manufacturing to the agribusiness sectors, with consequences for environmental policies.

Figure 11. Brazil's trade balance with China

Source: Authors' calculations based on UN COMTRADE data.

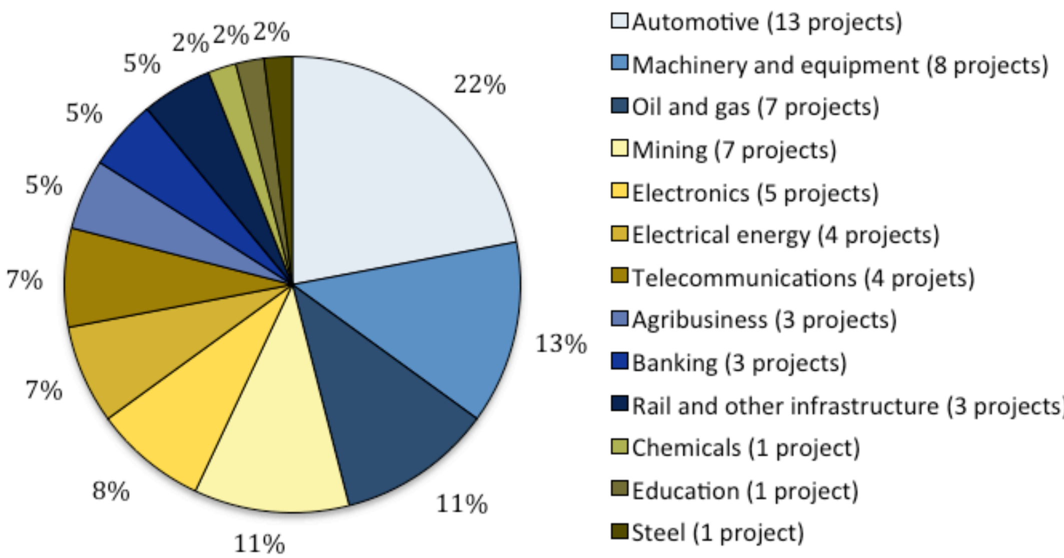
6. Financing from China

Another issue is the effect of Chinese finance in Latin America. China is a new and growing source of funding with less environmental restrictions, lower interest rates and different size loans (Gallagher et al., 2012).

Official data regarding the foreign direct investment (FDI) in Brazil are found in Brazil BCB (2014), in the census from the Brazilian Central Bank. The Chinese stock of FDI in Brazil (in capital shares and immediate investor) changed from US$582 million in 2010 to US$ 1,093 million in 2012. Looking as final investor, who occupies the top of the control chain, this FDI stock in capital shares went from US$ 7,874 million to US$ 10,226 million in the same period (Brazil´s total FDI stock is US$ 617,384 million for all countries). This 2012 value is divided by sector as: extractive Industries (82.3%); manufacturing (1.3%); trade and repair of vehicles (2.6%); and others (13.9%).

Most Chinese loans are for the oil, iron, steel, energy and telecom sectors. From 2007 to 2012, the China Brazil Business Council (CBBC) "recorded a total of 60 announced Chinese investment projects for a total of US$ 68.5 billion" (CBBC, 2013), of which 54 were in the 2010-2012 period and 47 were partially or completely state-funded. Regarding the investment motivation, 57% were resource seeking, but lately, from 2011-2012, market oriented investments dominated. Chinese investment projects are distributed amongst 14 Brazilian sectors, as shown in Figure 12.

