The effects of the Soy Moratorium on Amazon's land use: evidence from a geographic regression discontinuity design

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Abstract

In the beginning of the 2000's the Amazon arc of deforestation was the most active tropical frontier in the world, with most of the forest being replaced by crops and pastures. Pressure from International organizations and retailers called the agribusiness sector to improve it's conservation efforts. The Soy Moratorium agreement was one of the market initiatives created in response. Established in 2006, is a commitment by the soy industry not to purchase the grain produced in the Amazon biome in areas deforested after 2006. In this research we evaluate the policy impacts on Mato Grosso's deforestation and land use. The analysis uses a geographical regression discontinuity design, exploring the discontinuity in the Moratorium's validity in the state. Our main finding is that even though the Moratorium led to a reduction in deforestation, the policy did not significantly shift the agriculture land use dynamic. Our findings point to the fact that isolated market policies are not sufficient to secure conservation.
Keywords: Soy Moratorium, Amazon, Deforestation, Land use.

Resumo

No início dos anos 2000 o arco do desmatamento da Amazônia era a fronteira tropical mais ativa do mundo, com a maior parte da floresta sendo substituída por lavouras e pastos. Pressões por parte de organizações internacionais e empresas demandaram melhorias nos esforços de preservação pelo setor agropecuário. A Moratória da Soja, assinada em 2006, é uma das iniciativas de mercado criadas em resposta.A moratória é um acordo entre os principais agentes da indústria de não comprar o grão produzido em áreas no bioma Amazônico desmatadas após 2006. No presente artigo avaliamos os seus impactos sobre o desmatamento e uso do solo no Mato Grosso. A análise usou uma *geographical regression discontinuity design*, explorando a descontinuidade na vigência da moratória no estado. Nosso principal resultado é que, ainda que a Moratória tenha levado a uma redução no desmatamento, n ão foi capaz de mudar substancialmente a dinâmica do uso do solo pelo setor agrícola. Nossos resultados apontam para o fato que políticas de mercado isoladas não bastam para garantir a preservação.
Palavras-chave: Moratória da Soja, Amazônia, Desmatamento, Uso do solo.

Área: 11 - Economia Agrícola e do Meio Ambiente.
JEL: Q18, Q50, R14.

1 Introduction

Is estimated that by 2050 the world population will be of 9.1 billion people. This will call for an expansion in agricultural production in order to insure food security (FAO, 2009). Since land available for agriculture is limited, this will require improvements in agriculture productivity and will impel the expansion of the agricultural frontier in substitution to forest cover. In Brazil, the expansion of the Agricultural

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Frontier in the Center-West region was responsible for a large share of Amazon's deforestation in the recent decades. With the spike in Amazon's deforestation in 2004, the agribusiness sector was under pressure to change it's conservation efforts. This research investigates the impacts of the Soy Moratorium, the first zero-deforestation industry agreement to signed in the tropics (Gibbs et al., 2015).

Between 2001 and 2006, soybean fields expanded by one million hectares in the Amazon biome (Gibbs et al., 2015). Amazon's Arc of Deforestation - name attributed to the forest's southern border - became the world's most active tropical frontier during the 2000-2005 period (Morton et al., 2013).

In 2004, Amazon's deforestation reached a record-high of 27,000 square kilometers, which incited international attention over Brazil's conservation efforts. This pressured not only the Brazilian government but also retailers associated with the commodities produced in the region. Fearing commercial backlash and sanctions, the most relevant agents of the Soy industry signed the Soy Moratorium Agreement. The Moratorium is an agreement not to purchase Soybeans planted in the Amazon Biome in areas deforested after the 24th july 2006.

To analyse the impacts of the Soy Moratorium on Amazon's deforestation and land use our study will use satellite data of Mato Grosso's land use in conjunction to a geographic regression discontinuity design. In Section 2 we briefly review the main drivers of Amazon's land use and what has been debated about the Soy Moratorium agreement. In Section 3 we present our Empirical Strategy and the data used. In Section 4 we comment our results and on Section 5 we present our final remarks.

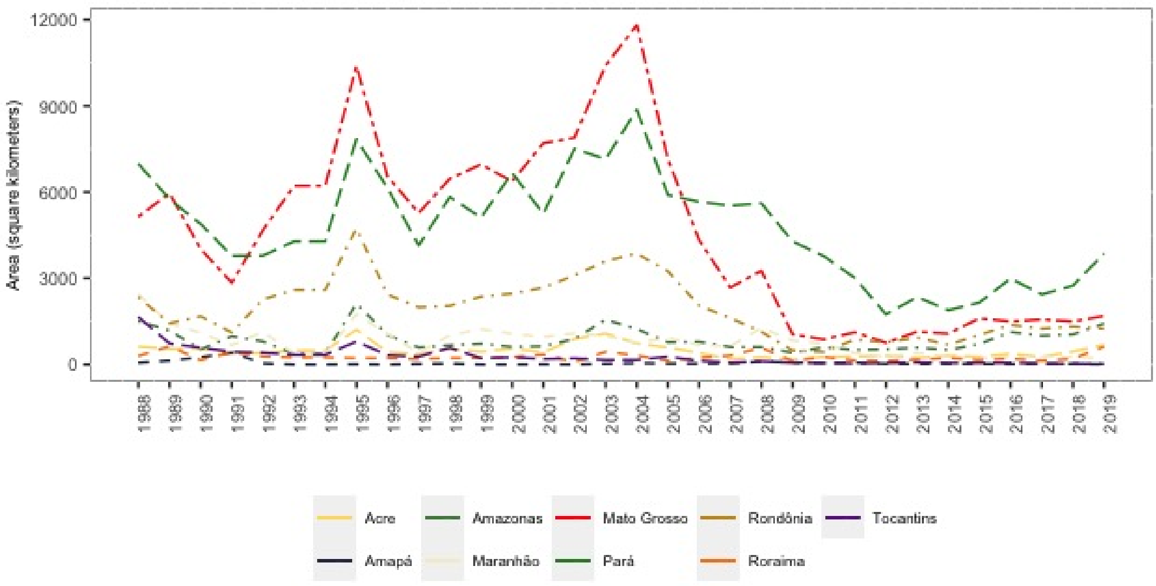
2 Background

In the 60's Brazil's federal government implemented policies promoting Amazon's occupation and incentives for agriculture production. This triggered the deforestation of large areas (Binswanger, 1991). Between 1978 and 1988 approximately 225,000 square kilometers of forests were cleared (Ferraz, 2005).

In the end of the 90's deforestation rates grew sharply, mainly driven by deforestation in Amazon's fringe states, Mato Grosso and Pará. Figure 1 presents the evolution of Amazon's deforestation since 1988, with the deforestation increment by state. The higher rate of deforestation in the bordering states is primarily explained by market access. Although land tenure policies generated incentives for deforestation in the entire Amazon region (Yanai et al., 2017), market access further encouraged deforestation in certain areas given that is a key incentive for the development of market oriented activities. The construction of paved roads in the region increased more then 100% between 1979 and 1999 and unpaved roads by 460% (Ferraz, 2005). Literature has evidenced the relation between roads, large landholdings and deforestation (Godar et al. (2012) and Carrero, Fearnside (2011)).

Although a part of Amazon's deforestation is undertaken by smallholders who clear land for subsistence consumption, it is mostly associated with large landholders interconnected with the commodity market. In fact, soy cultivation and cattle grazing are presented as the two main deforestation drivers in the 2000's (Diniz, Neto (2009), Macedo et al. (2012)). The expansion of crop areas in the region was mainly driven by changes in land prices, agriculture credit and roads (Ferraz, 2005).

Figure 1: Deforestation Increment by State



Source: INPE.

Between 1990 and 2007 the Brazilian cattle herd grew from 147 million to 200 million, with 83% of this taking place in Amazon forest areas. In the states of Mato Grosso and Pará 80% of deforestation was due to pasture expansion (Alix-Garcia, Gibbs, 2017). Despite the continuous expansion over the forest in the recent decades, livestock activities in the region have a low herd-density and there is evidence of low and even negative return rates for medium and small producers (Bowman et al., 2012). Specially in the 80's, land speculation and a race to property rights - obtaining tittle to open access lands through the exercise of "Direito da Terra" or "Grilagem"- were fundamental sources of income related to the activity in the region (Cattaneo, 2008). Deforestation, followed by pasture placement, delimited the appropriated area and assured land property rights and monitoring (Araujo et al., 2009).

