Do Market and Government Interventions Affect Greenhouse Gas Emissions?*

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Abstract

In 2006, the most important representatives of the Brazilian soy industry signed a moratorium, committing not to purchase soybeans planted in deforested areas in the Amazon Biome after July 2006. Furthermore, to stop clearing forests, the Brazilian government made the provision of rural credit in the Amazon region subject to stricter requirements in 2008. This paper studies how these two interventions affect greenhouse gas emissions, the primary cause of climate change. Using a panel of municipalities and a difference-in-differences strategy, we show that the two events substantially reduced deforestation, fires, pasture coverage area, and herd cattle size, leading to lower emissions. The outcomes point to a limitation in access to rural credit, one of Brazil's primary support mechanisms for agricultural production, as the possible mechanism underlying these effects. In addition, we found positive externalities in the form of lower greenhouse gas emissions in municipalities not affected by interventions but which are close to the Amazon Biome border.

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1 Introduction

Although forests are important carbon sinks, their stability is threatened by both natural and human disturbances, making deforestation a significant contributor to climate change. One of the biggest obstacles to reducing climate change is balancing the pressure to expand agriculture with environmental protection, especially considering that agriculture is a significant contributor to deforestation and greenhouse gas (GHG) emissions. Nearly 20% of all anthropogenic emissions came from clearing tropical forests, and emissions from deforestation and land use made up about a quarter of all global GHG emissions (Hansen et al., 2008; Gibbs and Herold, 2007; Stern, 2008).

To reduce forest clearing, policymakers and private markets worldwide have made significant efforts to design and put into practice various tools for law enforcement and incentive-based measures. However, more evidence on which types of policies are successful (or not) is still needed.

This article assesses the effects of market and government interventions implemented in the Brazilian Amazon on GHG emissions. First, in 2006, the Amazon Soy Moratorium (SoyM) was signed by the most important representatives of the Brazilian soy industry. The moratorium signatories is committed not to purchase soybeans planted in deforested areas in the Amazon Biome after July 2006. Second, Resolution 3545, published by the Brazilian Central Bank in 2008, made the provision of subsidized rural credit in the Amazon region contingent upon documentation of compliance with legal titling requirements and environmental regulations. Resolution 3545 thus represented a potential restriction of access to rural credit, one of Brazil's primary support mechanisms for agricultural production, because all credit agents were required to abide by the new regulations.

We used important elements in the execution of the two prominent events to help us design our empirical analysis. The terms of SoyM and Resolution 3545 were limited only to landholdings within the administrative boundaries of the Amazon biome. In order to assess the policy's effects inside the biome, we investigate this characteristic and use municipalities along the Amazon biome's external border as a control group. Due to the size and potential heterogeneity of the non-observables in the Amazon region, we only consider municipalities close to the border. Our benchmark sample consists of municipalities within 200 km or less from the border, while alternative samples take 100 km and 300 km into account.

Our potential meachanisms include environmental factors, such as deforestation and fires, and economic factors, including cattle herds (significant emitter of greenhouse gases), cropland and pastureland. To address our research question, we estimate a dynamic difference-in-differences model to test for pre- and post-treatment effects. In addition to measuring the main impact of the policies on greenhouse gas emissions, we also list possible channels through which these effects may have occurred. We demonstrate that before policy implementation, neither of the samples from the control or treatment municipalities exhibit any meaningful differential trends in observables.

Our findings show that the two interventions had a negative and significant impact on net GHG emissions, with the effect persisting throughout the analysis period. This result can be explained jointly by a significant negative effect on deforestation and fires and a prominent decrease in the pasture area and herd cattle size. Furthermore, we also show that Resolution 3545 was binding to restrict credit access for agriculture and livestock sectors. Merging the last result and Banerjee and Duflo (2012), we strengthen the argument that this potential restriction on the amount of credit that could be subsidized may have tightened credit restrictions, changing how farmers choose to produce their crops which results in an impact on deforestation and consequently, on GHG emissions. Finally, we also find that SoyM and Resolution 3545 generated significant spillovers into the Cerrado and Pantanal Biomes. In municipalities close to the Amazon Biome border but not affected directly by the interventions, we identify a negative and significant impact on fires and pasture area coverage. These are possible mechanisms by which we also identified a negative impact on GHG emissions.

The article is part of the literature on the impact assessment of environmental policies in Brazil. Recent works investigate the effectiveness of public policies and market solutions in preventing and controlling deforestation. However, to the best of our knowledge, we are the first to access the impacts of the policies on GHG emissions thoroughly.

The closest articles to this work are Assunção et al. (2020), which assess the impact of credit constraint, and Heilmayr et al. (2020), which assess the impact of the Soy Moratorium, both on deforestation. The article by Assunção et al. (2020) assesses the impact of Resolution 3545, which made subsidized credit to rural producers in the Amazon biome subject to strict compliance with environmental regulations and the legality of land tenure. Since the change in credit granting was only implemented for farmers in the Amazon biome, the authors use a difference-in-differences estimator as an identification strategy, using municipalities outside the border of the Amazon biome as a control group to assess the impact of the credit restriction policy within the biome. Using a panel of municipalities from 2003 to 2011, the authors find that the total area deforested during the sample period was about 60% lower than it would have been in the absence of resolution 3545, with the effect being potentiated in municipalities whose livestock is the main economic activity.

Assunção et al. (2020) also explores two mechanisms by which this reduction in deforestation may have occurred. On the one hand, by increasing environmental and land tenure requirements for granting credit, Resolution 3545 on deforestation should directly reduce access to subsidized credit. On the other hand, this credit-granting policy allowed farmers to only signal compliance with legal norms in the future so that credit granting could be carried out. With this, it is possible that farmers, who did not comply with the environmental regulations, have changed their behavior regarding deforestation for reasons other than credit reduction. Using a difference-in-differences strategy, they find that the first mechanism is prevalent: there was a significant reduction in Rural Credit; specifically, the reduction for specific loans to livestock farmers was responsible for 75% of this effect.

Heilmayr et al. (2020) assesses the Soy Moratorium's impact on the Amazon biome's deforested area. The authors use a triple differences model as an identification strategy, in which they compare deforested areas between different biomes (first difference) after the adoption of the Soy Moratorium (second difference) and between locations with different potentials for soybean production (third difference). The results postulate that the Soy Moratorium reduced the deforested area in territories with potential soy plantations in the Amazon by 32 percentage points relative to the counterfactual, preventing an area of more or less 9,000 km2 from being deforested between 2006-2016.

Aiming to investigate agricultural displacement and deforestation leakage, Moffette and Gibbs (2021) uses a difference-in-differences approach in which the treatment is linearly proxied by distance from the Cerrado biome's spatial limit. The results show that SoyM induced agricultural displacement into the less regulated ecosystem, the Cerrado biome, and deforestation leakage. From 2007 to 2013, soy production increased 31% closer to the Amazonian border than it did in areas farther away. Agricultural displacements led to deforestation leakage increasing by 12.7% in the Cerrado biome compared with before SoyM.

Even though GHG emissions are a serious global issue, there is little systematic evidence on how market and government interventions affect these emissions. This paper aims to fill this gap by making four main contributions. First, we analyze emissions as our primary outcome, trying to give a more general vision of how SoyM and Resolution 3545 may have been efficient as climate mitigation policies. Second, to the best of our knowledge, we are the first work to analyze the two prominent events jointly — a unique setting in which market and government-based mitigation policies interact to reduce deforestation. Third, we comprehensively investigate possible channels through which the Moratorium and the Resolution may have impacted GHG emissions: deforestation, fires, coverage area concerning soy and pasture, and cattle herd size. Fourth, we evaluate the persistence of the effects by using a dynamic difference-in-differences model. Finally, we also investigate unintended policies spillovers to neighboring municipalities, trying to elucidate if there was a shift in deforestation and agricultural activities from inside protected regions to outside protected regions that could explain a possible spillover effect on GHG Emissions.

The remainder of this paper is organized as follows. Section 2 provides the institutional context on SoyM and Resolution 3545. Section 3 presents the data and summary statistics, while section 4 describes the methodology. Section 5 shows the results, and robustness and specification checks. Section 6 concludes.

2 Institutional Context

2.1 Soy Moratorium

Brazil's Soy Moratorium (SoyM) was a zero-deforestation agreement implemented by the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the National Grain Exporters Association (ANEC). The SoyM was launched in May 2006 after a contentious Greenpeace report called for the companies to leave the Amazon and linked three American commodities traders (Cargill, Bunge, and ADM) to millions of hectares of deforestation there. Public opinion also called on firms closely linked to deforestation to take active action in a climate of unsteady law enforcement capacity and uncertainty arising from political cycle swings, despite more significant conservation laws and enforcement. Furthermore, international sanctions and negative consumer perception in the North American and European markets contributed to the threat to the soy sector.

ABIOVE and ANEC replied to the Greenpeace report by introducing the SoyM, which put an initial two-year prohibition (2006-2008) on buying soy from freshly deforested areas in the Amazon biome. The objective was to stop the conversion of forests into soy crops in the Amazon biome and enhance the value of having an environmentally sustainable soy chain in domestic and international markets. In other words, the purchase and financing of soy from rural landowners that sow it in previously forested areas were prohibited from this date.

Up until 2016, the SoyM was renewed annually or biannually. After that, it was permanently renewed. The original agreement forbade soybean production on lands cleared after July 24, 2006; however, at the end of 2014, to align with the 2012 Forest Code revisions changes, the deforestation cutoff date became July 22, 2008. Through a careful monitoring process using remote sensing satellite photos with complementary geographical and temporal resolutions, soy crops in regions cleared of trees after 2008 are found. A review team of interpreters thoroughly examines these images. In addition to these analyses, databases from the following organizations are used: Agrosatélite, FUNAI, Ministry of the Environment, IBGE, INCRA, and PRODES.

Important to note that even with the change in the deforestation cutoff date, the moratorium has been in effect since 2006.

The Soy Working Group (Grupo de Trabalho da Soja, GTS), which is responsible for the intervention, keeps an eye on municipalities that are totally or partially covered by the Amazon Biome and that cultivated more than 5,000 hectares of soy in the previous harvest (which represents 98% of the soybean planted area in the biome), monitoring and enforcing the agreement every year. The agrarian reform settlement areas, conservation units, and indigenous lands are not monitored. By comparing soy areas to a map of the deforested areas in the reference date obtained from the PRODES satellite monitoring system, the monitoring system may identify locations where soy expansion has occurred. Furthermore, polygons deforested after 2008 identified with soy are audited by INPE for their veracity and accuracy, increasing the robustness of the inspection process.

Likewise, the intervention formerly urged and now requires that soy producers register their properties in the Rural Environmental Registry (Cadastro Ambiental Rural in Portuguese, CAR) to correlate breaches to specific perpetrators. The GTS compiles an annual list of farms with SoyM breaches using data from the CAR, satellite measurements, and field inspections. Soy merchants must consult this list to ascertain whether potential suppliers have broken the SoyM.

This market solution introduces many disincentives that may reduce deforestation and, consequently, GHG emissions in the Amazon biome by forbidding the purchase of soy produced on recently cleared lands. Farmers of soy are hesitant to invest in directly converting forests to soy production if they think the SoyM will prohibit the sale of non-compliant soy. After the historic cutoff, the SoyM also forbids the spread of soy onto cleared pastures or other croplands. In turn, this might reduce the speculative value of deforestation for cattle ranchers and other investors by limiting the predicted earnings from future land uses for currently forested lands.