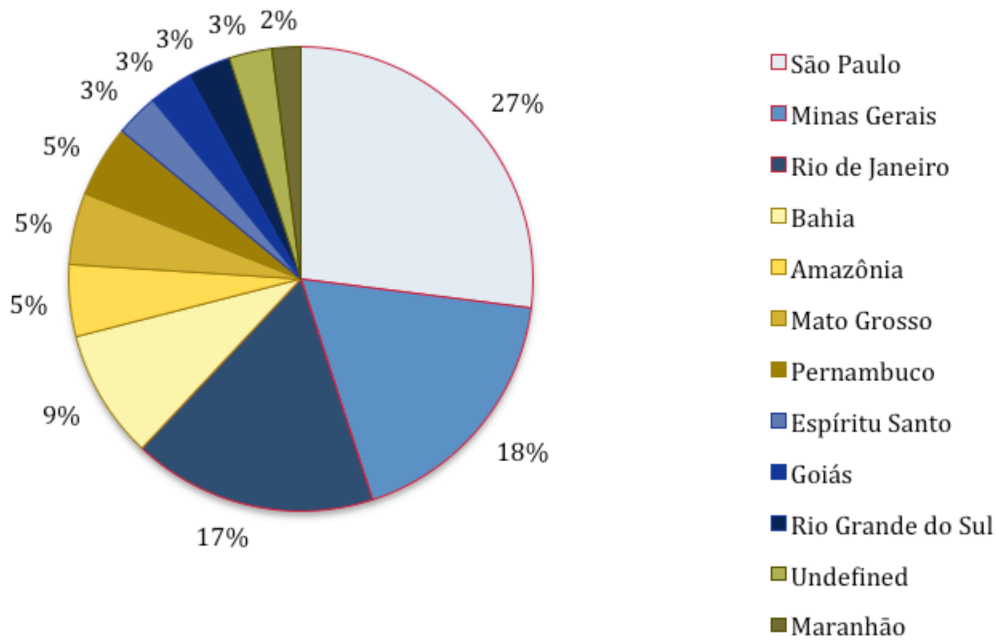
Figure 12. Chinese investment projects by sector (number of projects), 2007 to June 2012.



Source: CBBC (2013, p. 14).

The Chinese investment is highly concentrated in the three states of the Southeast macro-region: São Paulo (27% - Banking, Telecom, Automotive and Electronics), Minas Gerais (18% - Machinery and Equipment) and Rio de Janeiro (17% - electrical energy, oil and gas) (Figure 13). Mato Grosso and Amazonas each accounts for 5%.

Figure 13. Chinese Investment projects by State (number of projects).



Source: CBBC (2013, p.15).

The official website of the state of Mato Grosso reports that the China Development Bank Corporation (CDBC) intends to finance the China Railway Engineering Corporation (CREC), which, together with the Asian Trade & Investments (ATI) (a holding in Hong Kong), is interested in building and operating a 1800-km railroad between Cuiabá (Mato Grosso) and Santarém (a port city on the Amazon River); the railway (EF-170) would cut through Amazonia beside the BR-163 Highway (Mato Grosso, 2012; Bland, 2013; CBBC, 2013). The China National Machinery Import & Export Corporation (CMC) would be among the partners, according to *Business News Americas* (2011). CREC staff also met with the governor of Mato Grosso, who led a delegation to China to negotiate support for the planned railway (Lucatelli, 2012).

The Cuiabá- Santarém railway (Ferronorte) has long figured in Brazilian development plans (see Laurance et al., 2001), but the high cost has kept it from being built until now. This railway has appeared in Brazilian government plans since the 1990s (See: Fearnside, 2002a), but the project did not rise to the top of the priority list until China's interest in providing a US$ 10 billion loan to finance it became clear in 2012. Chinese financing could remove this barrier (Maisonnave, 2012).

Another project, the “Transcontinental Railway” (EF-354) is planned to link to the North-South Railway at Anapolis, Goiás, cutting across the entire state of Mato Grosso from east to west. It would connect Lucas do Rio Verde (a major soy production area in central Mato Grosso) to Porto Velho, Rondônia, which is already connected to a deepwater port on the Amazon River via the Madeira waterway. The railway project, which is led by VALEC (a Brazilian government-owned company under the Ministry of Transportation), would subsequently continue on from Porto Velho to Peruvian ports on the Pacific (VALEC, 2014). Just the Brazilian portion of the route totals 4400 km, including a connection of this railway from Mato Grosso to the Atlantic. The president of the Brazil-China Business Council has suggested that Chinese firms have “funds to finance partnerships with Brazilian construction companies” that would be “strategic” in completing the rail connection from Lucas do Rio Verde to the Atlantic (Amaral, 2014).

These major infrastructure development projects are intended to facilitate trade and save on logistical costs, improving and having more efficient export corridors in Brazil. The railway can be expected to stimulate substantial soy expansion in Mato Grosso. Soybean and Corn Advisor Inc. (2012) reports “The [Cuiabá-Santarém] railroad alone could save soybean producers in the state R$2 billion annually in reduced transportation costs.”