The increase in global demand for meat and soy since the end of the 90's led to the establishment of Brazil as a relevant commodity producer. In the described scenario, this further increased the incentives for cattle expansion over forest areas seeking both land appropriation and production expansion. The transformation of forests into pasture, process referred in the literature as *F2P conversion* is described as the main Amazon deforestation driver (Barreto, Silva, 2010).

In addition, favorable market conditions for the soy industry and technological improvements led to the replacement of pasture areas, relatively less productive, by crops. This process is referred in the literature as *P2C conversion* and is associated to most of the soy expansion in the Amazon (Cohn et al. (2016)). Literature has found that this substitution pushes cattle grazing, relatively less productive but also less capital intensive, to the bordering forests areas (Gollnow et al. (2018) and Richards et al. (2014)).This process is referred in the literature as *land use displacement*. Is estimated that since 2002 the indirect deforestation effect from soy entering and pushing pastures contributed to a third of Amazon's total deforestation. (Richards et al., 2014).

In the end of the 90's deforestation rates continued to rise and in 2004 reached a peak, when 27 thousand square kilometers were deforested. Subsequently, a set of government actions were taken in order to contain the forest's devastation. The policies managed to reduced the deforested area to 4 thousand square kilometers in 2012 (INPE, 2019). The effectiveness of the set of policies adopted after 2004 has been widely debated in the literature. One of the most effective, the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), was established in 2004 and fully implemented in 2006, and combined a set of technological changes and legal actions. The policy was crucial for the deforestation decrease (Assunção et al., 2017a) [1].

2.1 The Soy Moratorium agreement

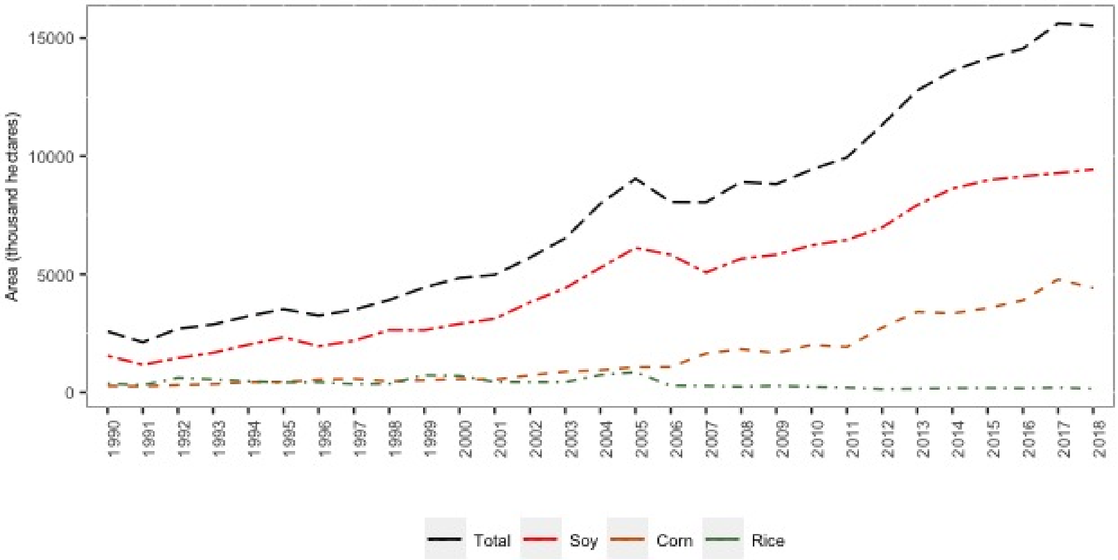
In the 70's soybeans cultivation increased substantially in Brazil. This occurred mainly due to: (i) favorable market conditions, (ii) government incentives and (iii) technological improvements that increased productivity (Hirakuri, Lazzarotto, 2014). In the following decades the Center-West region became a relevant producer, with the planted area expanding from 2.6 million hectares in 1973 to 8.5 million in 1999. The region's poor soil quality and deficient logistics were offset by the great land availability and technological improvements. These aspects, associated with the soil declivity which favors mechanization, led to the development of large-scale agriculture (Helfand, De Rezende, 2000). Figure 2 shows the evolution of the Soy area and compa res it to other relevant cultures.

In Mato Grosso, the cultivation of soybeans on Amazon forest areas took place mostly on degraded pasture and in replacement to other cultures. Notwithstanding, between 2001 and 2005, a period of favorable market conditions for the soy industry, a third of crop expansion took place in forest-occupied areas. The cultivated soy area went from 3 million hectares to 6 million between 2001 and 2005. Direct conversion from forest to soy crops - process referred in the literature as P2C - represented 12% of the deforestation of large areas (larger than 25 hectares) (Macedo et al., 2012).

International organizations turned their attention to Amazon's deforestation following 2004's peak. There were critics not only to the Brazilian government, but also to the associated retailers and indus-

[1] Changes also occurred in the concession of rural credit, conditioning it to environmental law requirements, also had an important role Assunção et al. (2013). Changes in the agriculture sector also impacted the deforestation pattern following 2004 (Assunção et al. (2012) e Hargrave, Kis-Katos (2013))

Figure 2: Total Crop Area - Selected Cultures - Mato Grosso



Source: IBGE - PAM.

tries. A series of international campaigns started criticising international buyers of Brazil's commodities produced in the Amazon region (Greenpeace (2006) and Greenpeace (2009) are two examples). As a consequence, the soy and meat industries suffered the menace of international sanctions and commercial backlash in the US and Europe. In this scenario, in 2006 the most relevant agents of the national soy industry[2], with the support of the Brazilian government and institutions such as Greenpeace, signed the Soy Moratorium agreement. The accord is an compromise by the sector not to purchase Soy planted in areas of the Amazon Biome deforested after July 24 2006. The Amazon Biome area is considered as established by IBGE (ABIOVE, 2018).

The 2007-2008 soybean harvest was the first to be monitored and in each harvest ABIOVE releases a report on the monitoring. The agreement has been periodically renewed and since 2016 has been extended indefinitely. With the changes in Brazil's forest code the deforestation reference became the deforested areas up to July 22nd 2008 for the 2012-2013 harvest. Each year the signing members monitor municipalities, completely and partially covered by the Amazon Biome, which planted more then 5000 hectares of soy in the previous harvest. Table 1 shows the number of municipalities that planted more than 5,000 hectares in 2006. Mato Grosso is the state that concentrates most of then.

According to ABIOVE (2018) in the 2017-2018 harvest 95 municipalities were monitored and these represent 98% of the soy planted in the Amazon region. The area not in compliance with the agreement corresponded to 1,4% of the monitored area and represents 4,6% of the total deforested area of the Amazon Biome (in the monitored municipalities) in the period.

In 2009, conservation agreements were also made in the cattle industry. Gibbs et al. (2016) found

[2] Brazilian Association of Vegetable Oil Industries (ABIOVE) and National Grain Exporters Association (ANEC)

Table 1: Cultivated Soy Area in 2006 - Amazon Covered States

	Acre	Amapá	Amazonas	Maranhão	Mato Grosso	Pará	Rondônia	Roraima	Tocantins
>=5000 hectares	0	0	0	0	38	6	6	0	4
<5000 hectares	22	16	62	110	54	138	46	15	36
% Municipalities	0%	0%	0%	0%	70%	4%	13%	0%	11%

Source: PAM - IBGE.

that agreements by major meatpacking companies in the state of Pará significantly reduced deforestation in supplying properties. However, in contrast to the Soy agreement, the intervention has a limited geographical scope and leaves room for frauds since ranchers can move the cattle between properties. In contrast, the Soy Moratorium agreement leaves no room for this kind of issue since the monitoring occurs at a property level and the monitoring entities look for the soy crops within these properties.

Regarding the Moratorium effectiveness in reducing deforestation, literature has found mixed evidence. Kastens et al. (2017) and Gibbs et al. (2015) found that the agreement reduced the direct conversion of forest to soy crops in Mato Grosso. However, both methodologies do not adequately control for other confounders that could impact deforestation and land use. On the other hand, Peixoto (2017) has found no clear effect on deforestation within soy-producing municipalities when analysing the entire Amazon region.