Since the monitoring is done at the property level using CAR registry data, the SoyM almost eliminates the possibility of fraud. In addition, there are only a few trading companies in the soy sector, and the Moratorium signatory associations account for 98% of Amazon's soy commerce (Piatto et al. (2016)). As a result, few purchasers may have the power to influence the producers.

Finally, both the proportion of recently deforested areas planted with soy and the proportion of fresh soy planted on recently cleared fields have substantially decreased. Since SoyM, soy cultivation has spread primarily over the grassland in the Amazon. As a result, there has been extraordinarily high SoyM compliance. Between 2008 and 2015, GTS identified only 371.55 km^2 with soybeans in disagreement with SoyM, equivalent to 1.2% of the deforested area in the biome (Piatto et al. (2016)).

2.2 Resolution 3545

In Brazil, rural credit operations follow the guidelines and requirements outlined in the Manual of Rural Credit (Manual de Crédito Rural, MCR) of the Central Bank. It encompasses instruments to finance rural production commercialization, investment, and short-term operations funds. All members of the National Rural Credit System (Sistema Nacional de Crédito Rural, SNCR) must follow the MCR's rules, which consist of state banks, commercial banks, and credit cooperatives.

The yearly Crop and Livestock Plan (Plano Agricola e Pecuário, PAP), also referred to as the Harvest Plan, is one of the primary policy instruments used in Brazil to determine the concession of rural loans (Plano Safra). The Ministry of Agriculture, Cattle and Supplying (Ministério da Agricultura, Pecuária e Abastecimento, MAPA) releases the PAP in the first semester of every year, a summary of the guidelines created for agricultural policy in each harvest year. The document aims to provide producers with advice and information regarding factors crucial to the nation's agricultural production. The PAP's main components include the government's plans for the amount of credit to be lent to both commercial and family production and the subsidized interest rates applied to a sizable portion of the projected credit loans.

Resolution 3545, published by National Monetary Council (Conselho Monetário Nacional, CMN) on February 29, 2008, stipulated that to receive rural credit for agricultural activities in the Amazon Biome, borrowers had to comply with environmental laws — compliance with the recommendations and restrictions of agroecological zoning and Ecological-Economic Zoning; the validity of their land claims; and the regularity of their rural establishments. The conditions only applied to establishments that were totally or partially inside the biome (frontier municipalities, whose territory is only partially located within the biome) — according to Resolution 3583, published on July 1, 2008.

The resolution represented a potential restriction on official rural credit because all related institutions, including public banks, private banks, and credit cooperatives, were required to abide by the new regulations. This requirement meant that the portion of official rural credit subsidized by lower interest rates might also be restricted. Other agriculture finance forms, like trade credit and supplier credit, were not subject to this prohibition.

To prove eligibility for taking credit, after Resolution 3545, the borrower had to present: (i) the Certificate of Registry of the Rural Establishment (Certificado de Cadastro de Imóvel Rural, CCIR); (ii) a declaration stating the absence of current embargoes caused by economical use of illegally deforested areas; and (iii) a state-issued document attesting the environmental regularity of the establishment hosting the project to be financed, or, in the absence of the such document, a state-issued certificate indicating that the documentation necessary for regularization had been received. The terms of the resolution apply not just to landowners but also partners, sharecroppers, and renters.

Although they seemed severe initially, Resolution 3545 was subject to conditions that softened the new credit limits. This softness was significant for small-scale farmers— Resolution 3545 previously created exclusions for three classes of small credit takers in its original form. The first group, comprised of Pronaf beneficiaries and rural producers operating in areas smaller than or equal to four fiscal modules, was still required to present the CCIR. However, an individual declaration attesting to the existence of the required legal reserve and area of permanent protection, as well as the absence of current embargoes caused by the economical use of illegally deforested areas within the credit taker's establishment, could replace the rest of the documentation.

The second group, which consists of National Program of Land Reform beneficiaries who fall under Pronaf groups A and A/C, may substitute a declaration from the National Institute of Colonization and Land Reform (Instituto Nacional de Colonização e Reforma Agrária, Incra) for all supporting documents. The only need for this second group became attesting to the environmental regularity of the land reform settlement or stating that a time frame for its regularization has been agreed upon. The third category, limited to family farmers within Pronaf group B, was exempt from this requirement. These exemptions meant that Resolution 3545 had fewer onerous requirements for small producers since the three groupings referred to small-scale producers.

Resolution 3545 reflected a uniform shift in policy across regions since it set the same limitations and exceptions in all the municipalities to which it applied. However, structural variability may have caused its effects on rural credit concession and, consequently, on deforestation to vary across economic sectors. The makeup of the sources utilized to satisfy the financial requirements for crop and livestock production is a significant structural distinction that we consider.

FAO (2007) claims that as more agricultural funding, notably for producing soybeans, has been secured through agreements with merchants, input and processing companies, retailers, and market operators, the proportionate involvement of formal rural credit contracts has dropped. An estimated 30% of the financial needs of the Brazilian soybean production sector are covered by government credit; however, the remaining funds are provided by traders and the processing industry (40%), the input industry (15%), and farmers' resources (10%). Other sources, such as agricultural machinery manufacturers, meet 5% of the financial needs.

Based on this scenario, crop farming sectors less reliant on rural governmental credit may be able to find alternate sources of funding to make up for the reduction in official rural credit imposed by Resolution 3545. Thus, producers in this sector would be able to maintain investment and deforestation at the same levels as before the intervention by the credit program.

Furthermore, beginning in the early 1990s, crop production in Brazil also benefited from pertinent technical advancements, notably with the widespread use of direct seeding. No similar pattern was seen for cattle farming, which continues to be a low-productivity activity in the nation. Instead of increasing production by operating on the extensive margin as cattle ranchers do, crop producers probably invest a higher portion of rural credit loans in intensifying their operations. Since resources were not initially being utilized to drive agricultural output into forest regions, a fall in rural loans for crop producers in this situation could not result in a decline in forest clearings. We investigate these possible sectoral variations.

3 Data and Summary Statistics

We use annual data from 2003 to 2018. From a georeferenced map containing the location of the municipalities and the limits of the Amazon biome, it is possible to create two subsamples of municipalities within and outside the Amazon Biome using a specific distance from the centroid of the municipalities about the biome border. We used municipalities with centroids within 200km of the biome border as a sample.

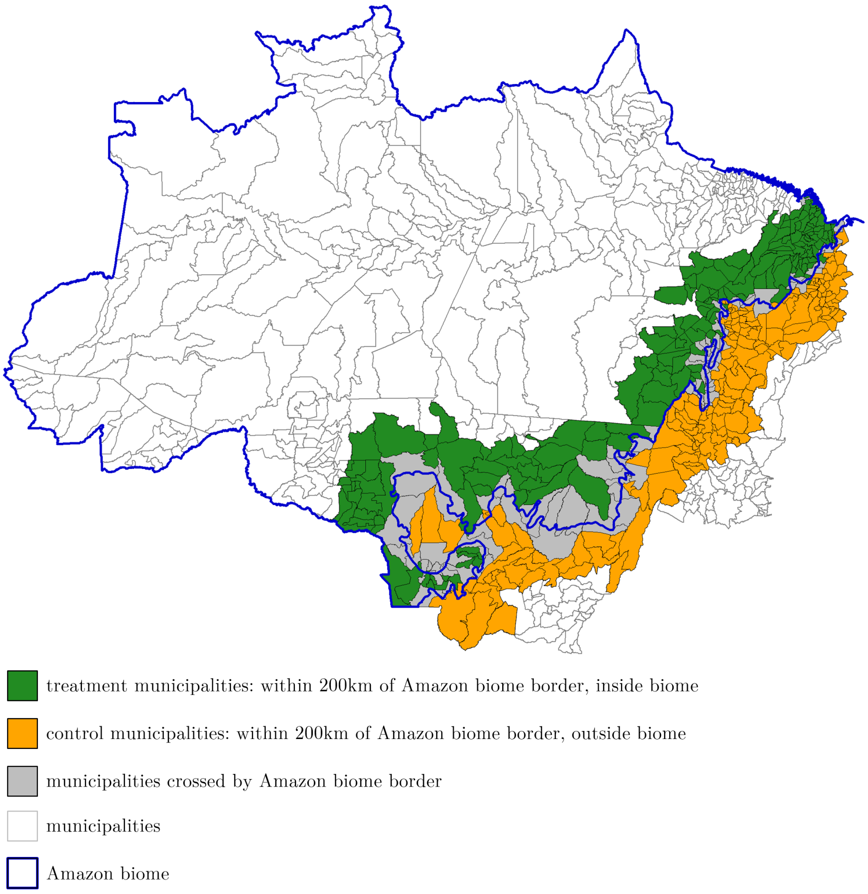
Considering, in particular, the restriction imposed by the change in Rural Credit — that only properties partially or totally within the Amazon biome were subject to the conditions of Resolution 3545, we excluded municipalities whose boundaries cross the biome's border. We allow only inclusion of those at least 90% of the territory is on one side of the biome border. Furthermore, we guarantee that all properties in the municipalities exposed to treatment have been subject to a change in the Rural Credit policy. Figure 1 illustrates the sample's stratification, composed of 338 municipalities whose centroid is within 200km of the biome border and situated with more than 90% of the territory inside or outside the Amazon biome.

3.1 Greenhouse Gas (GHG) Emissions Data

Emissions data are obtained through the System of Estimates of Emissions and Removals of Greenhouse Gases (SEEG), an initiative of the Climate Observatory. Estimates of GHG emissions and removals are generated according to the Intergovernmental Panel on Climate Change (IPCC) guidelines and in data obtained from government reports, institutes, research centers, sectoral entities, and non-governmental organizations (DE AZEVEDO et al., 2018).

All greenhouse gases contained in the national inventory are considered, such as

Figure 1: Legal Amazon, Amazon biome and benchmark sample (200km)



Notes. The figure illustrates the Amazon Biome border, as well as municipality limits for the states of Acre, Amazonas, Amapá, Maranhão, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins (all of which are partly or entirely located in the Amazon biome). Our benchmark sample is composed of treatment and control municipalities located within 200 km of the Amazon biome border. We allow only inclusion of those at least 90% of the territory is on one side of the biome border.

carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). SEEG estimations include emission sources of all sectors and their respective gases, as follows:

- Agriculture: covers estimations of all anthropogenic non-CO_2 emissions (CH_4 and N_2O) from agricultural systems (livestock and cropping) soils, except for fuel combustion and sewage emissions;

- Land Use Change: covers estimations associated with land cover and user change mapped using satellite data. The changes in land cover represent the main emissions and removals of CO_2, and the changes in land use represent the intensity of these emissions and removals. This sector also estimates emissions from burned forest residues (CH_4 and N_20) and liming;

- Energy: covers GHG emissions that occur through two different processes: (i) fuel combustion and (ii) fugitive emissions;

- Industrial Process and Product Use: covers GHG Emissions that occurred in chemical or physical material transformation in industrial activities;

- Waste: covers estimations of GHG emissions from solid waste and wastewater treatment and discharge, except emissions related to the waste generated from agricultural and livestock activities, which are accounted for in the agriculture sector;

All estimates are also expressed in terms of CO_2 equivalents (CO_2e) using GWP (Global Warming Potential) and GTP (Global Temperature Change Potential) conversion values of the second, fourth, and fifth IPCC assessment reports IPCC (1996, 2007, 2013). In order to smooth out the cross-sectional variation in GHG emissions — which arises from heterogeneity in the size of municipalities — we use a logarithmized annual measure of GHG emissions.