It should be remembered that major construction projects such as these very frequently involve corruption with significant effects on decision-making in the Brazilian government. An example is provided by revelations regarding the ongoing construction of Brazil’s North-South Railway, with recent revelations being just the latest in a series of scandals since construction began in 1986 (Mello & Amora, 2012). Options for improved regulation of this process include the establishment of a system of railway use permits that would be sold through auctions organized by the Brazilian government.

7. Global investments for Chinese demand

Chinese investments in Brazil, such as the planned soy railway from Mato Grosso to the Amazon River, are not the only way that China's market influences infrastructure and deforestation in Amazonia. Multinational (as well as Brazilian) corporations are also investing with the intent of supplying Chinese markets. For example, Bunge, a multinational soy company currently responsible for 25% of Brazil's production, opened a US$700 million soy port in Barcarena, at the mouth of the Amazon River, in April 2014. The company expects its exports from Brazil to double in the next 10 years, mainly as exports to China, and considers Brazil to be the only capable of responding to China's expected increase in demand in the coming years (Freitas, 2014). In the future, the soy to be exported from Barcarena is expected to arrive from Mato Grosso by barge via the planned Tapajós Waterway. This waterway would convert the Tapajós River in Pará, and its tributaries in Mato Grosso (the Teles Pires and Juruena Rivers) into navigable "*hidrovias*" to bring soy to the Amazon River from the northern part of the state of Mato Grosso. The waterway is a high priority in the "transport axis" of Brazil's current five-year development plan, the second "Program for the Acceleration of Growth" (PAC-2). Land use in the northern part of Mato Grosso is currently dominated by cattle pasture, but the reduced cost of transportation would lead to the area being converted to soy. The Tapajós waterway is controversial because it depends on a series of hydroelectric dams and locks being built to allow barges to pass a number of formidable rapids. Part of Amazonia National Park has already been degazetted to make way for the São Luiz de Tapajós reservoir (e.g., WWF Brasil, 2012). The São Luiz de Tapajós and Jatobá reservoirs would flood land of the Munduruku tribe that has not yet been officially designated as an "indigenous land" (Lourenço, 2014). The government plans to remove part of the Juruena National Park to make way for the

São Simão Alto and Salto Augusto Baixo Dams on the Juruena River (WWF Brasil, 2014). Most controversial is the Chacorão Dam, which would flood 18,721 ha of the Munduruku Indigenous Land. This dam does not appear in Brazil's current ten-year plan for energy expansion (Brazil, MME, 2013) and in the "energy axis" of PAC-2, but it is a key part of the waterway plan (Brazil, MT, 2010) and it appears in the viability study for the Tapajós Dams (CNEC, 2014).

The branch of the Tapajós waterway on the Juruena River would connect roads to bring soy from the central-western portion of the state, including Sapezal -- location of the 44,500-ha property that serves as headquarters of the A. Maggi Group, which has 20 properties spread throughout Mato Grosso (e.g., Ondei, 2012). Blairo Maggi, known as the "soy king" in Brazil, is an influential senator and past governor of Mato Grosso; in 2005 he was presented with the Greenpeace "golden chainsaw award" (Greenpeace, 2005). The Juruena River branch of the waterway would begin at a new port in Juina on the Juruena River and at Porto dos Gaúchos on the Arinos River, a Juruena tributary. Soy would reach these ports via roads from the south, including a new road (MT-319) to connect Juina to Vilhena, in eastern Rondônia, bisecting two indigenous areas (Macrologística, 2011).

Blairo Maggi also has an 80,800 ha property in Querência, in northwestern Mato Grosso. This would export soy via the BR-163 (Cuiabá-Santarém) Highway that is planned for reconstruction under PAC-2. This soy export corridor is expected to have strong impacts on deforestation other than that caused by expansion of soy plantations (Fearnside, 2007). The Maggi plantation in Querência would be linked to the BR-163 via the MT-322 (former BR-080) Highway Reconstruction of this east-west road bisecting the Xingu Indigenous Park is resisted by indigenous peoples; the Mato Grosso state government released a statement that an agreement had been reached to allow construction (Martins, 2014), but the indigenous groups involved are emphatic that no such agreement was made (Mayalu Kokometi Waurá Txucarramãe, pers. com., 2014). A. Maggi is Brazil's largest soy company. The multinationals Cargill, Bunge and ADM (Archer Daniels Midland) are also present in the portion of Mato Grosso to be served by the BR-163 connection through Pará.