In addition, there are critics that the industry agreements have overlooked Cerrado's conservation, which in the recent decadates has also been deforested for cropland expansion (Noojipady et al., 2017) [3]. Therefore, the restrictions on the soy cultivation in the Amazon could be generating a cross-biome leakage .

Further, although evidences show that the Moratorium is associated with a reduction in Amazon's deforestation, is hard to establish causality since after 2004 a set of government actions and changes in the brazilian law took place (Rudorff et al. (2011), Nepstad et al. (2014)). In addition, there is evidence of violations by the soy producers. Between 2009 and 2016, 54 municipalities did not comply with the agreement and 59 thousand hectares of the forest were converted to soy crops. This represents 12,45% of the total deforestation within these municipalities in the period (Silva, Lima, 2018).

Apart from the possible violations by soy producers, an important aspect to consider when evaluating the Soy Moratorium is its possible indirect impacts on land use decisions. Police implications arise not only from it's prior objectives - in the case of the Moratorium to cease the conversion of Forest to soy crops - but also from agents response according to their preferences (Rausch, Gibbs, 2016). In a scenario where deforestation is a function of land value, the incentives to deforest are highly associated with the return of land as a productive asset (Angelsen, 1999). Therefore, there are two possible indirect effects of the Moratorium. First, the expansion of soy crops to areas occupied by pasture or other cultures, since new

[3] Cerrado's devastation for agriculture purposes has been a concern. In fact, there is an initiative of expanding the Soy Moratorium to the Cerrado areas. Soterroni et al. (2019) debates this issue.

deforestation for soycrops is no longer possible, which could displace these land uses to neighboring Forest areas and generate indirect deforestation. Second, the expansion of soy cultivation to areas which are not covered by the Amazon Biome, in the case of Mato Grosso, to the Cerrado and Pantanal biomes, causing cross-biome leakage.

There is a scarce number of articles that investigate these effects. Using satellite data Gollnow, Lakes (2014) found that in Mato Grosso there was an increase in indirect deforestation after 2006. There is also evidence of an increase in Cerrado's deforestation after the implementation of the Moratorium (Noojipady et al., 2017). However, both references are limited to a descriptive analysis of the land use data and therefore cannot establish causality with the policy. Arima et al. (2011) investigates the Moratorium effects on indirect deforestation using data at a municipal level of crops extension, cattle herd and deforestation for the entire Amazon. Considering the large territorial extension of some municipalities in the Amazon region and the impossibility of locating spatially within each municipally the different land uses, the article cannot precisely analyse which land use changes occurred.

Our empirical strategy has the objective to extend the existing literature on the Soy Moratorium impacts on deforestation and land use. Our contribution will come from the use of satellite data in conjunction to a geographic regression discontinuity design. The existing literature on land use implications is limited to a description of the land use data or uses a less robust estimation strategy (as in Gollnow et al. (2018), Noojipady et al. (2017) and Arima et al. (2011)).

We will limit our study to Mato Grosso state since our identification strategy is built using the discontinuity of the policy validity along Amazon's border. The Empirical Strategy to be presented has the goal to investigate the Moratorium impacts on Amazon's forest cover loss (FCL), analysing if it induced cross-biome leakage, and on land use.

3 Metodology

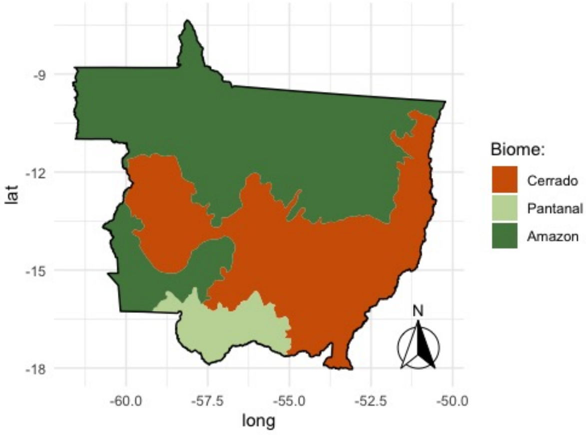
3.1 Empirical Stategy

Our empirical strategy will explore the fact that the Moratorium is only valid within the Amazon Biome. This rule generates a discontinuity on the the police's validity within the Mato Grosso state since is only partially covered by the Biome, as it can be seen in Figure 3. Therefore the treatment jumps discontinuously along the Biome border, which motivates the use of Geographic Regression Discontinuity (GRD) design.

Multiple authors have explored the use of geographical frontiers as a source of treatment discontinuity [4]. Including the literature investigating Amazon's deforestation (Crespo Cuaresma, Heger (2019), Burgess

[4] Holmes (1998) and Koster et al. (2012) are two examples.

Figure 3: Mato Grosso's Biomes



Source: IBGE. Author's elaboration.

et al. (2018) and Anderson et al. (2016)). However, we believe to be the first using this strategy to investigate the impacts of the Soy Moratorium on Amazon's deforestation and Land Use.

As in the classic RDD setup, identification for the Geographic Regression Discontinuity (GRD) Design holds under the continuity assumption. As in Keele, Titiunik (2015), consider that the geographical location of observation i is given by it's latitude and longitude coordinates $(S_{i1}, S_{i2}) = \mathbf{S_i}$. Consider $\mathfrak{B}$ as a set of boundary points $\mathfrak{B}$. Let b be a boundary point, such that $b = (S_1, S_2) \in \mathfrak{B}$. Consider A^t and A^c as the sets of points that represent, respectively, treated and non treated areas. Treatment assignment, represented as $T_i = T(S_i)$, is a deterministic function of S_i, such that $T_s = 1$ for $s \in A^t$ and $T_s = 0$ for $s \in A^c$. Therefore, treatment has a clear discontinuity along border points $\mathfrak{B}$. Considering the two-dimensional nature of the score, the continuity assumption states that:

$$\lim_{s \to b} E\{Y_{i0} | S_i = s\} = E\{Y_{i0} | S_i = b\}$$
$$\lim_{s \to b} E\{Y_{i1} | S_i = s\} = E\{Y_{i1} | S_i = b\}$$

for all $b \in \mathfrak{B}$. That is, the conditional regression functions are continuous in s at all points b on the boundary. This requires that the average potential outcomes under treatment and control be continuous at all points on the boundary (Keele, Titiunik, 2015). In our study, this means that the potential outcomes near the boundary, deforestation and different land uses, observed in the Amazon side of the boundary is very similar to the other side (geographically defined as Cerrado and Pantal). Therefore, assuming similar potential outcomes and controlling for covariates, any differences after 2006 could be attributed to the Moratorium.

In our investigation the score S_i is defined by i's location within the Amazon biome or not. We consider that units within a certain distance to the border, but in opposite sides, are valid counterfactuals for each other. Therefore, within a certain distance from the border, the treatment can be considered a "quasiexperiment" (Lee, Lemieux, 2009).

Other characteristics of this specific police motivate the use of a GRD design. Firstly, it can be argued that the Amazon and Non-Amazon areas within Mato Grosso consistently differ in their vegetation which invalidates our continuity assumption. However, the Amazon-Cerrado transition region is the world's largest Ecotone[5] and this transaction area was not considered when, in the 80's, IBGE delimited the current geographical Biomes division. Therefore the abrupt division between the Amazon and other biomes in Mato Grosso does not reflect reality [6]. Therefore, we believe that up to a certain range, is possible to consider both sides of the border as being good conterfactuals for each other. Further, since the agreement uses IBGE's geographical frontier as a reference, which was established prior to the agreement, we are secure that there was no manipulation on the treatment's attribution that could make the GRD design invalid.

Although the physical aspects that could possibly impact deforestation are very similar along the border, relevant differences in preservation policies between the Amazon biome and the other biomes could make our continuity assumption invalid. As mentioned, a set of police changes took place after 2004. The most relevant, PPCDAm had relevant impacts on deforestation (Assunção et al., 2017b) and started in 2006, the same year of the moratorium signature. Since the Plan comprehended the Legal Amazon, the entire Mato Grosso state was subject to it. Therefore, we believe that alongside the Amazon Biome border the Moratorium is the only relevant change that occurred in our period of analysis.