3.2 Other Data

Data on annual rural credit are obtained from the Common Registry of Rural Operations (Registro Comum de Operações Rurais, Recor) and Rural Credit and Proagro Operations System (Sistema de Operações do Crédito Rural e do Proagro, Sicor), both maintained by the Brazilian Central Bank (Banco Central, BC). The data set includes all rural contract records negotiated by official banks (both public and private) and credit cooperatives in these states.

Regarding deforestation, data comes from PRODES/INPE, which uses satellite-based photos processed at the municipal level. Every year, INPE analyzes photos from Landsat-class satellites to find forest clearings across the Brazilian Legal Amazon (BLA).

Furthermore, we use fires data from BDQueimadas/INPE. A vegetation burning focus indicates the existence of fire in an image resolution element (pixel), which varies from 375m×375m to 5km×4km, depending on the satellite. One or several active firefronts in this pixel may indicate a single focus or point.

Concerning land cover, we use data from MapBiomas, which is obtained from Landsat imagery collections. This data allows us to access pasture and agriculture coverage, especially soybean coverage. In addition, we also use data on herd cattle size from PPM/IBGE.

About controls, we account for: (i) soil soy suitability (data from the Food and Agriculture Organization's Global Agro-Ecological Zones, FAO-GAEZ); (ii) rural population share (data from the Brazilian Institute of Geography and Statistics, IBGE); and (iii) the extent of protected territory in each municipality, including the total area of protected areas and indigenous lands (data from the Ministry of the Environment and the National Native Foundation).

3.3 Summary Statistics

Table 1 presents the outcomes means, standard deviations, and minimum and maximum values, all based on the sample of 200 km threshold.

Table 1: Variables of interest descriptive statistics

	Main band: 200km			
	Mean	St. Dev.	Minimum	Maximum
Net GHG Emissions/1000	843.60	2095.90	-529.28	27537.40
Deforestation	9.30	33.06	0.00	580.40
Fire Focus	1259.01	2488.10	0.00	46910.00
Credit Crop/1000000	179.51	970.64	0.00	19854.06
Credit Cattle/1000000	109.61	444.67	0.00	22034.75
Soy Coverage	175.67	546.31	0.00	3949.48
Pasture Coverage	870.97	1113.90	3.43	7093.86
Heard of Cattle/1000	101.67	143.02	0.00	1113.13

Notes. This table presents the descriptive statistics of all relevant variables taken into account in the estimations performed in this paper. The analysis period is from 2003 to 2018. All monetary values have been deflated by the Brazilian Consumer Price Index (IPCA) calculated by IBGE and are denominated in 2003 reais. Notice that "Net GHG Emissions" have negative minimum values because SEEG estimates the sequestration of greenhouse gas gases for Brazilian municipalities, and a few of them are able to sequester more carbon than they release, which is mathematically represented with negative values.

4 Empirical Strategy

To assess the impact of the Soy Moratorium and Resolution 3545 on GHG emissions, we explored that both the market solution and the restriction on rural credit became effective only in properties located within the Amazon Biome. This fact makes it possible to create a treatment group composed of municipalities located entirely (more precisely, with at least 90% of their territory) within the Amazon biome and a control group composed of municipalities outside the Amazon biome.

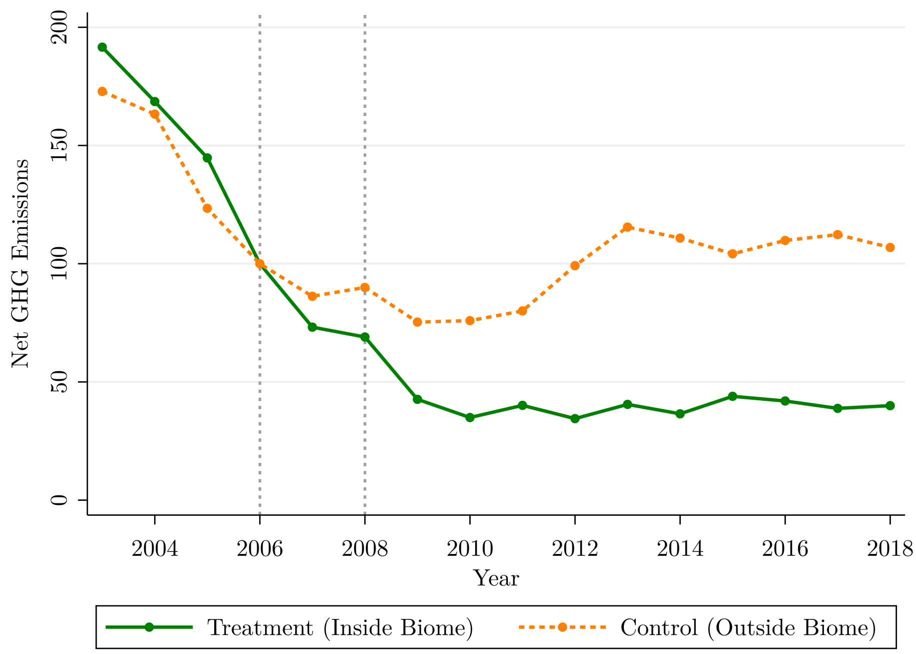
Therefore, we combine these geographic breaks, both in the case of the Soy Moratorium and Resolution 3545, with annual data at the municipal level to use a dynamic difference-in-differences specification. In particular, we estimate the following model:

$$y_{it} = SoyM_i \times \sum_{\substack{\tau=-3 \\ \tau\neq-1}}^{12} \beta_\tau \cdot \mathbf{I}\big(t - 2006 = \tau\big) + \rho_i + \phi_t + \lambda X_{it} + \varepsilon_{it} \tag{1}$$

where y_{it} is the dependent variable for municipality i at year t. Our dependent variables include net GHG emissions by agriculture, change in land use; deforestation; fires; soy and pasture coverage, and cattle herd size. The $SoyM_i$ variable equals 1 if municipality i is covered by the SoyM and Resolution 3545 (Treatment group municipalities) and zero otherwise (Control group municipalities). The indicator variable $\mathbf{I}(t - 2006 = \tau)$ measures the time relative to the year of implementation (2006) of the treatment in the municipalities and receives zero in all periods for the municipalities that make up the Control group. The parameter β_τ is the dynamic effect of the treatment. The omitted coefficient $\beta_{\tau=-1}$ corresponds to 2005, using the year before the SoyM as the base year. ρ_i and ϕ_t are fixed effects of municipality and year, respectively. X_{it} represents a vector of controls, which includes *soil soy suitability*, *rural population share* and *protected area share* in municipality i. Standard errors are clustered at the municipal level since the variation we measure occurs at the municipal level, and errors may be correlated within spatial units. Finally, we apply the natural logarithm transformation to the dependent variable in Equation 1 in order to report our baseline results.

Our difference-in-differences model identification hypothesis is that data on annual dependent variables in municipalities inside and outside the Amazon biome would have followed parallel trends in the absence of SoyM and Resolution 3545. Analyzing the raw patterns of the data, we show visual evidence of our principal dependent variable (Net GHG Emissions) identification hypothesis in Figure 2. We test for pre-trends in the Results section.

Figure 2: GHG emissions in Treatment and Control Municipalities, considering the benchmark sample (200km).



Notes. The graph displays the trend of average municipal Net GHG emissions over the sample period, 2003 to 2018, in tons of carbon dioxide equivalent (CO2e). Pre- and post-policy trends can be distinguished using the policy markers in 2006 and 2008. Data is from Brazil's Climate Observatory.

4.1 Leakage

To explore whether spillovers are likely to inflate our estimates of the SoyM and Resolution 3545's impacts, we compare data of dependent variables of untreated locations that are geographically proximate to treated units with more remote locations. Suppose nearby locations experienced a significant variation in dependent variables following the adoption of the SoyM and Resolution 3545 compared to more remote locations. In that case, this could be proof of spillovers caused by the two notable events.

For instance, SoyM and Resolution 3545 would have decreased deforestation in the Amazon Biome while increasing it in the Cerrado and Pantanal Biomes (Moffette and Gibbs (2021); Dou et al. (2018)). We hypothesize that the possible deforest expansion, displaced by the two notable events, would be concentrated in the Cerrado and Pantanal areas closest to the Amazon biome boundary since displaced farmers are likely to invest close to their initial targeted location for expansion. By comparing deforestation trends in the Cerrado and Pantanal regions close to the biome boundary with those in more remote areas of these biomes, we investigated the potential for cross-biome leakage.

Our empirical strategy consists in estimating the following equation:

$$y_{it} = Proximity_i \times \sum_{\substack{\tau=-3 \\ \tau\neq-1}}^{12} \beta_\tau \cdot \mathbf{I}\big(t - 2006 = \tau\big) + \rho_i + \phi_t + \lambda X_{it} + \varepsilon_{it} \quad (2)$$

where y_{it} is the dependent variable for municipality i at year t. Our dependent variables are the same as described for equation 1. The indicator variable $\mathbf{I}(t - 2006 = \tau)$, the parameter β_τ, and the fixed effects ρ_i and ϕ_t also remain the same as described in equation 1. We also apply the natural logarithm transformation to the dependent variable in Equation 2 in order to report our baseline results.

Following Moffette and Gibbs (2021), we calculated proximity to the border ($Proximity_i$) by using: (I) a binary variable that indicates whether a location is 100 kilometers or less from the biome border — receives 1 if the distance is on the interval [0;100] and 0 if the distance is on the interval (100;200] (Appendix Figure A.1 illustrates the sample's stratification); and (ii) an inverse distance formula, which, when the observation unit is closest to the biome border, the continuous treatment Proximity equals 1, and when it is farther away, it equals 0. The second transformation is as follows:

$$Proximity_i = \left| \frac{Dist_i}{MaxDist} - 1 \right| \quad (3)$$

where $Dist_i$ denotes the distance to the Amazon frontier of municipality i and $MaxDist$ is the farthest distance from the Amazon frontier in the Cerrado and Pantanal biome of all units of analysis.

5 Results

We divide the results into six parts. First, we study the effects of the two prominent events on net GHG emissions. Second, we analyze policies' impact on deforestation and fires, two mechanisms by which SoyM and Resolution 3545 can affect GHG emissions. Third, we enhanced the analysis of mechanisms by studying how variables related to agriculture and livestock may be affected by the analyzed policies. Fourth, we investigate how Resolution 3545 affects credit restriction, focusing on rural credit. We then show the leakage effects and finish with robustness and specification checks. In the interest of full disclosure, we present the magnitude of the coefficients in Appendix Table A.1.

5.1 Effects on GHG Emissions

Figure 3 presents baseline results on GHG emissions. The vertical dotted lines highlight the year of the two prominent events we analyze. The point estimate of every period after Resolution 3545 is negative and significantly differs from zero. Notably, the effect persists until the end of our analysis.

A potential drawback of our specification is that the two prominent events are close in time; thus, it could be challenging to assess whether the SoyM had any impact. Figure 3 suggests this is a valid concern as GHG emissions do not significantly decrease in treatment municipalities relative to control municipalities after the SoyM.