Another branch of the Tapajós waterway would extend up the Teles Pires River to Sorriso; this requires a series of five dams, two of which (Sinop and São Manoel) are already under construction. The São Manoel Dam is located adjacent to an indigenous area and has already provoked conflicts with the Kayabi tribe (ISA, 2013).

Yet another area of Mato Grosso that is expected to be converted from pasture to soy is the southwestern corner of the state. This area would be opened for soy export by the planned Guaporé waterway that would connect with the Madeira River waterway once locks are installed in the recently built Santo Antônio and Jirau Dams, plus one additional planned dam (Guajará Mirim, also known as "Cachoeira Riberão") (Fearnside, 2014). Soy would be transported by barge to Maggi's soy terminal and deepwater port at Itacoatiara, on the Amazon River near the confluence with the Madeira. As with all of Brazil's major soy facilities, China is the main destination for exports.

An intriguing possible change in China's future soy imports has been raised by reported discussions within China of banning genetically modified organisms (GMOs). Were this to occur, Brazil would experience the negative consequences of excessive dependence on a single trading partner. However, China might find an immediate switch to non-GMO imports difficult to implement quickly, given the scale of the country's demand for imported soy. Were Brazil to attempt to convert its soy back to non-GMO varieties, the effort and expense needed to obtain uncontaminated harvests would be substantial. Ironically, Brazil was one of the last major soy-producing countries to make the switch to GMOs. Even Maggi himself opposed the switch when Europe was the major importer of Brazilian soy and the price of non-GMO soy was higher than that for GMO soy by an amount that made non-GMO soy the more profitable option (see Fearnside, 2001a). The price differential subsequently diminished, and GMOs were made legal in Brazil in 2003 (Decree 4680) over the objections of the Ministry of the Environment. Since concern over risks of GMO technology is greatest among European consumers, Brazil's switch to GMO soy undoubtedly contributed to the replacement of Europe by China as the main destination for Brazilian exports.

8. Land purchases by China

Currently land purchased directly by foreigners is limited to a maximum of 50 rural modules (making the limit 5000 ha in most of the Amazon region). The Brazilian government is planning to lower this limit with the express purpose of inhibiting land purchases by China (Reuters, 2011). Among other effects, the Brazilian government believes that a spate of recent Chinese land purchases is an important factor in a sharp rise in land prices in the country (*Latin American Herald Tribune*, 2012). However, the rising price of soy is also a factor (Agrimoney.com, 2011). Chinese land purchases in Brazil in progress in January 2012 are shown in Table 1.

Table 1: Chinese land purchases in Brazil in progress in January 2012

Company	Area	Investment	Purpose
1. Chongquin Grain Group China	100,000 ha, with option to expand to 200,000 ha.	US$879 million, much of this from the CDB	Soybeans
2. Pengxin Group China	200,000 ha		Cotton, soybeans

Source: GRAIN (2012).

The China National Agricultural Development Group Corporation, the Pengxin Group China and the Chongqing Grain Group have announced acquisitions of land (GRAIN, 2012; Raimundo & Azevedo, 2011). This is part of the strategy connected with the railroad project cited above, with a joint venture including the Chinese Chongqing Huapont Pharm. Co. Ltd. (a Chinese pesticide industry), the Brazilian Agricultural Cooperative Consortium (which includes 16 cooperatives of grain producers from different states) and Chinatex Corporation, which is a large Chinese state-owned company engaged in producing, trading and integrated service of textiles and edible oils (Cintra, 2013).

This is undoubtedly very incomplete, since the Brazilian government stopped tracking foreign land purchases in 1994 and only resumed collection of this information in April 2012. Restrictions on outright purchases by foreigners are not likely to halt the trend to increasing control of land from abroad because Brazil's 1988 Constitution changed the definition of "Brazilian" companies: rather than requiring a majority of the capital to be Brazilian, companies can be classified as "Brazilian" merely by having a headquarters in Brazil. Moreover, the lower house of the National Congress is currently debating the question of land acquisition by foreigners and a number of influential deputies have proposed changes in the law in order to relax existing restrictions (Brazil, Agência Câmara de Notícias, 2012).