3.2 Empirical specification

Using the Geographical discontinuity we consider the distance to the border as a running variable. Pixels that fall inside of the Amazon biome receive positive distances, while outside the biome have a negative value. Observations were constructed in a 3 kilometer pixel resolution. Our main specification is the following linear model

$$Y_i^N = \alpha + \gamma A_i + f(ci) + \beta X_i + \varepsilon_i,\ for\ -h < c_i < h \tag{1}$$

where Y_i^N is the normalized variation in one of our outcomes of interest - FCL_i^N, $F2C_i^N$, $F2P_i^N$ and $P2C_i^N$ - in pixel i. The following section explains how these variables were constructed. We estimate Equation 1 for each year of the 2000-2011 period. Each yearly estimation t is analysing the land use changes that took place between t and $t+1$. Although the Soy Moratorium was still in place after 2011, the agreement had a regiment change in the 2012-2013 harvest with the new Brazilian forest code. Therefore, we preferred to restrict our analysis to the period subject to the initial rule.

[5]Ecotone is defined as a transition area between two biomes. The Amazon and Cerrado Ecotone is the world's largest and is considered to have 6 thousand square kilometers of extension (Marques et al., 2019).

[6]Is estimated that certain transaction areas were miscalculated up to 245,5% (Marques et al., 2019).

A_i is a binary variable indicating if the pixel i falls inside the Amazon biome. $f(ci)$ is a polynomial that equals $f(ci) = A_i * f(c_i) + (1 - A_i) * f(c_i)$.We consider the same polynomial for each side of the border. In our main specification we assumed a linear regression model, therefore, $f(\cdot)$ is a first-order linear function. We perform robustness checks using a quadratic polynomial specification.

In order to investigate the Moratorium's impact we are interested in γ, which measures the difference in the outcomes of interest on the Amazon Biome side of the border (treated) compared to the other side (non-treated). We are estimating equation 1 by OLS in a yearly basis. Therefore, any impact caused by the moratorium would be noticed by comparing the yearly coefficients. More specifically, by observing whether there is any change in behaviour before and after 2007 [7].

The optimal bandwidth h was optimally estimated as proposed by Imbens, Kalyanaraman (2012). As in Burgess et al. (2018), for estimations to be comparable, our preferred bandwidth is the average of the optimal bandwidths calculated across all years, which is 51 km from the border [8]. We estimated the optimal bandwidth using the yearly forest cover lost and a uniform kernel. The same optimal bandwidth was used for the four variables to establish comparison. As a robustness check we estimated equation 1 using the minimum and maximum optimal bandwidths found, which measure 41,5 kilometers and 61,3 kilometers.

X_i is a set of covariates controlling for natural and infrastructure characteristics that affect deforestation and land use. We considered the average land slope, distance to paved roads and distance to navigable water. Finally, we also considered if pixel i falls within a Conservation Unit or Indigenous Land.

Additionally, it can be argued that since the Moratorium only monitors municipalities that produce soybeans, the policy would impact only these areas. Therefore, we also estimated Equation 1 considering only the observations within the municipalities that planted more then 5000 hectares of soybeans in 2006.

3.3 Data

Data regarding land use transition comes from Mapbiomas[9]. The source uses Landsat satellite images to produce land use transition maps with a resolution of 30 meters. In our initial estimates data will be aggregated in a 3 kilometer pixel resolution. We will use Mapbiomas Collection 4.1, the most recent to be made available [10]. Mapbiomas classifies in each pixel the annual change from a category of land use to another. Land use classification is divided between two large groups, anthropic and natural land uses.

[7] The 2007-2008 harvest was the first to be monitored (ABIOVE, 2009).

[8] Using this band, with our 3km-pixel resolution, we have 35,231 observations each year.

[9] Mapbiomas is a initiative by Climate Observatory's that produces yearly land use data by a collaborative network of NGOs, universities and technology companies

[10] Which is the collection with the best identification accuracy. The land use identification is made by a random forest machine learning algorithm and has an accuracy of 95% in the Amazon and 80% in Cerrado, our focal areas. Check MAPBIOMAS (2019) for a complete description of the data.

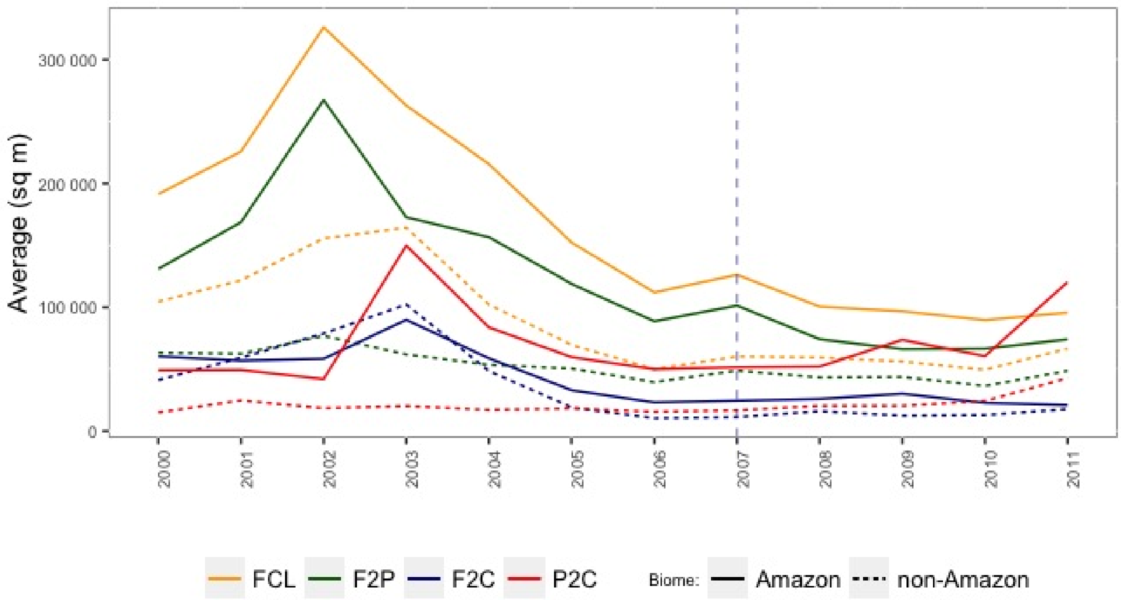
For our estimations we will mainly use the following categories: (i) Natural Forest[11]; (ii) Pasture and (iii) Agriculture. Is important to point out that Mapbiomas detects all crops, not only soybeans. Therefore we are considering all crops in our analysis and we are analysing the Moratorium's impact on the entire agriculture sector. Table 2 summarizes how we aggregated the land use change data to be used in our estimations. For each transition, Y_{it} represents the total area within the pixel i that went through the land use change from the year t to $t+1$.

Table 2: Land Use Transition Data

	Land Use Change:			
Y_{it} :	FCL_{it}	$P2C_{it}$	$F2C_{it}$	$F2P_{it}$
From - Year (t)	Natural Forest	Pasture	Natural Forest	Natural Forest
To - Following Year (t+1)	Anthropic Land Use	Crop: Annual,Perennial or Semi-perennial	Crop: Annual,Perennial or Semi-perennial	Pasture

Figure 4 presents the evolution of our variables of interest throughout the 2000-2011 period within our 51 km bandwidth around the Amazon biome border. We report the mean land use change of our 3 kilometer pixel observations. Is clear that for both Amazon and non-Amazon areas there was a sharp reduction in forest cover lost. In addition, specially in the Amazon region, the conversion of forests into pastures follows the trend in forest cover lost.

Figure 4: Land Use Changes



Source: Mapbiomas.

Our units of observation exhibit significant cross-sectional variation in all four categories of land use change. This is due to the heterogeneity in forest cover and land use in each pixel. For this reason we

[11]Which comprehends Forest Formation,Savanna Formation, Mangrove and Grassland. Therefore accounting for Cerrado, Pantanal and Amazon vegetations.