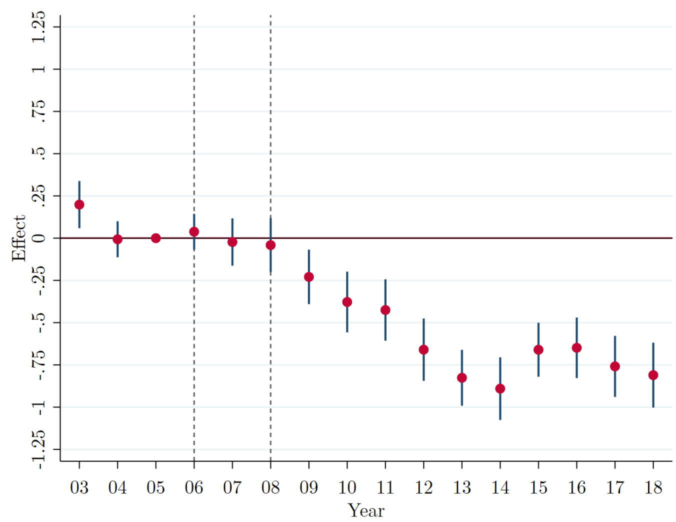
Conceptually, the results are consistent with SoyM working as an initial shock with a slight drop in GHG emissions. Resolution 3545 operates as an intensification shock, even with a more pronounced negative shock than SoyM. GHG emissions remain significantly lower after Resolution 3545 in treatment versus control municipalities.

5.2 Effects on Deforestation and Fires

Concerning mechanisms, we start by showing the effects on deforestation, presented in Figure 4. The results pointed out that SoyM, in conjunction with Resolution 3545, effectively reduced deforestation inside Amazon Biome compared to municipalities outside the biome. In addition, the effects persist over time until the end of the analysis.

In line, Figure 5 documents a decrease in fires in the Amazon biome compared to municipalities outside the biome, with the effect also persisting over time. Together, the last pieces of evidence show that the effects of SoyM and Resolution 3545 on deforestation and fires are strongly decarbonizing, especially when we consider that these two activities are significant emitters of GHG. In response to a shock, carbonizing

Figure 3: Emissions: Baseline Results



Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the logarithm of net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

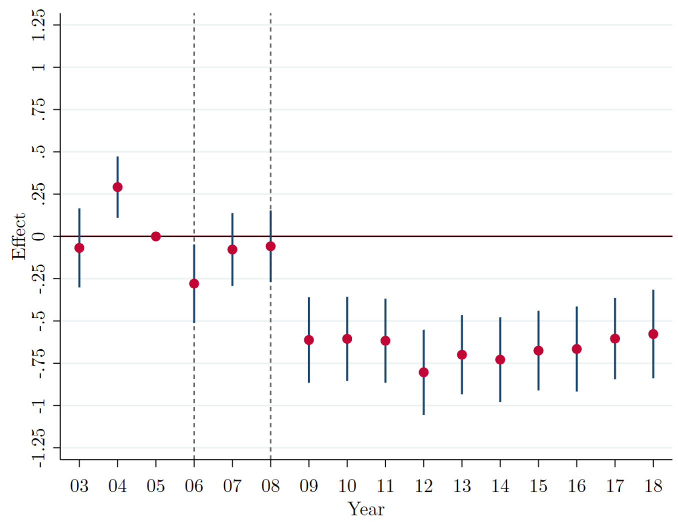
output increases greenhouse gas emissions. Examples of carbonizing production reactions in agriculture are those that result in deforestation and fires for land clearance. Decarbonizing production reactions to shock results in decreased GHG emissions, such as converting land to lower-emission crops (Da Mata and Dotta (2021)).

5.3 Effects on Agriculture and Livestock

Beyond deforestation and fires, production responses from SoyM and Resolution 3545 can lead to further GHG emissions decarbonization. In Figure 6, we assess the role of land-use conversion to soy crops. The results show no significant change in the soybean coverage area. Furthermore, Figure 7 shows the effects of the two prominent events on pasture coverage. As we can see, since SoyM, there has been a significant decrease in pasture coverage when comparing treatment municipalities with control municipalities, with this effect persisting and intensifying over time. Despite pre-trend problems regarding the effect on pasture cover, Appendix Figure A.2 shows that after 2008 there was an evident detachment of the pasture coverage trend (raw data) between the treatment municipalities and the control municipalities. While control municipalities maintained the upward trend in the pasture coverage area, treatment municipalities experienced an apparent trend reversal after the two prominent events, especially after Resolution 3545 in 2008.

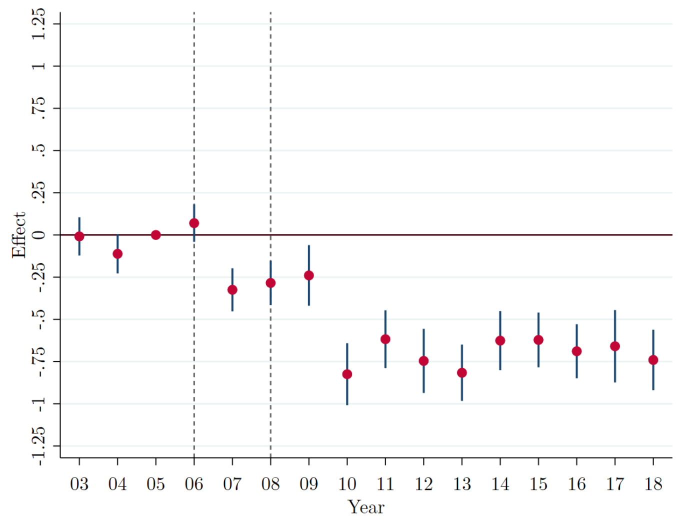
However, when discussing decarbonization, especially concerning livestock, the vital driver of emissions is not the pasture area but the cattle herd's size. Based on this, Figure 8 displays SoyM and Resolution 3545's effect on the cattle herd size. The

Figure 4: Deforestation: Baseline Results



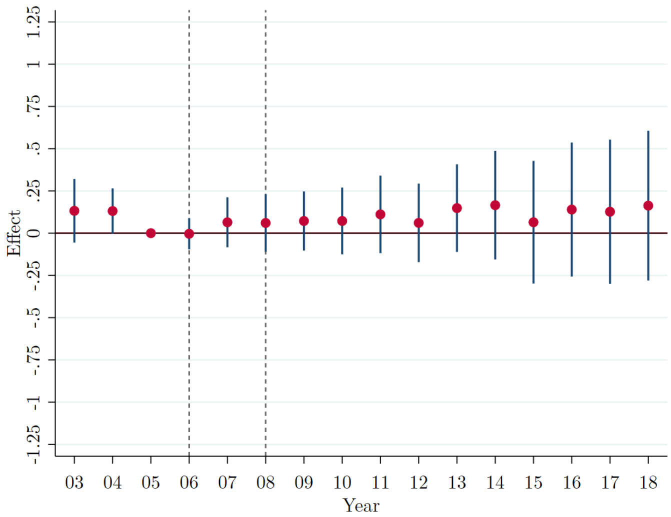
Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the area of deforestation in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure 5: Number of Fires: Baseline Results



Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the number of fire focus in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at municipality level. Confidence intervals: 95%.

Figure 6: Soybean Coverage: Baseline Results



Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the soy coverage area in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

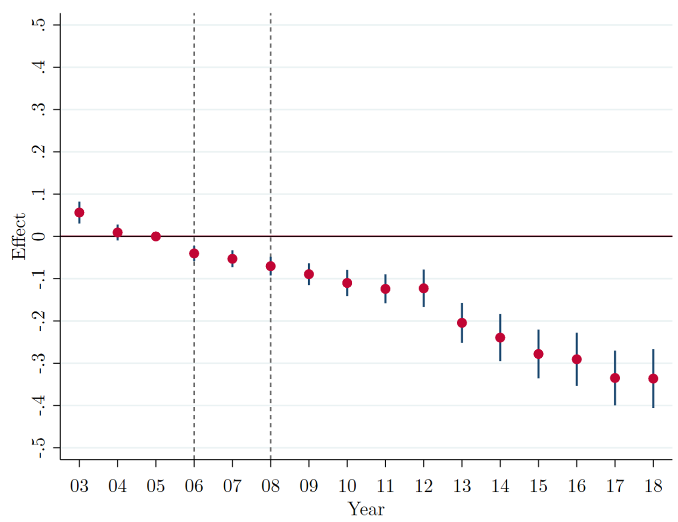
results show a significant decrease in the number of cattle herds. This result validates the impact on livestock as strongly decarbonizing, considering this activity is a significant emitter of carbon dioxide (CO_2) and methane (CH_4). Again, despite pre-trend problems regarding the effect on cattle herd size, Appendix Figure A.3 shows that after 2008 there was an evident detachment of the cattle herd trend between the treatment municipalities about the control municipalities.

5.4 Effects on Rural Credit Concessions

After examining SoyM and Resolution 3545's impact on deforestation and GHG emissions, we examine its possible credit-related mechanisms. Resolution 3545's effects on deforestation should be a direct result of lessened access to rural credit if requirements for legal land titling were immediately binding. On the other hand, farmers who were currently breaking environmental regulations could have changed their deforestation practices for reasons other than a direct reduction in credit. If this is the case, producers would not experience a credit effect because their desire to comply makes them compliant, but deforestation would still be reduced. To examine these two mechanisms, we evaluate the impact of Resolution 3545 on rural credit loans in Figure 9.

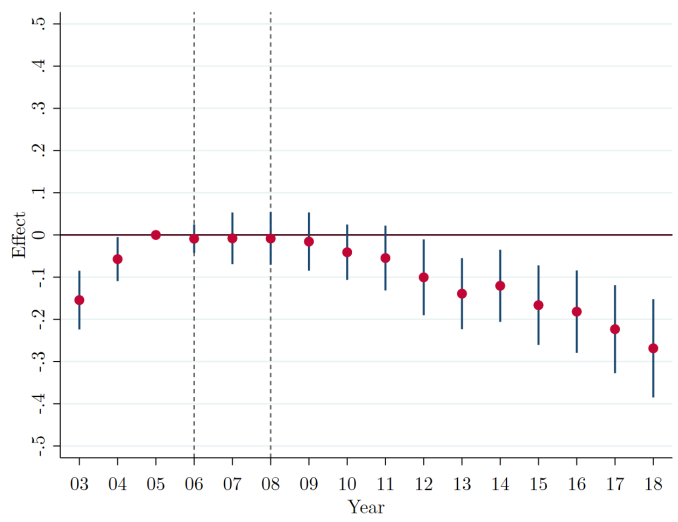
The results show that Resolution 3545 effectively impacted rural credit concessions, with this effect persisting and intensifying over time. According to this finding, Resolution 3545's effects on deforestation and, as a result, on GHG emissions directly reflect a decrease in deforestation in response to a decrease in rural credit availability.