9. China's impact on "sustainable development"

The changes driven by China's commodity purchases from and investments in Brazil's Amazon region, including the state of Mato Grosso, have significant impact on the set of concerns grouped under the rubric of "sustainable development." The term "sustainable development" implies that what is happening is "development," meaning a change in a direction seen as improving human wellbeing (not to be confused with "growth," or increase in the throughput of matter and energy – or their proxy in terms of money (e.g., Daly & Cobb, 1989). The adjective "sustainable" implies that these benefits will last for a very long time, theoretically indefinitely. The widely used description of sustainable development from the World Council on Environment and Development's 1987 "Bruntland Report" allows the current generation's actions to be considered "sustainable" if future generations, which are presumably wealthier and more technologically advanced, are capable of coping with the environmental and social losses provoked by the current generation's activities (WCED, 1987). This allows the current generation's activities to be considered “sustainable” even if these activities destroy their bases of support, as by exhausting a non-renewable resource such as a mineral deposit or by destroying a potentially renewable one like a forest of a fishery.

Deforestation destroys a potentially renewable resource, eliminates indigenous and traditional cultures that predominated in the area (clearing only takes place at some time after expelling the traditional inhabitants), and provokes losses of environmental services such as maintaining biodiversity, carbon storage and water cycling (Fearnside, 2008b). Throughout most of Brazilian Amazonia, deforestation has been for low-value cattle pastures that are ephemeral and that support only a few people after the initial clearing activity has passed (Fearnside, 1986, 2002b). Soil and other limits constrain this activity (Fearnside, 1997b, 1998), but land speculation, land-tenure establishment, money laundering, fiscal incentives and a variety other “ulterior” motives have driven clearing for pasture even in agronomically unpromising locations (Fearnside, 2005a; Carrero & Fearnside, 2011). Recent dramatic increases in beef prices and the opening of export options by elimination of foot-and-mouth disease have added a significant economic force to the previous drivers for pasture: beef that a decade ago could only be exported in canned form is now shipped abroad frozen or even as live cattle. Is the conversion of Amazon forest to cattle pasture “sustainable development”? Various indicators suggest that it is neither sustainable nor development (Fearnside, 1979, 1989c).

Particularly in the state of Mato Grosso, soybeans have replaced tropical forest with a land use that can generate much more financial return than does either cattle pasture or management of the original forest. Soy cultivation is entirely mechanized and generates relatively little employment per hectare. Those who own or are employed in the soy plantations enjoy substantially higher incomes than most Brazilians. Soy production centers in Mato Grosso have some of the highest human-development indices in Brazil, the municipality of Sorriso having become famous by being ranked number one among Brazil’s 5570 municipalities (*Folha de São Paulo*, 2005). Most of the individuals involved in soy cultivation are relatively recent arrivals from other parts of Brazil, especially the states of Rio Grande do Sul, Santa Catarina and Paraná, rather than the descendants of the population that inhabited Mato Grosso before these areas were converted to soy.

The physical sustainability of soy cultivation depends on the purchase (in some cases including importing from other countries) of inputs such as fertilizer, lime, pesticides and herbicides. The financial viability of supplying, for example, soil nutrients from distant sources once the initial stocks are depleted depends on the costs relative to those in other potential production areas. An example of potential loss of competitive viability is provided by soy in Bolivian Amazonia, where older plantations in the Santa Cruz area have progressively been abandoned in favor of moving farther north into the rainforest portion of the country (Barber et al., 1996; Fearnside, 2001a). Phosphorus is a non-renewable resource that is limiting in Amazonian soils and for which global resources are expected to be depleted well before the end of the current century (United States, CEQ & Department of State, 1980). Brazil is not particularly well-endowed with phosphate deposits (de Lima et al., 1976; Beisiegel & de Souza, 1986). The supply of phosphorous could be significantly altered by plans of the Peruvian government to build a railway connecting the phosphate-rich area of Piura, located on the Pacific coast in the north of Peru, with Cruzeiro do Sul in the Brazilian state of Acre; this is one of several plans for a rail connection from Brazil to a Pacific port in Peru, with soy export to China being the main justification (Dourojeanni, 2013). Brazil's planned "Transcontinental Railway" would connect Mato Grosso to this railhead (Marquina, 2013).