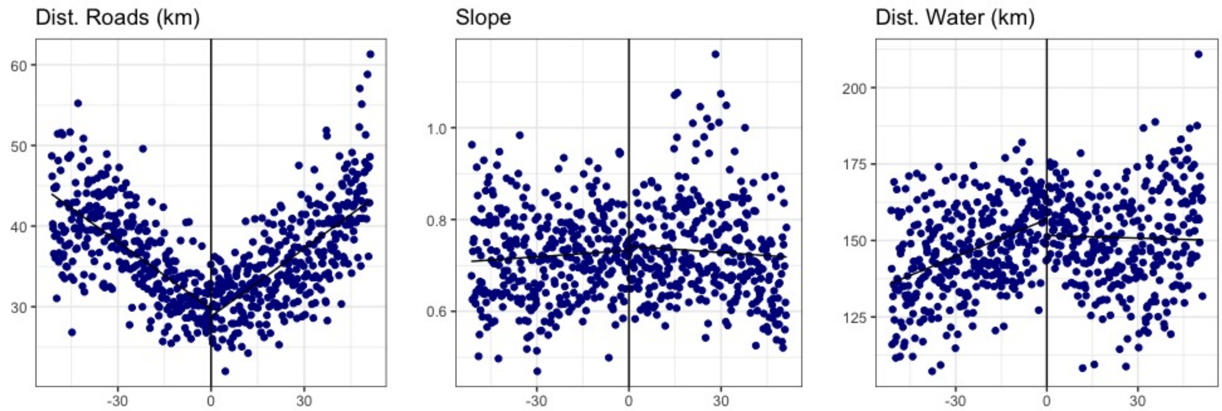
normalized our land use transition variables to make sure that our analysis is considering only the relative variations in land use change. Our normalized variables were constructed as:

$$Y_{it}^{N} = \frac{Y_{it} - \overline{Y_i}}{sd(Y_i)}$$

where Y_{it} is one of the four variables presented in Table 2. $\overline{Y_i}$ and $sd(Y_i)$ are the mean and the standard deviation in each land use change, calculated for each location i over the 2000 - 2011 period[12].

Regarding our covariates, in Figure 5 we presents their distribution relative to the distance from the biome border. All variables are evenly distributed across the border and there no significant differences that could invalidate our assumptions. In Figure A.1 we present the geographical distribution of Conservation Units and Indigenous Lands across Mato Grosso. Since they are not evenly distributed across the Biome border and there is evidence in the literature that they affect deforestation (as in Pfaff et al. (2015)), is relevant to consider the existence of these areas when estimating the moratorium impacts [13].

Figure 5: Covariates Distribution across the Amazon Biome border



Note: Horizontal axis represents the distance from the Amazon border in Kilometers. Positive distances represent areas within the Amazon biome.

4 Results and Discussion

Equation's 1 estimates for the Amazon coefficient are presented in Table A.1. Since our running variables were standardized we can interpret the reported coefficients as the effect on the standard deviation of our variables. In figure 6 we plotted the coefficient of interest - γ - for each year with 95% confidence intervals for our main estimation. In the same figure we also plotted the coefficient for the estimates considering only the pixels within municipalities that produced more then 5,000 hectares of soybeans in 2006.

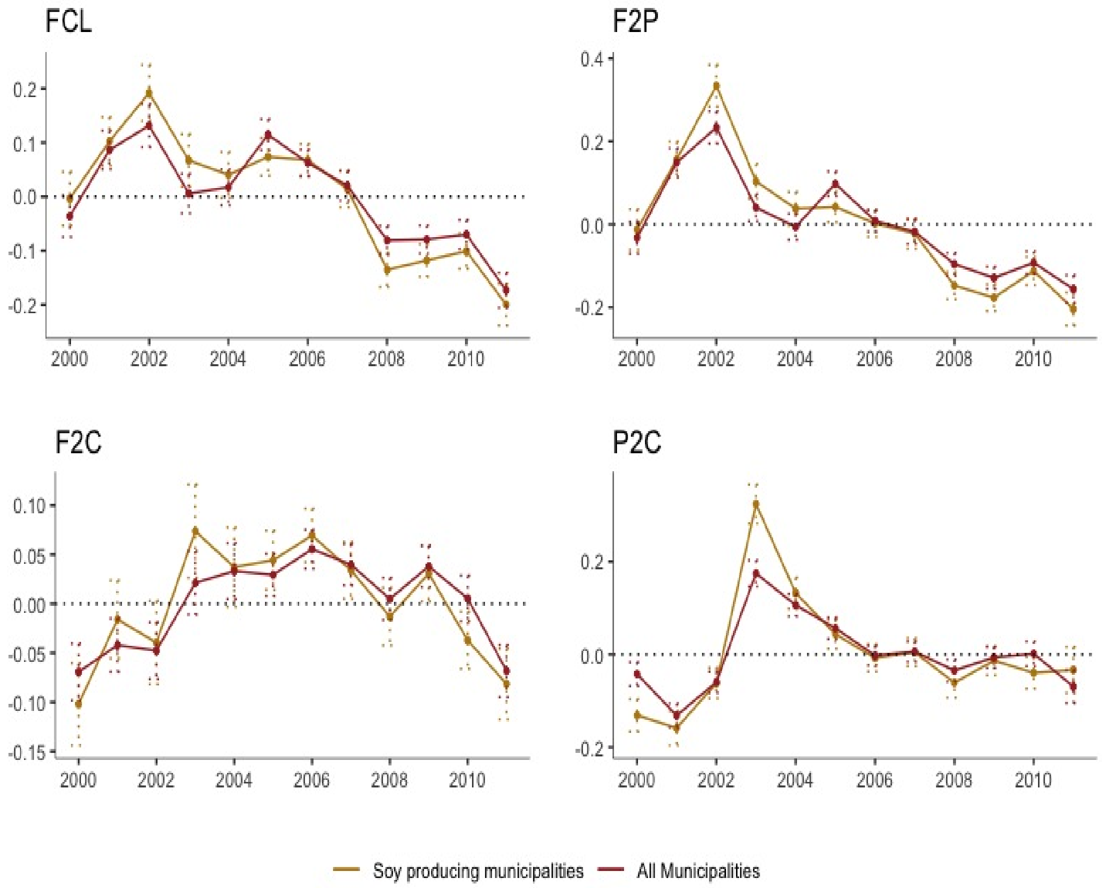
[12]To make this clear, we are analysing land use changes starting from 2000-2001 up to 2011-2012.

[13]We used Mato Grosso state data on these areas to check when they were formally installed. From this date, we considered the existence of the areas in a location i.

The complete estimation results considering only soy producing municipalities are presented in table A.2. Both estimates follow the same trend.

In Figure 6 is noticeable a downward trend in both Forest Cover Lost and Forest to pasture conversion after 2007, the first year of the Soy Moratorium monitoring. This indicates that Amazon areas had a decrease in the deforestation following the moratorium, which is in line with the findings by Macedo et al. (2012) and Gibbs et al. (2015).

Figure 6: Estimated Coefficients



Note: On both estimates we are considering the observations within the 51km band. We used linear polynomials and covariates were included.

In addition, the negative coefficients after 2007 show that the non-Amazon areas in Mato Grosso had a relative higher Forest Cover Lost in comparison to Amazon areas. Figure 4 clearly shows how the gap between the average deforestation in both sides of the border became more narrow after 2007. This reinforces the idea by Noojipady et al. (2017) that the Moratorium altered the dynamic of soy expansion in the Amazon and generated cross-biome leakage to the neighboring Cerrado biome. Regarding the reduction in the Forest to Pasture conversion, which follows the trend in FCL, we view it as a consequence of the decrease in deforestation since, most commonly, the initial use of the recently deforest areas is pasture.

Regarding the trend in F2C, Amazon's Forest to Crop conversion was relatively higher in the years prior to the moratorium, but it was not clearly altered after 2007. Although literature points out that the moratorium led to a decrease in the pasture to soy conversion in the Amazon , as indicated by Gibbs et al. (2015), results show that after 2007 there are no significant differences in the pasture to crop conversion between the two sides of the border. We recognize the fact that we are not only analysing soy crops, therefore, this result is not directly comparable to the other literature findings. However, the fact that we find no clear evidence of a reduction in the forest to crop conversion after 2007 demonstrates that the soy moratorium alone is not sufficient to stop Amazon's deforestation for agriculture land use. Future research can explore this issue, analysing if the moratorium induced the expansion of other crops in areas deforested after July 2006. As is shown in Figure 2 the cultivated corn area grew significantly after 2006.