Figure 7: Pasture Coverage: Baseline Results



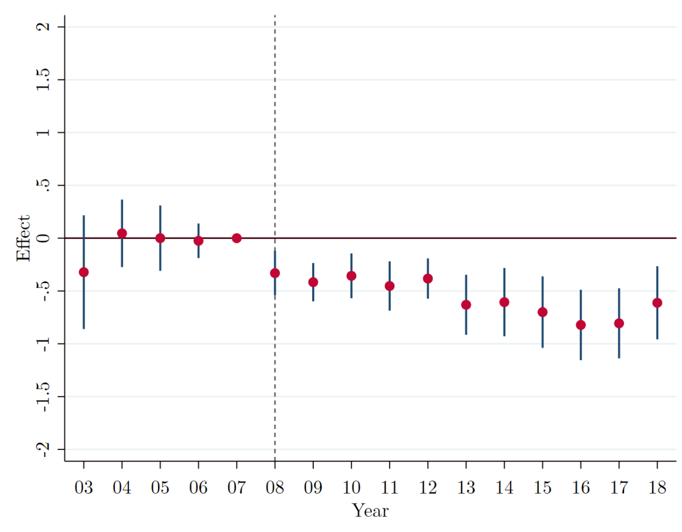
Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the pasture coverage area in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure 8: Herd of Cattle: Baseline Results



Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the cattle herd size in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure 9: Rural Credit Concessions: Baseline Results



Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the total value of rural credit concession in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

We still examine whether Resolution 3545 affected different credit contract types. We begin by separating credit for cattle ranching and crop farming activities. Appendix Figure A.4 shows that Resolution 3545's impact on credit for use in cattle ranching activities is negative and significant. In the same way, Appendix Figure A.5 shows that the two prominent events' impact on credit for use in crop farming activities is significant and even more negative.

Overall, the results indicate that access to credit and deforestation are correlated with the two principal activities analyzed here — crop farming and cattle ranching.

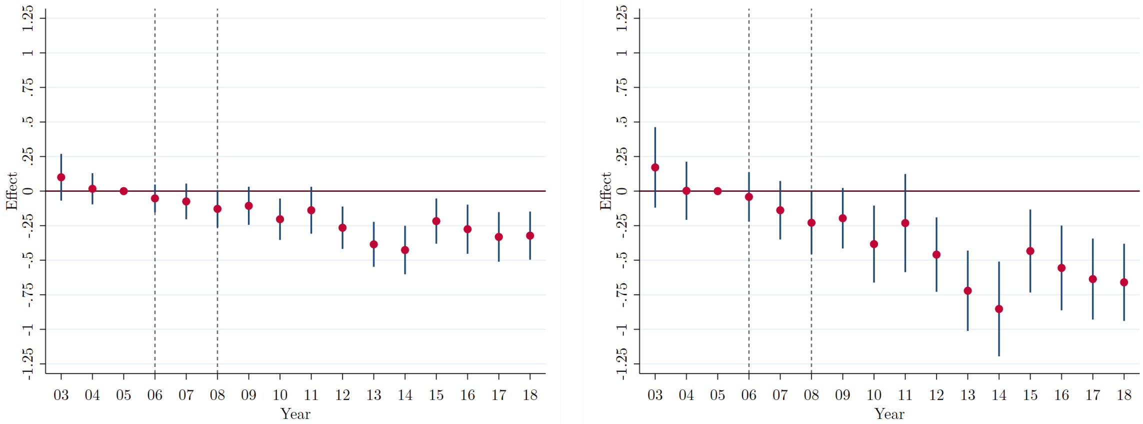
5.5 Leakage

About leakage, our results show that the SoyM and Resolution 3545 generated substantial spillovers into the Cerrado and Pantanal biomes. Figure 10 shows that the two prominent events negatively impacted net GHG emissions in municipalities close to the biome border compared to the more distant ones.

Regarding the mechanisms, the only variable that can explain the effect on GHG emissions is the number of fires (Figure 11). Immediately after Resolution 3545, we can see a positive effect on fires, but with this effect inverting after 2009 and becoming significantly negative, supporting a negative effect on GHG emissions. When we look at deforestation in Figure 12, there was a positive and significant effect in 2009, behaving similarly to what happens with fires. However, this effect ceases to be persistent in subsequent periods.

When we look at soy coverage (Figure 13), it is interesting to note that after SoyM,

Figure 10: Emissions: Leakage Results



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of the 200 km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the logarithm of net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

there was a significant positive effect on municipalities close to the biome border, even with this effect ceasing to be significant after 2009. The advance of soy seems to have occurred mainly in forest and pasture areas, especially when we consider the effect on the pasture coverage area is negative and significant after implementing interventions (Figure 14). Figure 15 shows there is no significant leakage effect on herd cattle size.

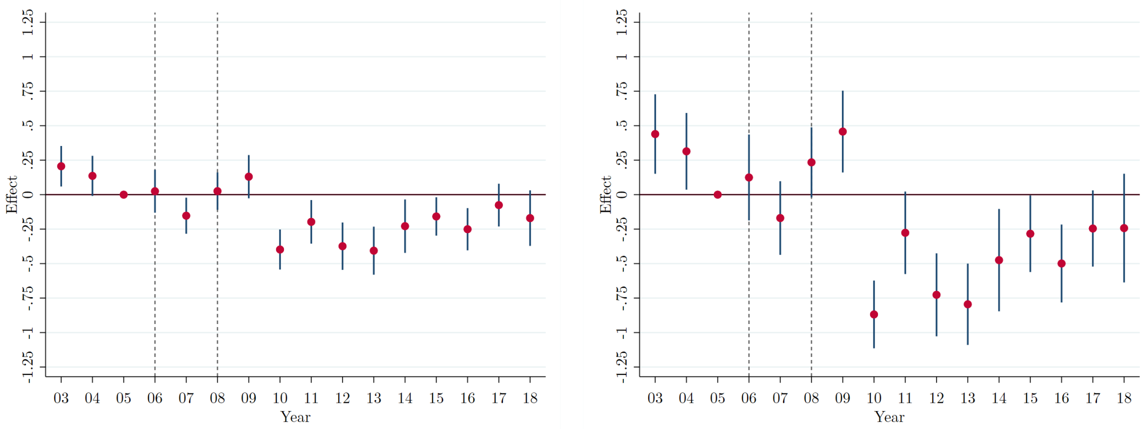
This outcome might be the result of a change in the land market, where the increased use of pasture for soy production brought about competition between soy producers and cattle ranchers. The trend is that the advance of soy, which would previously occur in the Amazon Biome, has been expurgated to the neighboring biomes (Cerrado and Pantanal). Interestingly, this advance has occurred chiefly over areas that used to be pasture and not towards forests.

Unifying the last results, SoyM and Resolution 3545 result in positive spillovers to neighbors' biomes — Cerrado and Pantanal. The spillovers we identify here were caused by agricultural displacements and changes in location choices for those who, in the absence of the two policies, would have continued or further expanded their agricultural activities in the Amazon Biome. However, spillovers can happen in various ways, making our estimated effects lower bounds because some agricultural displacements could also occur in our counterfactual.

5.6 Robustness and Specification Checks

We run several specification tests and exercises for robustness. We detail each exercise and demonstrate how generally solid our findings are. We only report the robustness

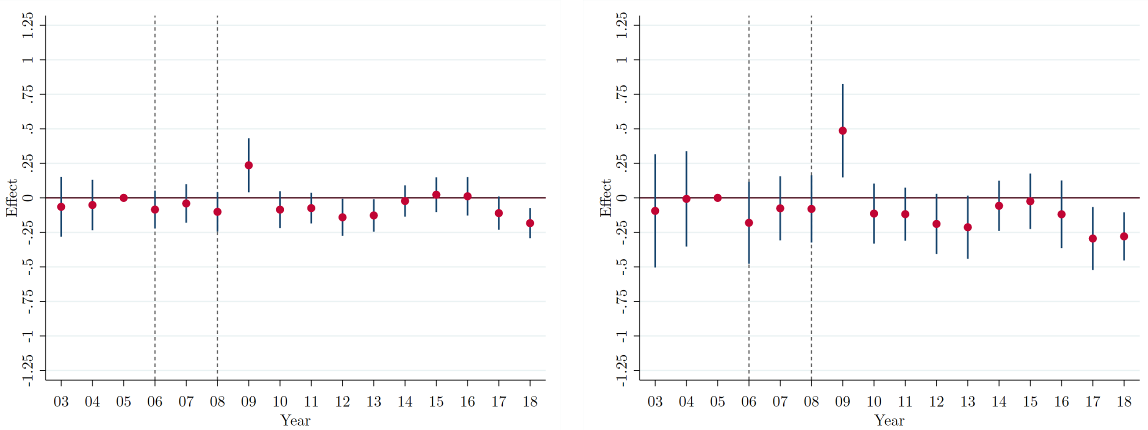
Figure 11: Number of Fires: Leakage Results



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of the 200 km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the number of fire focus in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

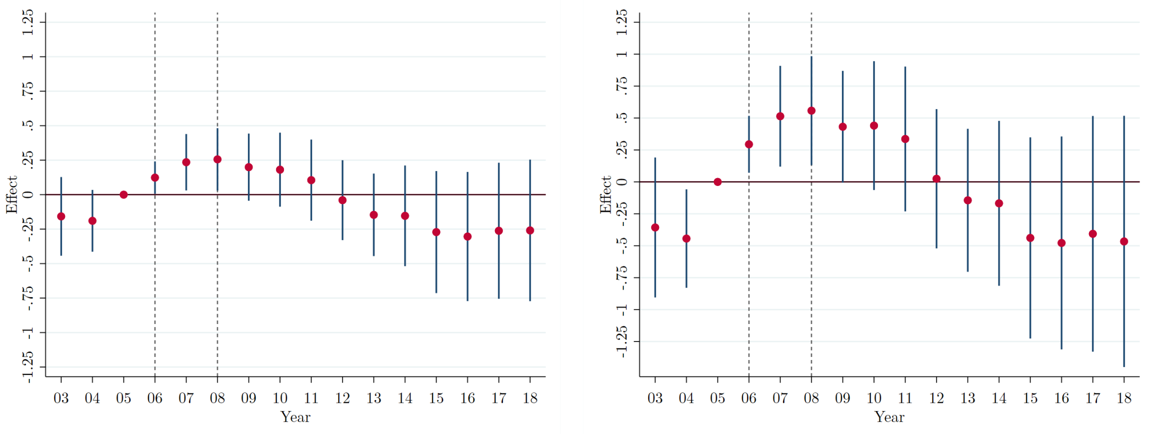
Figure 12: Deforestation: Leakage Results



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of the 200 km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the area of deforestation in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

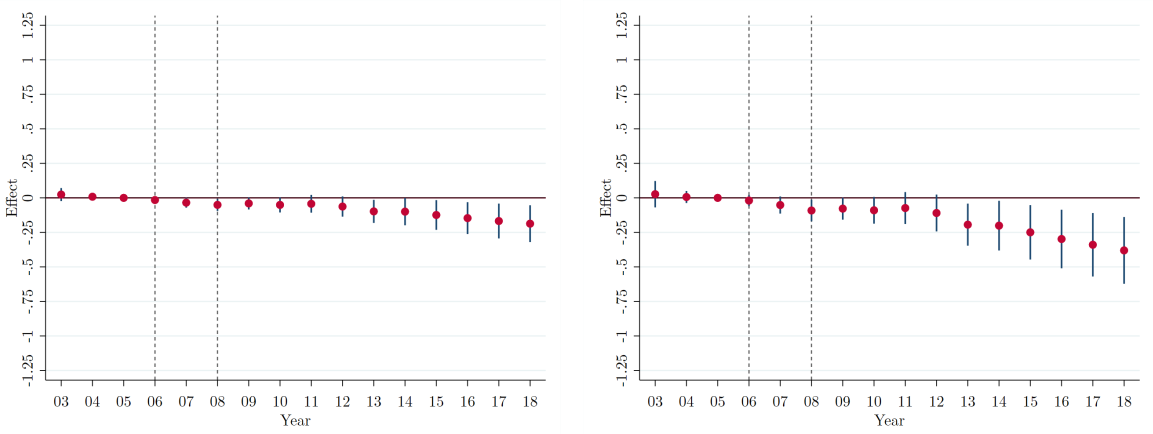
Figure 13: Soy Coverage: Leakage Results