So, is converting tropical forest (or former tropical forest that first is converted to cattle pasture) into soy plantations "sustainable development"? Different parties would respond differently to this question, depending on whether they are economic winners or losers as a result of the transformation to soy. Those concerned with the environment are likely to conclude that encouraging soybeans is not a wise development path (Fearnside, 2001a, 2008c).

Expansion of soybeans is different from many types of development in terms of "net benefits" *sensu* Zarsky and Stanley (2013). Projects such as establishment of a mine have major environmental and social impacts in surrounding communities, plus gains from employment opportunities and from the monetary flows derived from wages and procurement. In such cases, interviews with community members and meetings held in the area can reveal strong dissatisfaction among affected people, indicating a net impact. The Marlin mine case in Guatemala studied by Zarsky and Stanley (2013) offers a clear example. In the case of soy plantations in Mato Grosso, however, only the winners remain in the area. The losers have sold their land or been otherwise expelled, and are now spread across frontiers elsewhere in Amazonia.

Successive waves of displacement have taken place before reaching the soy plantation stage. First the indigenous peoples were displaced (or killed), followed by occupation either by small farmers or by ranchers. The ranchers may either follow a first wave of small farmers, or, alternatively, may obtain the land directly without its passing through the small-farmer phase. Logging is also a major activity, which may occur in forested land held by actors of any size from small farmers to large ranchers. Timber may be bought or stolen, including logs taken from unclaimed land (or from indigenous areas and conservation units). Logging is a temporary and unsustainable phase, and most loggers move on to other frontiers after exhausting the resource (Lentini et al., 2011). Finally, the land is bought by soy farmers. Extreme income concentration has repeatedly been the result of conversion of land to soybeans throughout Latin America (Kaimowitz et al., 1999). The net balance and the apportionment of blame for the various environmental and social impacts is therefore complicated. Once established, soy farmers continue to clear the remaining forest despite the widely believed myth that they only plant in degraded cattle pasture and thus provide an economic boom at no environmental cost (e.g., Macedo et al., 2012).

10. Conclusions

The estimates confirmed the effect of soybean planted area in increasing exports to China and in increasing deforestation, even though deforestation rates were lower in 2010 than in 2000 and the general downward trend continued through 2012. Exports to China from the Brazilian Legal Amazon were also significant in explaining the increase in deforestation.

The cattle herd size also had a significant relation to increases in deforestation, but the relationship of cattle to soybean planted area is strong and positive. Therefore, the change in land use from pasture to soybean cropping (unless it occurs in degraded areas) may lead to more deforestation. The increase in cattle would, however, lead to more pasture and deforestation associated with opening new areas. The recent authorization of Chinese beef imports may lead to additional deforestation.

Chinese purchases of agricultural and forestland and Chinese imports of commodities such as timber and aluminum also cause environmental impacts in Amazonia. Chinese financing and investment in Amazonian infrastructure such as railways and mineral processing facilities have additional impacts.

Brazil's ability and willingness to mitigate the risks of soy-led expansion has been very limited. This is in part due to a newly emboldened ruralist class that has benefited from the boom.

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12. Technical Appendix

The system uses the following variables, for the Brazilian Legal Amazon: endogenous variables of deforested area (Defor) and the FOB value of Brazilian exports to China (Export); and exogenous variables of soybean planted area

(SoyArea), cattle herd (Herd), beef price (BeefPrice), soybean price (SoyPrice)[5], and a trend variable (Trend). Previous-year deforestation, SoyArea, previous-year herd, beef and soybean prices and previous-year exports as instruments (the variables used in the first step of the three-stage linear system). All variables refer to the Legal Amazon from 2000 to 2010 with values expressed as logarithms. The system can then be expressed as (1) for year "t".