Results also point out that after 2007 the pasture to crop conversion remained stable and with no statistically significant difference between both sides of the border. Again, since we are observing conversion to all crops, this indicates that the moratorium did not significantly impacted the conversion of pastures into crops in the Amazon. Again, for a better understanding of this issue a deeper analysis of farmers decisions and trade-offs is necessary.

Future research can improve our estimations by identifying soybeans crops and other specific crops, and by comprehending how crop rotation in Mato Grosso takes place. Regardless, the presented information calls our attention to the fact that a sector-specific policy is not sufficient to curb deforestation. As it can been in Figure 4, a individual policy by the soy industry did not led to zero deforestation neither eliminated forest to crop conversion. Only integrated market and governmental policies, which account for the entire agriculture and farming sector, can deal with such a complex economic issue.

These findings are robust to a series of of specifications. Equation 1 was also estimated using a quadratic polynomial and results are presented in Table A.3. We also report the coefficient of interest for the estimation with no covariates in Table A.4. Results are not sensible to the polynomial or the inclusion of covariates. In Table A.5 we present robustness checks varying the distance to the border. Results are not significantly affected by the change in the bandwidth.

5 Conclusion

In this paper we proposed a new empirical strategy to investigate the effects of the Soy Moratorium in Amazon's land use. Our contributions come from the use of satellite data in conjunction to a geographic regression design. We believe to be the first to explore the discontinuity in the Moratorium's validity in Mato Grosso.

Our findings support the existing evidence that the Moratorium induced a reduction in Amazon's deforestation. We found a clear reduction in the Forest to Pasture conversion, which is probably mostly a consequence of the reduction in deforestation. Although is difficult to differentiate the Moratorium impacts from the set of police changes that took place after 2004, we believe that by restricting our analysis to Mato Grosso and to a narrow band across the border we managed to control for the most relevant Amazon conservation policies, specially PPCDAm.

Regarding the effects on land use transition, considering all agriculture land use, we found no evidence of significant impacts on forest to crop conversion or forest to pasture conversion. Our results point out to the fact that land use decisions in the Amazon forest involve a complex set of factors and industries. Therefore Amazon's conservation cannot be secured by individual initiatives comprehending only one productive sector.

References

Moratória da Soja: Termo de Compromisso. // . 2009.

ABIOVE . Moratória da soja: Safra - 2017/2018. 2018. 36.

Alix-Garcia Jennifer, Gibbs Holly K. Forest conservation effects of Brazil's zero deforestation cattle agreements undermined by leakage // Global Environmental Change. 2017. 47, June. 201–217.

Anderson Liana O, Martino Samantha, Harding Torfinn, Kuralbayeva Karlygash, Lima Andre. The Effects of land Use Regulation on Deforestation: Evidence from the Brazilian Amazon // OxCarre Working Papers. 2016. 172, 0. 1–54.

Angelsen Arild. Agricultural expansion and deforestation : modelling the impact of population , market forces and property rights // Journal of Development Economics. 1999. 58. 185–218.

Araujo Claudio, Bonjean Catherine Araujo, Combes Jean Louis, Combes Motel Pascale, Reis Eustaquio J. Property rights and deforestation in the Brazilian Amazon // Ecological Economics. 2009. 68, 8-9. 2461–2468.

Arima Eugenio Y., Richards Peter, Walker Robert, Caldas Marcellus M. Statistical confirmation of indirect land use change in the Brazilian Amazon // Environmental Research Letters. 2011. 6, 2.

Assunção Juliano, Gandour Clarissa, Pessoa Pedro, Rocha Romero. Property-level assessment of change in forest clearing patterns: The need for tailoring policy in the Amazon // Land Use Policy. 2017a. 66, 2017. 18–27.

Assunção Juliano, Gandour Clarissa, Rocha Romero. DETERring Deforestation in the Brazilian Amazon: Environmental Monitoring and Law Enforcement. Rio de Janeiro, 2017b.

Assunção Juliano, Gandour Clarissa, Rocha Romero, Rocha Rudi. Does credit affect deforestation? Evidence from a rural credit policy in the braziliam Amazon. 2013. 48.

Assunção Juliano, Gandour Clarissa, Rocha Rudi. Deforestation Slowdown in the Legal Amazon: Prices or Policies? 2012. 37.

Barreto P, Silva D. Will cattle ranching continue to drive deforestation in the Brazilian Amazon ? // Environment and Natural Resources Management in Developing and Transition Economies. 2010. 1–23.

Binswanger H. Brazilian policies that encourage deforestation in the Amazon. // World Development. 1991. 19, 7. 821–829.

Bowman Maria S., Soares-Filho Britaldo S., Merry Frank D., Nepstad Daniel C., Rodrigues Hermann, Almeida Oriana T. Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production // Land Use Policy. 2012. 29, 3. 558–568.

Burgess Robin, Costa Francisco J M, Olken Benjamin A. Wilderness Conservation and the Reach of the State: Evidence from National Borders in the Amazon // NBER Working Paper No. 24861. 2018. 21.

Carrero Garbiel C., Fearnside Philip M. Ecology and Society Forest clearing dynamics and the expansion of land holdings in Apuí, a deforestation hotspot on Brazil's Transamazon Highway // Ecology and Society. 2011. 16, 2.

Cattaneo Andrea. Regional comparative advantage, location of agriculture, and deforestation in Brazil // Journal of Sustainable Forestry. 2008. 27, 1-2. 25–42.

Cohn Avery S., Gil Juliana, Berger Thomas, Pellegrina Heitor, Toledo Chantal. Patterns and processes of pasture to crop conversion in Brazil: Evidence from Mato Grosso State // Land Use Policy. 2016. 55. 108–120.

Crespo Cuaresma Jesús, Heger Martin. Deforestation and economic development: Evidence from national borders // Land Use Policy. 5 2019. 84. 347–353.

Diniz Marcelo Bentes, Neto Nicolino Trompieri. Causas do desmatamento da Amazônia:uma aplicação do teste de causalidade de Granger acerca das principais fontes de desmatamento nos municípios da Amazônia Legal brasileira Marcelo // Nova Economia. 2009. 19, 1. 121–151.

FAO . How to Feed the World in 2050 // How to Feed the World in 2050. Rome, 2009. 1–35.

Ferraz Claudio. Explaining Agriculture Expansion and Deforestation: Evidence from the Brazilian Amazon - 1980/98 // Texto para discussão - IPEA. 2005. 828.

Gibbs H. K., Rausch L., Munger J., Schelly I., Morton D. C., Noojipady P., Soares-Filho B., Barreto P., Micol L., Walker N. F. Brazil's Soy Moratorium // Science. 2015. 347, 6220. 377–378.

Gibbs Holly K., Munger Jacob, L'Roe Jessica, Barreto Paulo, Pereira Ritaumaria, Christie Matthew, Amaral Ticiana, Walker Nathalie F. Did Ranchers and Slaughterhouses Respond to Zero-Deforestation Agreements in the Brazilian Amazon? // Conservation Letters. 2016. 9, 1. 32–42.

Godar Javier, Tizado Emilio Jorge, Pokorny Benno. Who is responsible for deforestation in the Amazon? A spatially explicit analysis along the Transamazon Highway in Brazil // Forest Ecology and Management. 2012. 267. 58–73.

Gollnow Florian, Hissa Leticia de Barros Viana, Rufin Philippe, Lakes Tobia. Property-level direct and indirect deforestation for soybean production in the Amazon region of Mato Grosso, Brazil // Land Use Policy. 2018. 78, June 2017. 377–385.

Gollnow Florian, Lakes Tobia. Policy change, land use, and agriculture: The case of soy production and cattle ranching in Brazil, 2001-2012 // Applied Geography. 2014. 55. 203–211.

Greenpeace . Eating up the Amazon. 2006. 62.

Greenpeace . Slaughtering the Amazon. 2009. 40.

Hargrave Jorge, Kis-Katos Krisztina. Economic Causes of Deforestation in the Brazilian Amazon: A Panel Data Analysis for the 2000s // Environmental and Resource Economics. 2013. 54, 4. 471–494.