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of the 200 km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the soy coverage area in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

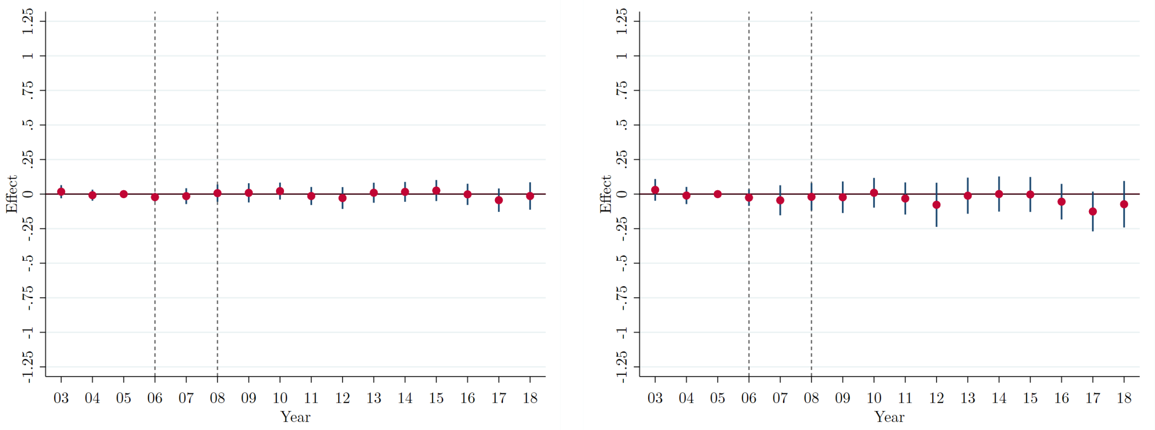
Figure 14: Pasture Coverage: Leakage Results



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of the 200 km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the pasture coverage area in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure 15: Herd of Cattle: Leakage Results - Binary Treatment Variable



(a) Binary Treatment **(b)** Continuous Treatment

Notes. All results are expressed in percentage points. The figure shows the leakage results of 200km's sample. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the cattle herd size in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at municipality level. Confidence intervals: 95%.

exercise figures in the online Appendix A to conserve space. The primary dependent variable, Net GHG Emissions, is the central variable of focus.

Alternative measures of GHG emissions. We start by using two different ways of aggregating the GHG emissions variable, the first using gross emissions only from the agriculture and land use change sectors — Appendix Figure A.6, and the second using gross emissions from all sectors surveyed by SEEG — Appendix Figure A.7. The results show that the effect of the analyzed policies is largely robust to the choice of sectors and aggregation (gross or net).

Sample Selection. To alleviate concerns about sample selection, we ran the principal regression on two alternative samples. Figure A.8 shows the results for the 100km sample (205 municipalities), and Figure A.9 shows the results for the 300km sample (424 municipalities). The effects remain robust to the choice of the distance band. In addition, we also checked whether the permissibility of admitting municipalities crossing the border of the Amazon biome but which have 90% of their territory inside or outside the biome is biasing our results. Figure A.10 shows the result for our benchmark sample (200km), excluding all municipalities crossed by the biome border. Results are robust to this exclusion.

Controls. Since agricultural commodity prices are drivers of deforestation, we include this as an additional control on our principal specification (Panayotou and Sungsuwan (1994); Barbier and Burgess (1996); Angelsen (1999); Assunção et al. (2015)). We build an output price series that captures exogenous variations in the demand for locally produced agricultural commodities because agricultural prices are endogenous to local agricultural production and, consequently, local deforestation activity. Using prices from the Brazilian state of Paraná, which is not an Amazon state, and agricultural information from the annual Municipal Crop Survey (PAM/IBGE) and Municipal Livestock Survey (PPM/IBGE), we create annual indices of crop and cattle prices similar to Assunção et al. (2015). We introduce cross-sectional variation by weighing Paraná output prices by each product's local (municipal) relevance. We also use principal component analysis to combine crop prices into a single index. Appendix Figure A.11 shows that including prices as additional control does not change our conclusions concerning emissions. Still, concerning controls, Appendix Figure A.12 shows the results of our main specification on emissions without adding any controls. Results also remain robust.

Inference. We also examined the results' robustness to different standard error clustering. We perform an inference assessment proposed by Colella et al. (2019) to account for arbitrary dependence in the error terms. Appendix Figure A.13 shows that the significance of the results holds after applying the inference correction. Moreover, in Appendix Figure A.14, we use uniform confidence intervals. Once more, the results' significance is highly robust.

Transformations of the dependent variable. Remember that the dependent variable in our baseline results was transformed using the log formula. We look into it and discover that results are reliable when not using any transformation - see Appendix Figure A.15.

Concurrent conservation policies. The Brazilian federal government launched conservation policies in the second half of the 2000s to actively prevent tropical forest clearing and promote forest conservation. Two of these measures, namely the expansion of protected areas and the stepping up of monitoring and law enforcement, stand out for having been put into practice concurrently with SoyM and Resolution 3545.

Surveillance and law enforcement were significantly improved by adopting monitoring technology based on remote sensing, in the middle of the 2000s, through the Real-Time System for Detection of Deforestation (DETER). The system gathers and analyzes satellite imagery of forest cover to identify hotspots for recent deforestation and generate georeferenced alerts that target law enforcement operations in the Amazon. In addition, with the list of priority municipalities at the end of the decade, enforcement was further improved. Municipalities that needed priority action to stop, monitor, and combat illegal deforestation were categorized on this list. The first list was issued in early 2008 and included 36 priority municipalities. In parallel with enforcement initiatives, the development of PAs accelerated in the mid-2000s. The BLA's overall protected area increased by more than 520,000 square kilometers between 2004 and 2009. A little over 43% of BLA territory was protected by the decade's end.

As inputs can be spatially reallocated and interventions can interact with both geographical features and other policies, recent studies have also shown that the impact of conservation efforts may go beyond direct effects and program borders (Garcia (2015); Andrade (2016); Pfaff and Robalino (2017)). Based on this, we examine the robustness of our estimates in the face of potential effects brought on by PAs and enforcement actions.

Once we eliminate municipalities that experienced variation in concurrent policies during the analysis period, we check whether our results are robust to sample selection in Appendix Figure A.16. More specifically, we exclude all municipalities in our sample that changed their PA coverage from 2003 to 2008. Additionally, we exclude the eight sample municipalities on the federal government's 2008 priority list. Finally, we exclude municipalities that prioritize enforcement. To do this, we consider the distribution of environmental fines at the municipal level. Most of the fines are concentrated in a few municipalities, creating an uneven distribution. As a result, we exclude municipalities above the 90th percentile of the distribution of fines as determined in 2008.

6 Concluding Remarks

This paper proposed an investigation of the direct and secondary impacts of the Soy Moratorium and Resolution 3545, market and government interventions to mitigate climate change by reducing deforestation. We examine its effects on GHG emissions by taking advantage of the commitment restriction to the Amazon biome and using a difference-in-differences method. The results show the two prominent events helped contain emissions in the Amazon biome. The effects can be explained mainly by a documented decrease in deforestation and fires, as well as by a decline in the activity of the livestock sector.

We also show that the interventions significantly affected credit concession, supporting the hypothesis that Resolution 3545 only impacted deforestation and GHG emissions through the credit channel. Given that significant credit constraints and imperfections characterize the economic environment in the Amazon biome, this evidence suggests that the conditioning of rural credit is an effective policy instrument to combat illegal deforestation.

Having explored the effect on GHG emissions and the potential mechanisms, we also evaluate the possibility of leakage effects. The results show that municipalities close to the biome border but not directly affected by implementing interventions have a negative impact on net GHG emissions, with this effect persisting over time. Although we can see a negative impact on fires, deforestation does not document a similar outcome. Furthermore, we also report an increase in soy coverage area right after SoyM, although this effect ceases to be significant over time. This soy advance seems to have occurred initially in forest areas and later in pasture areas, elucidating how the two interventions have impacted agricultural displacement.

Finally, it's critical to note that there is a trade-off between internal and external validity in our setting. By limiting the sample of municipalities to those close to the border, internal validity is arguably strengthened. In contrast, external validity is difficult to achieve in a vast and diverse region like the Legal Amazon.

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Online Appendix to "Do Market and Government Interventions Affect Greenhouse Gas Emissions?"

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July 27, 2023

A Extra Tables and Figures

A.1 Tables

Table A.1: Dynamic Difference-in-Differences: Coefficients

	Dep. variable						
	Net GHG Emissions	Deforestation	Fires	Soy Area	Pasture Area	Herd Cattle Size	Rural Credit
β_{2003}	0.199**	-0.073	-0.008	0.132	0.056***	-0.154***	-0.322
	(0.071)	(0.120)	(0.058)	(0.095)	(0.013)	(0.035)	(0.274)
β_{2004}	-0.006	0.297**	-0.112	0.131	0.009	-0.057*	0.046
	(0.054)	(0.092)	(0.059)	(0.068)	(0.010)	(0.027)	(0.162)
β_{2005}	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)	(.)	(.)	(0.157)
β_{2006}	0.038	-0.269*	0.070	-0.004	-0.040***	-0.009	-0.025
	(0.054)	(0.118)	(0.056)	(0.047)	(0.009)	(0.017)	(0.083)
β_{2007}	-0.023	-0.076	-0.325***	0.064	-0.053***	-0.008	0.000
	(0.071)	(0.110)	(0.065)	(0.075)	(0.010)	(0.031)	(.)
β_{2008}	-0.041	-0.055	-0.284***	0.060	-0.070***	-0.008	-0.331**
	(0.081)	(0.108)	(0.067)	(0.086)	(0.011)	(0.032)	(0.107)
β_{2009}	-0.229**	-0.603***	-0.240**	0.072	-0.089***	-0.016	-0.417***
	(0.082)	(0.129)	(0.091)	(0.089)	(0.013)	(0.035)	(0.092)
β_{2010}	-0.378***	-0.602***	-0.825***	0.072	-0.110***	-0.041	-0.357**
	(0.091)	(0.127)	(0.093)	(0.100)	(0.016)	(0.033)	(0.108)
β_{2011}	-0.425***	-0.614***	-0.618***	0.111	-0.124***	-0.055	-0.453***
	(0.092)	(0.127)	(0.087)	(0.116)	(0.017)	(0.039)	(0.119)
β_{2012}	-0.660***	-0.799***	-0.746***	0.061	-0.123***	-0.100*	-0.382***
	(0.094)	(0.129)	(0.097)	(0.118)	(0.023)	(0.046)	(0.097)
β_{2013}	-0.826***	-0.691***	-0.816***	0.148	-0.204***	-0.139**	-0.631***
	(0.084)	(0.119)	(0.085)	(0.132)	(0.024)	(0.043)	(0.144)
β_{2014}	-0.891***	-0.727***	-0.626***	0.166	-0.239***	-0.120**	-0.606***
	(0.094)	(0.128)	(0.089)	(0.163)	(0.028)	(0.043)	(0.164)
β_{2015}	-0.660***	-0.672***	-0.622***	0.065	-0.278***	-0.166***	-0.700***
	(0.081)	(0.121)	(0.082)	(0.184)	(0.029)	(0.048)	(0.172)
β_{2016}	-0.649***	-0.661***	-0.689***	0.140	-0.291***	-0.182***	-0.822***
	(0.091)	(0.129)	(0.081)	(0.201)	(0.032)	(0.050)	(0.169)
β_{2017}	-0.759***	-0.599***	-0.659***	0.127	-0.335***	-0.223***	-0.806***
	(0.092)	(0.123)	(0.109)	(0.217)	(0.033)	(0.053)	(0.169)
β_{2018}	-0.811***	-0.574***	-0.740***	0.163	-0.336***	-0.269***	-0.612***
	(0.098)	(0.135)	(0.091)	(0.225)	(0.035)	(0.059)	(0.176)
Observations	5048	5232	5360	3472	5360	5360	5360
Baseline Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes. This table presents the results of Equation 1 for dependent variables: [1] Net GHG Emissions; [2] Deforestation; [3] Fires; [4] Soy Coverage Area; [5] Pasture Coverage Area; [6] Herd Cattle Size; and [7] Rural Credit Concession. All results presented include baseline controls. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipal level. *p¡0.1; **p¡0.05; ***p¡0.01