$$\mathrm{Dlog(Defor)}_t = \beta_0 + \beta_1 \mathrm{Dlog(Herd)}_{t-1} + \beta_2 \mathrm{Dlog(SoyArea)}_t + \beta_3 \mathrm{Dlog(Export)}_t + \beta_4 \mathrm{Dlog(SoyPrice)}_t + \beta_5 \times \mathrm{Dlog(BeefPrice)}_t + \beta_6 \times \mathrm{Trend} + \varepsilon_{1t}$$

$$\mathrm{Log(Export)}_t = \beta_7 + \beta_8 \mathrm{Log(Herd)}_{t-1} + \beta_9 \mathrm{Log(SoyArea)}_t + \beta_{10} \mathrm{Log(Export)}_{t-1} + \varepsilon_{2t} \quad (1)$$

where the variables are as described above and the Dlog operator denotes the first difference between the logarithms, or $\mathrm{Dlog}(X_t)=\log(X_t)-\log(X_{t-1})$. This is done to account for the increase in deforested area, as well as the size of the cattle herd, the area in soybeans and prices.

The estimation follows the three-stage least-squares method, where a generalized least-squares estimator is applied to a system of equations (in this case two equations) with a variance-covariance parameter matrix estimated in a previous step (in the first and second stages, the endogenous variables are regressed against instrumental variables and forecasts of endogenous variables are then used to calculate the variance-covariance parameter matrix).

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[5] Prices from the World Bank Global Economic Monitor (GEM) Commodities price database, available at: <http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=Global-Economic-Monitor-%28GEM%29-Commodities>. Soybeans price: (US), c.i.f. Rotterdam in $/mt; Beef price: Meat, beef (Australia/New Zealand), chucks and cow forequarters, frozen boneless, 85% chemical lean, c.i.f. U.S. port (East Coast) in cents/kg.

Unfortunately, at this time we do not have data on exports by municipality. Municipal-level data would increase the degrees of freedom in this combination of cross-sectional and time-series data, allowing spatial regression techniques to be applied.

The results of the system estimation, as in Equation 1, are presented in Table 2. The system residual Portmanteau tests for autocorrelations showed no autocorrelation at the 90% confidence level. There were satisfactory fits in both equations, with most of the parameters significant at the 99% confidence level, except the intercept in the second equation.

Table 2. System estimation for the change in the Brazilian Amazon deforestation and its exports to China, 2002-2010

Variable	Coefficient	Standard Error	t-Statistic	Prob.
Dependent: Change in Deforestation (Dlog(Deforest))				
Intercept	3.375	0.188	17.932	0.000
$Dlog(Herd)_{t-1}$	0.142	$4.59*10^{-3}$	30.949	0.000
$Dlog(SoyArea)_{t}$	0.035	$1.84*10^{-3}$	19.050	0.000
$Dlog(Export)_{t}$	0.014	$1.02*10^{-3}$	13.614	0.000
$Dlog(SoyPrice)_{t}$	0.043	$1.24*10^{-3}$	34.304	0.000
$Dlog(BeefPrice)_{t}$	-0.020	$1.11*10^{-3}$	-17.830	0.000

Trend	-0.002	$9.36*10^{-3}$	-17.982	0.000
Dependent: Exports (Dlog(Export))				
Intercept	9.174	9.096	1.009	0.347^{NS}
$Log(Herd)_{t-1}$	-2.105	0.867	-2.427	0.046*
$Log(SoyArea)_t$	1.987	0.557	3.596	0.009
$Log(Export)_{t-1}$	0.910	0.057	16.007	0.000
	Increase in Deforestation		Exports	
R^2	0.9997		0.9912	
Adjusted R^2	0.9986		0.9859	

Source: Research data. Note: Portmanteau tests confirmed the hypothesis of no residual autocorrelations, as did system residual normality tests. NS= statistically not significant; * = statistically significant at 95% confidence; all other coefficients were significant at the 99% confidence level.

In the equation for the increase in deforestation, the difference in soybean planted area as well as the previous year herd exhibited a positive relationship, meaning that the expansion in soybean planted area or in the herd may increase deforestation. Additionally, increases in exports to China and the world price of soybean have a statistical association with the increase in deforestation. The beef price, in the other direction, exhibited a negative relationship with the change in deforestation.

In the export equation, the cattle herd size in the previous year reduces exports to China. The current exports are positively related both to soybean planted area and to exports in the previous year. All of these results may be explained by the fact that most of soybeans in the Legal Amazon are, in fact, exported, and that China is expanding its imports. This functions like a learning-by-doing process, strengthening the trade relationship.