Helfand Steven M., De Rezende Gervásio Castro. Padrões regionais de crescimento da produção de grãos no Brasil e o papel da região Centro-Oeste // Texto para discussão - IPEA. 2000. 731. 20.

Hirakuri M., Lazzarotto J. O agronegócio da soja nos contextos mundial e brasileiro. Londrina, 2014.

Holmes Thomas J. The effect of state policies on the location of manufacturing: evidence from state borders // Journal of Political Economy. 1998. 106, 4. 667–705.

INPE . Projeto PRODES - Monitoramento da Floresta Amazônica Brasileira por Satélite. 2019.

Imbens Gguido, Kalyanaraman Karthik. Optimal bandwidth choice for the regression discontinuity estimator // Review of Economic Studies. 2012. 79, 3. 933–959.

Kastens Jude H., Brown J. Christopher, Coutinho Alexandre Camargo, Bishop Christopher R., Esquerdo Júlio César D.M. Soy moratorium impacts on soybean and deforestation dynamics in Mato Grosso, Brazil // PLOS ONE. 2017. 12, 4. 1–21.

Keele Luke J., Titiunik Rocío. Geographic boundaries as regression discontinuities // Political Analysis. 2015. 23, 1. 127–155.

Koster Hans R.A., Ommeren Jos van, Rietveld Piet. Bombs, boundaries and buildings: A regression-discontinuity approach to measure costs of housing supply restrictions // Regional Science and Urban Economics. 7 2012. 42, 4. 631–641.

Lee David S., Lemieux Thomas. Regression Descontinuity Designs in Economics. 2009.

MAPBIOMAS . MapBiomas General "Handbook". 2019. 39.

Macedo M. N., DeFries R. S., Morton D. C., Stickler C. M., Galford G. L., Shimabukuro Y. E. Decoupling of deforestation and soy production in the southern Amazon during the late 2000s // Proceedings of the National Academy of Sciences. 2012. 109, 4. 1341–1346.

Marques Eduardo Q., Marimon-Junior Ben Hur, Marimon Beatriz S., Matricardi Eraldo A.T., Mews Henrique A., Colli Guarino R. Redefining the Cerrado–Amazonia transition: implications for conservation // Biodiversity and Conservation. 2019.

Morton D. C., Le Page Y., DeFries R., Collatz G. J., Hurtt G. C. Understorey fire frequency and the fate of burned forests in southern Amazonia // Philosophical Transactions of the Royal Society B: Biological Sciences. 2013. 368, 1619.

Nepstad Daniel, McGrath David, Stickler Claudia, Alencar Ane, Azevedo Andrea, Swette Briana, Bezerra Tathiana, DiGiano Maria, Shimada João, Da Motta Ronaldo Seroa, Armijo Eric, Castello Leandro, Brando Paulo, Hansen Matt C., McGrath-Horn Max, Carvalho Oswaldo, Hess Laura. Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains // Science. 2014. 344, 6188. 1118–1123.

Noojipady Praveen, Morton C. Douglas, Macedo N. Marcia, Victoria C. Daniel, Huang Chengquan, Gibbs K. Holly, Bolfe L. Edson. Forest carbon emissions from cropland expansion in the Brazilian Cerrado biome // Environmental Research Letters. 2017. 12, 2.

Peixoto Pedro Henrique Guimarães Pinto. Forests for markets: Can a market ban on soybeans deter deforestation in the legal amazon? 2017. 42.

Pfaff Alexander, Robalino Juan, Sandoval Catalina, Herrera Diego. Protected area types, strategies and impacts in Brazil's Amazon: Public protected area strategies do not yield a consistent ranking of protected area types by impact // Philosophical Transactions of the Royal Society B: Biological Sciences. 2015. 370, 1681.

Rausch Lisa L., Gibbs Holly K. Property arrangements and soy governance in the brazilian state of mato grosso: Implications for deforestation-free production // Land. 2016. 5, 2.

Richards Peter D., Walker Robert T., Arima Eugenio Y. Spatially complex land change: The indirect effect of Brazil's agricultural sector on land use in Amazonia // Global Environmental Change. 2014. 29. 1–9.

Rudorff Bernardo Friedrich Theodor, Adami Marcos, Aguiar Daniel Alves, Moreira Maurício Alves, Mello Marcio Pupin, Fabiani Leandro, Amaral Daniel Furlan, Pires Bernardo Machado. The soy moratorium in the Amazon biome monitored by remote sensing images // Remote Sensing. 2011. 3, 1. 185–202.

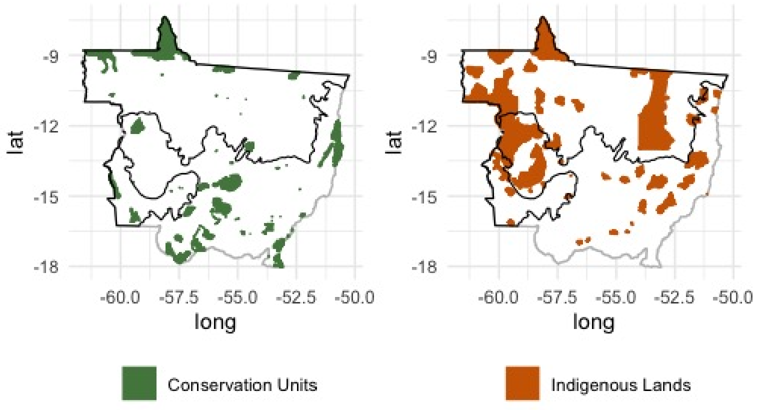
Silva C. A., Lima Mendelson. Soy Moratorium in Mato Grosso: Deforestation undermines the agreement // Land Use Policy. 2018. 71, November 2017. 540–542.

Soterroni Aline C., Ramos Fernando M., Mosnier Aline, Fargione Joseph, Andrade Pedro R., Baumgarten Leandro, Pirker Johannes, Obersteiner Michael, Kraxner Florian, Câmara Gilberto, Carvalho Alexandre X. Y., Polasky Stephen. Expanding the Soy Moratorium to Brazil's Cerrado // Science Advances. 2019. 5. 1–9.

Yanai Aurora Miho, Nogueira Euler Melo, Alencastro Graça Paulo Maurício Lima de, Fearnside Philip Martin. Deforestation and Carbon Stock Loss in Brazil's Amazonian Settlements // Environmental Management. 2017. 59, 3.

6 Appendix

Figure A.1: Geographic Distribution of Conservation Units and Indigenous Lands across Mato Grosso



Note: Black outline represents the Amazon Biome frontier.

Table A.1: Effect on Forest Cover Loss and Land Use by Year - *Linear polynomials and controls*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
***Panel I**: Forest Cover Loss*												
Amazon Biome - γ	-0.0361 .	0.0864 ***	0.1315 ***	0.0058	0.0173	0.1146 ***	0.0626 ***	0.0204	-0.0808 ***	-0.0791 ***	-0.07 ***	-0.1731 ***
	(0.02)	(0.018)	(0.02)	(0.019)	(0.017)	(0.015)	(0.013)	(0.014)	(0.014)	(0.013)	(0.014)	(0.016)
***Panel II**: Pasture to Crop Conversion*												
Amazon Biome - γ	-0.0422 **	-0.1314 ***	-0.0595 ***	0.1747 ***	0.1062 ***	0.0566 ***	-0.0021	0.0061	-0.0345 **	-0.0063	0.0016	-0.069 ***
	(0.013)	(0.013)	(0.012)	(0.014)	(0.012)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)	(0.014)	(0.018)
***Panel III**: Forest to Crop Conversion*												
Amazon Biome - γ	-0.0694 ***	-0.0421 **	-0.0476 **	0.0211	0.0332 *	0.0294 **	0.0555 ***	0.0398 ***	0.0049	0.038 ***	0.0054	-0.0683 ***
	(0.015)	(0.014)	(0.015)	(0.016)	(0.014)	(0.011)	(0.01)	(0.011)	(0.011)	(0.011)	(0.012)	(0.014)
***Panel IV**: Forest to Pasture Conversion*												
Amazon Biome - γ	-0.0322 .	0.1489 ***	0.2337 ***	0.0402 *	-0.006	0.0978 ***	0.0083	-0.0178	-0.0961 ***	-0.1291 ***	-0.0927 ***	-0.156 ***
	(0.02)	(0.018)	(0.02)	(0.017)	(0.016)	(0.015)	(0.013)	(0.015)	(0.014)	(0.014)	(0.014)	(0.017)