A.2 Figures

Figure A.1: Legal Amazon, Amazon biome and leakage sample (200km)

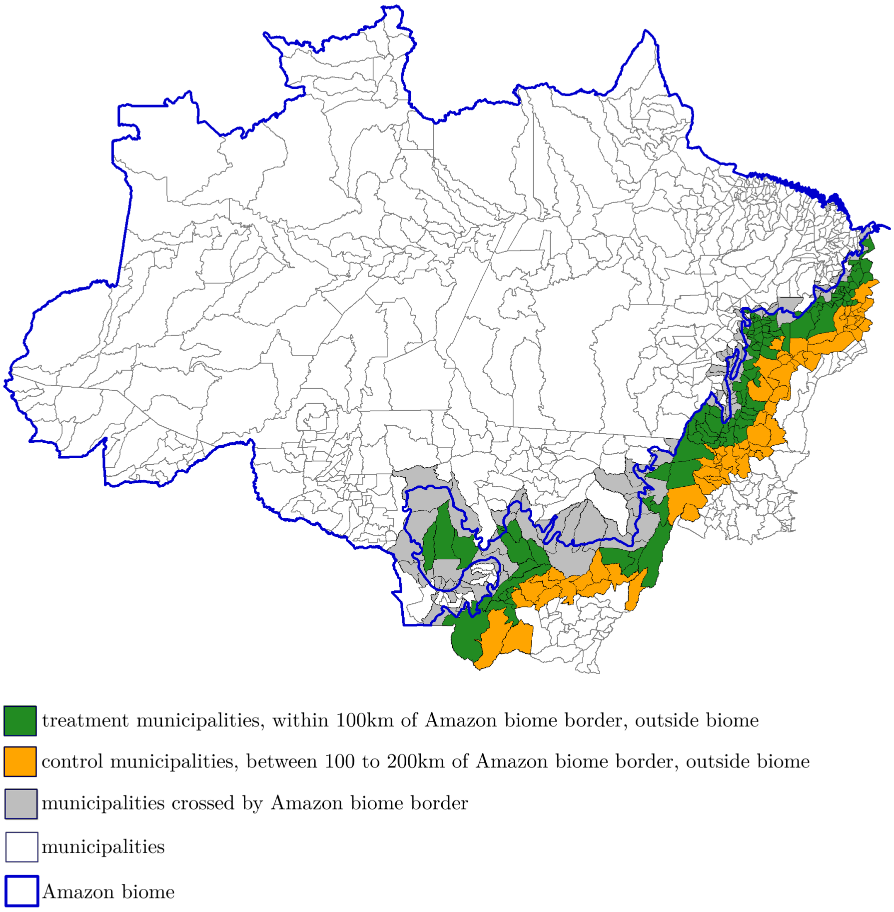
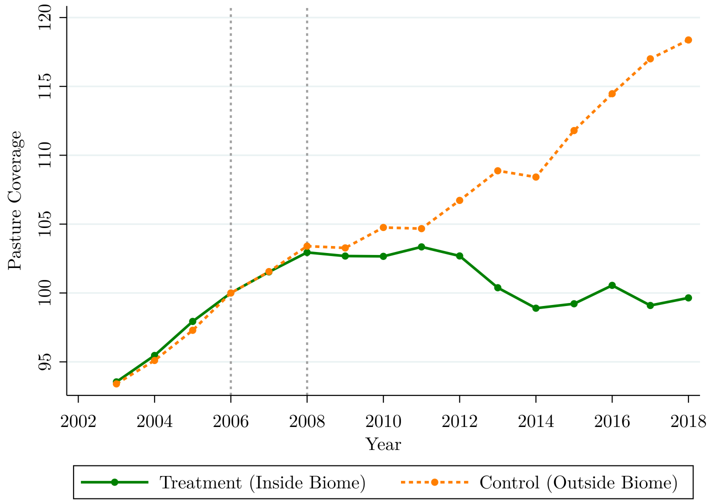
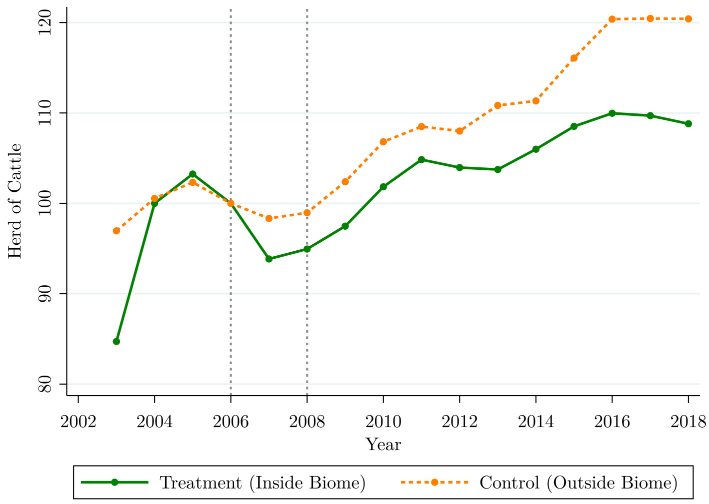


Figure A.2: Pasture Coverage in Treatment and Control Municipalities, considering the benchmark sample (200km).



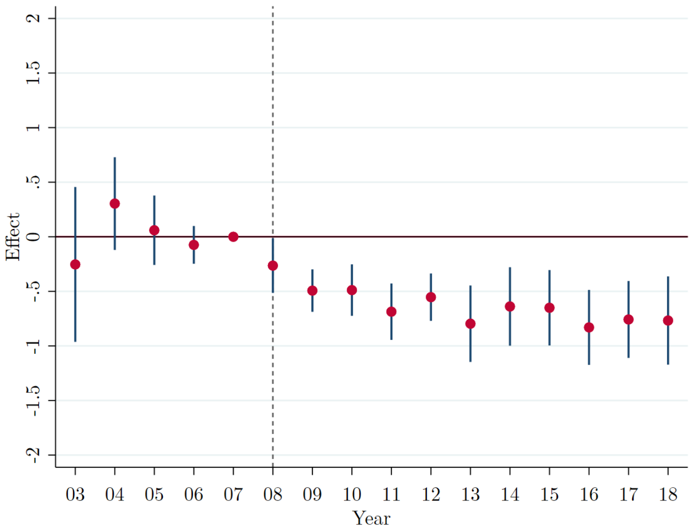
Notes. The graph displays the average municipal pasture coverage trend from 2003 to 2018. Pre- and post-policy trends can be distinguished using the policy markers in 2006 and 2008. Data is from MapBiomas.

Figure A.3: Cattle Herd Size in Treatment and Control Municipalities, considering the benchmark sample (200km).



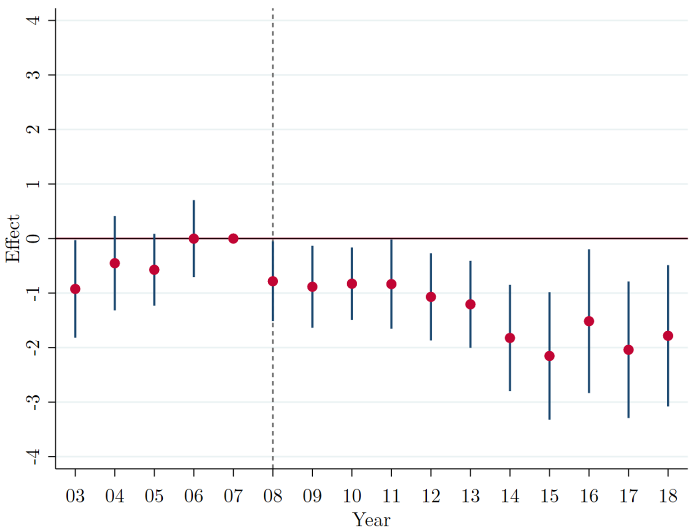
Notes. The graph displays the average cattle herd size trend from 2003 to 2018. Pre- and post-policy trends can be distinguished using the policy markers in 2006 and 2008. Data is from PPM/IBGE.