Table A.2: Soy Producing Municipalities - *Linear polynomials and infrastructure controls*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
***Panel I**: Forest Cover Loss*												
Amazon Biome - γ	-0.0037	0.1023 ***	0.192 ***	0.0671 **	0.0404 .	0.0736 ***	0.0677 ***	0.0142	-0.1353 ***	-0.118 ***	-0.1008 ***	-0.1996 ***
	(0.025)	(0.023)	(0.026)	(0.025)	(0.022)	(0.018)	(0.015)	(0.017)	(0.016)	(0.015)	(0.017)	(0.02)
***Panel II**: Pasture to Crop Conversion*												
Amazon Biome - γ	-0.0331	-0.1309 ***	-0.1584 ***	-0.0617 ***	0.324 ***	0.1322 ***	0.0438 **	-0.0074	0.0049	-0.0607 ***	-0.0132	-0.0394 *
	(0.018)	(0.019)	(0.017)	(0.021)	(0.017)	(0.016)	(0.015)	(0.015)	(0.016)	(0.016)	(0.017)	(0.025)
***Panel III**: Forest to Crop Conversion*												
Amazon Biome - γ	-0.1021 ***	-0.0159	-0.0395 .	0.0738 **	0.0372 .	0.0442 **	0.0695 ***	0.034 *	-0.013	0.0307 *	-0.0371 *	-0.0816 ***
	(0.021)	(0.02)	(0.022)	(0.024)	(0.021)	(0.015)	(0.014)	(0.015)	(0.015)	(0.014)	(0.015)	(0.018)
***Panel IV**: Forest to Pasture Conversion*												
Amazon Biome - γ	-0.0125	0.1563 ***	0.334 ***	0.1037 ***	0.0377 .	0.042 *	0.0021	-0.0221	-0.1476 ***	-0.1768 ***	-0.1127 ***	-0.2041 ***
	(0.025)	(0.022)	(0.026)	(0.021)	(0.021)	(0.019)	(0.017)	(0.019)	(0.017)	(0.016)	(0.017)	(0.02)

Table A.3: Effect on Forest Cover Loss and Land Use by Year - *Quadratic polynomials and controls*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
***Panel I**: Forest Cover Loss*												
Amazon Biome - γ	-0.0181	0.0952 ***	0.1032 ***	-0.0114	-0.0188	0.0685 ***	0.065 ***	0.0261	-0.0871 ***	-0.06 **	-0.0393 *	-0.1731 ***
	(0.027)	(0.025)	(0.028)	(0.026)	(0.024)	(0.02)	(0.017)	(0.019)	(0.019)	(0.018)	(0.019)	(0.016)
***Panel II**: Pasture to Crop Conversion*												
Amazon Biome - γ	-0.0449 *	-0.0851 ***	-0.0442 **	0.0642 **	0.0871 ***	0.0799 ***	0.0027	0.0266 .	-0.0195	-0.0237	-0.0086	-0.069 ***
	(0.018)	(0.018)	(0.016)	(0.02)	(0.017)	(0.016)	(0.015)	(0.015)	(0.017)	(0.016)	(0.019)	(0.018)
***Panel III**: Forest to Crop Conversion*												
Amazon Biome - γ	-0.0524 *	0.0167	0.0109	-0.0267	0.0189	0.033 *	0.0248 .	0.0337 *	-0.0327 *	0.0189	0.0051	-0.0683 ***
	(0.021)	(0.019)	(0.021)	(0.023)	(0.021)	(0.015)	(0.014)	(0.015)	(0.015)	(0.015)	(0.017)	(0.014)
***Panel IV**: Forest to Pasture Conversion*												
Amazon Biome - γ	-0.0494 .	0.0943 ***	0.1255 ***	0.0381 .	-0.0101	0.0676 **	0.0395 *	0.0093	-0.0861 ***	-0.0927 ***	-0.0518 **	-0.156 ***
	(0.027)	(0.025)	(0.028)	(0.023)	(0.022)	(0.021)	(0.018)	(0.021)	(0.019)	(0.019)	(0.02)	(0.017)

Table A.4: Effect on Forest Cover Loss and Land Use by Year - *Linear polynomials and no controls*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
***Panel I**: Forest Cover Loss*												
Amazon Biome - γ	-0.034 .	0.0895 ***	0.1333 ***	0.007	0.0126	0.116 ***	0.0594 ***	0.016	-0.0806 ***	-0.0765 ***	-0.0711 ***	-0.1717 ***
	(0.02)	(0.018)	(0.02)	(0.019)	(0.017)	(0.015)	(0.013)	(0.014)	(0.014)	(0.013)	(0.014)	(0.017)
***Panel II**: Pasture to Crop Conversion*												
Amazon Biome - γ	-0.0414 **	-0.1316 ***	-0.0595 ***	0.1735 ***	0.1069 ***	0.057 ***	-0.003	0.005	-0.0351 **	-0.0053	0.0034	-0.07 ***
	(0.013)	(0.013)	(0.012)	(0.014)	(0.012)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)	(0.014)	(0.018)
***Panel III**: Forest to Crop Conversion*												
Amazon Biome - γ	-0.0674 ***	-0.0413 **	-0.0453 **	0.0231	0.0345 *	0.0295 **	0.0544 ***	0.0371 ***	0.0038	0.0378 ***	0.0035	-0.0698 ***
	(0.015)	(0.014)	(0.015)	(0.016)	(0.015)	(0.011)	(0.01)	(0.011)	(0.011)	(0.011)	(0.012)	(0.014)
***Panel IV**: Forest to Pasture Conversion*												
Amazon Biome - γ	-0.0296	0.1518 ***	0.234 ***	0.0397 *	-0.0124	0.0992 ***	0.0061	-0.0206	-0.0955 ***	-0.1266 ***	-0.0932 ***	-0.1529 ***
	(0.02)	(0.018)	(0.02)	(0.017)	(0.016)	(0.015)	(0.013)	(0.015)	(0.014)	(0.014)	(0.014)	(0.017)

Table A.5: Robustness - *Linear polynomials and controls*

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
***Panel I**: Forest Cover Loss - 41 km band*												
Amazon Biome - γ	-0.0208	0.0831 ***	0.1152 ***	0.0038	0.0095	0.0994 ***	0.0676 ***	0.0225	-0.0817 ***	-0.0696 ***	-0.0613 ***	-0.1677 ***
	(0.021)	(0.02)	(0.022)	(0.02)	(0.018)	(0.016)	(0.013)	(0.015)	(0.015)	(0.014)	(0.015)	(0.018)
***Panel II**: Forest Cover Loss - 61 km band*												
Amazon Biome - γ	-0.0404 *	0.09 ***	0.1255 ***	0.0035	0.0412 **	0.1221 ***	0.0637 ***	0.0175	-0.0772 ***	-0.086 ***	-0.0855 ***	-0.1745 ***
	(0.018)	(0.017)	(0.019)	(0.018)	(0.016)	(0.014)	(0.012)	(0.013)	(0.013)	(0.012)	(0.013)	(0.015)
***Panel III**:Forest to Pasture Conversion- 41 km band*												
Amazon Biome - γ	-0.0296	0.1288 ***	0.1971 ***	0.0393 *	-0.0066	0.0917 ***	0.0206	-0.0042	-0.0911 ***	-0.1198 ***	-0.0831 ***	-0.1429 ***
	(0.021)	(0.019)	(0.021)	(0.018)	(0.017)	(0.016)	(0.014)	(0.016)	(0.015)	(0.015)	(0.015)	(0.018)
***Panel IV**:Forest to Pasture Conversion- 61 km band*												
Amazon Biome - γ	-0.0283	0.1677 ***	0.2392 ***	0.0439 **	0.0142	0.1007 ***	0.0085	-0.0293 *	-0.1021 ***	-0.1438 ***	-0.1087 ***	-0.1619 ***
	(0.018)	(0.016)	(0.018)	(0.016)	(0.015)	(0.014)	(0.012)	(0.014)	(0.013)	(0.013)	(0.013)	(0.016)