Figure A.4: Rural Credit Concessions for Livestock: Baseline Results



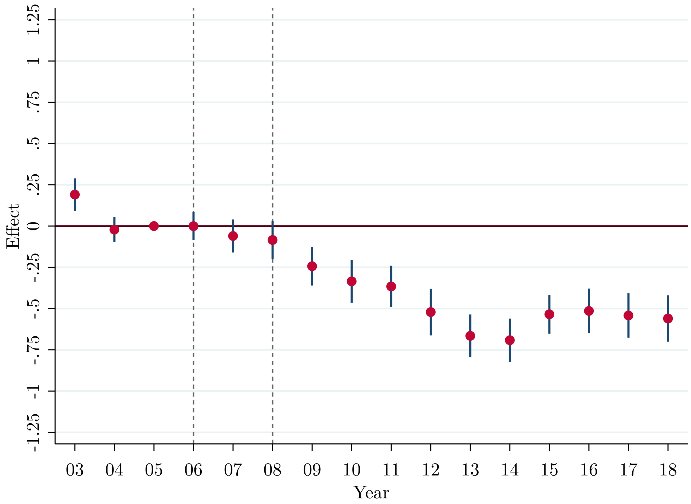
Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the total value of rural credit concession for the livestock sector in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%

Figure A.5: Rural Credit Concessions for Agriculture: Baseline Results



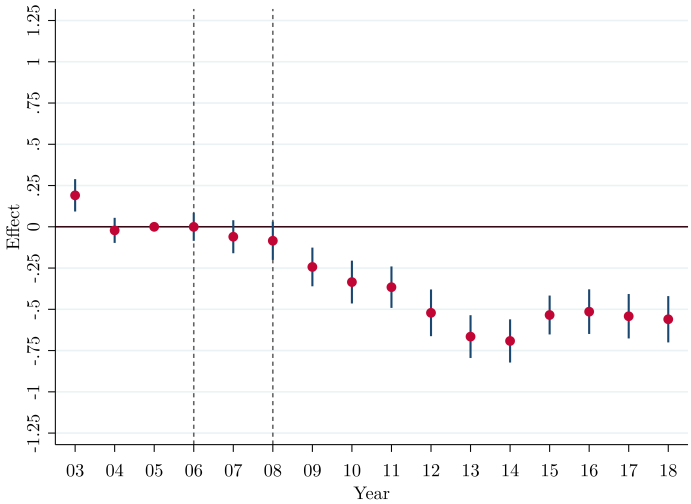
Notes. All results are expressed in percentage points. The figure shows the baseline results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the total value of rural credit concession for the agriculture sector in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%

Figure A.6: Gross Emissions by Sectors



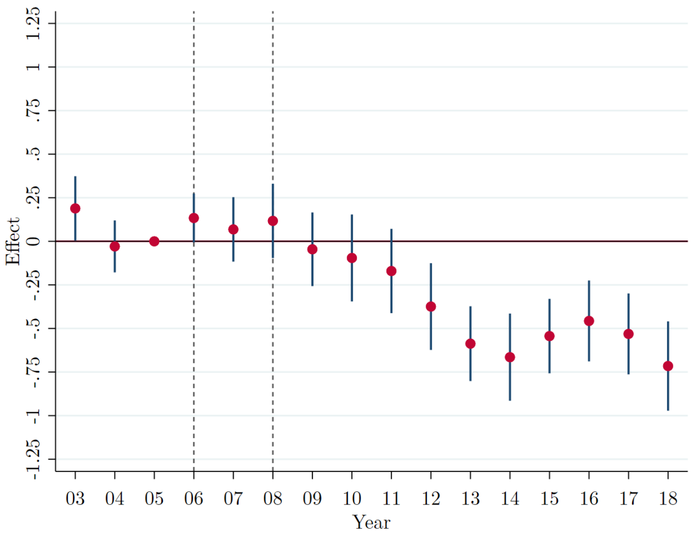
Notes. All results are expressed in percentage points. The figure shows the GHG emissions results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the gross GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.7: Gross Emissions by All Sectors



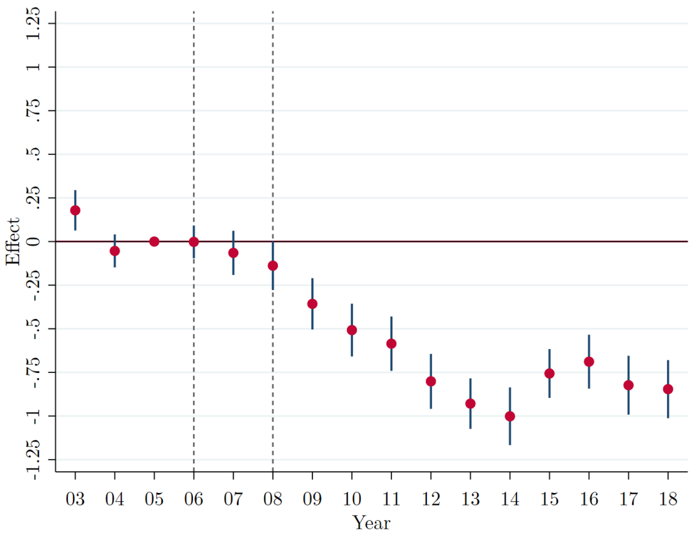
Notes. All results are expressed in percentage points. The figure shows the GHG emissions results. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the gross GHG emissions by all sectors in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.8: Emissions: 100km Sample



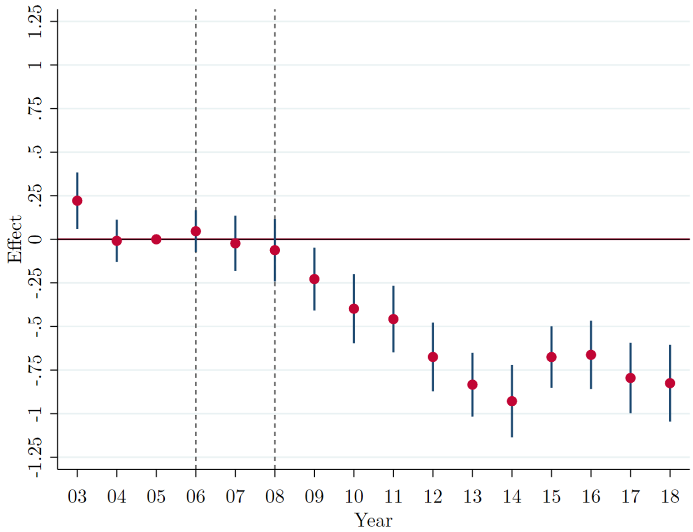
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. Dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.9: Emissions: 300km Sample



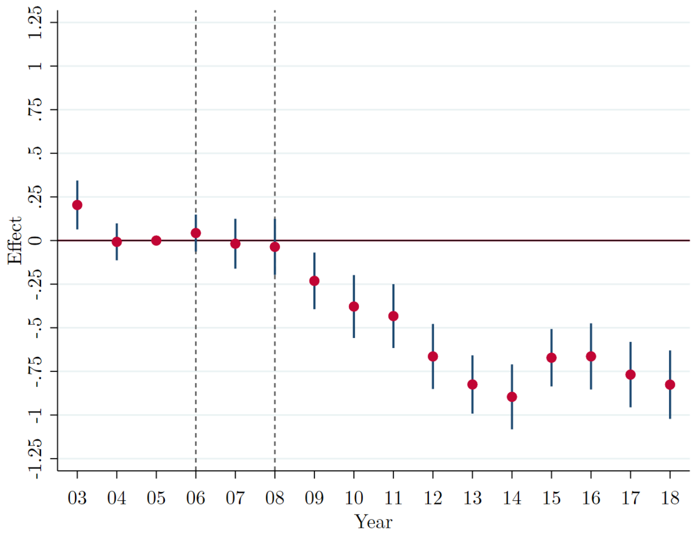
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.10: Emissions: Exclude all municipalities crossed by the biome border.



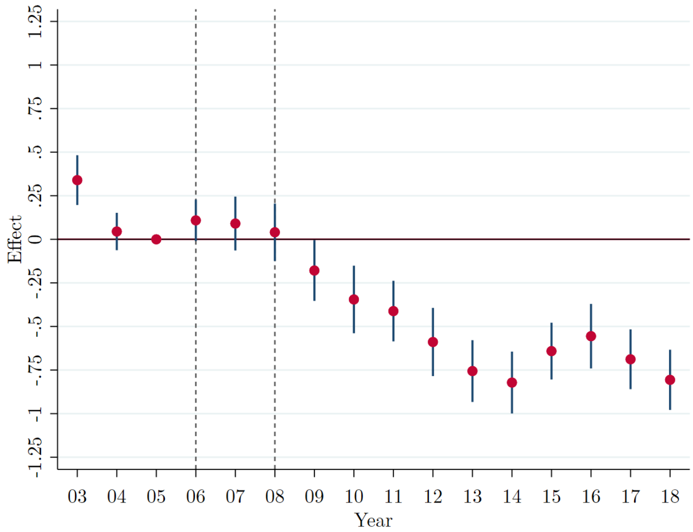
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.11: Emissions: Prices Control



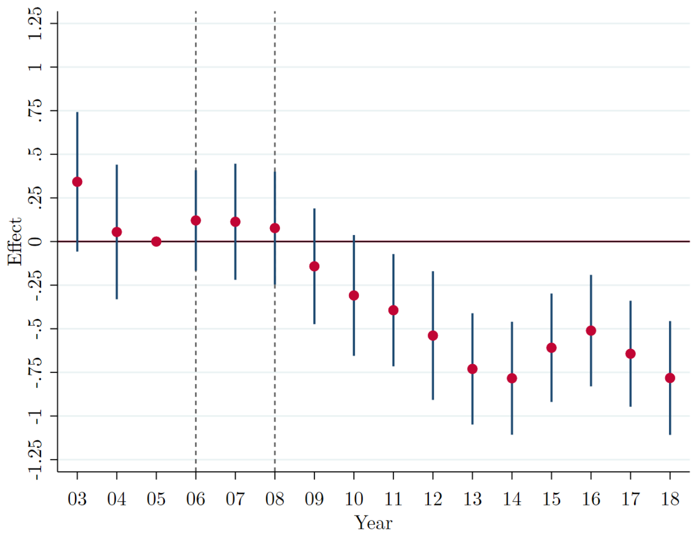
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.12: Emissions: Without Controls



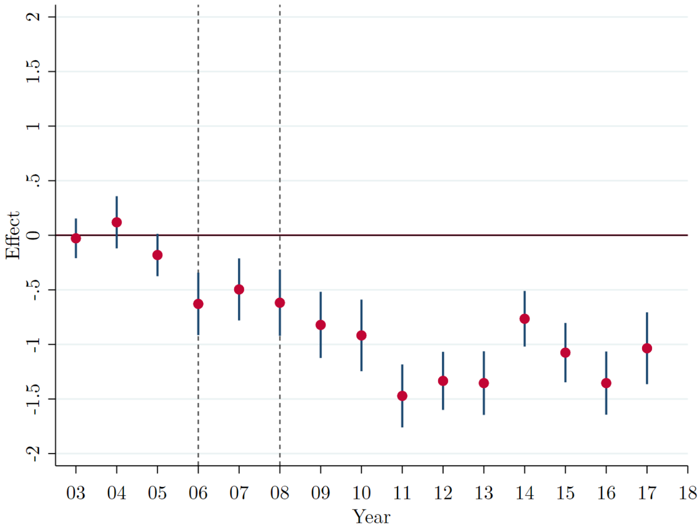
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.13: Emissions: Arbitrary dependence in the error terms



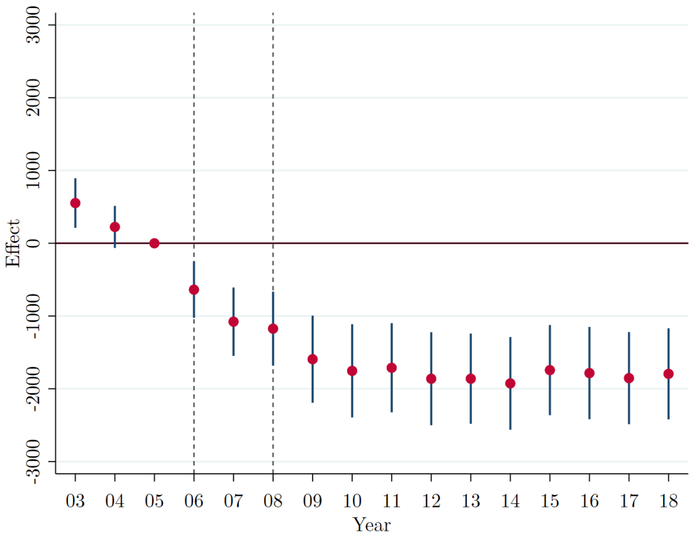
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.14: Emissions: Uniform Intervals



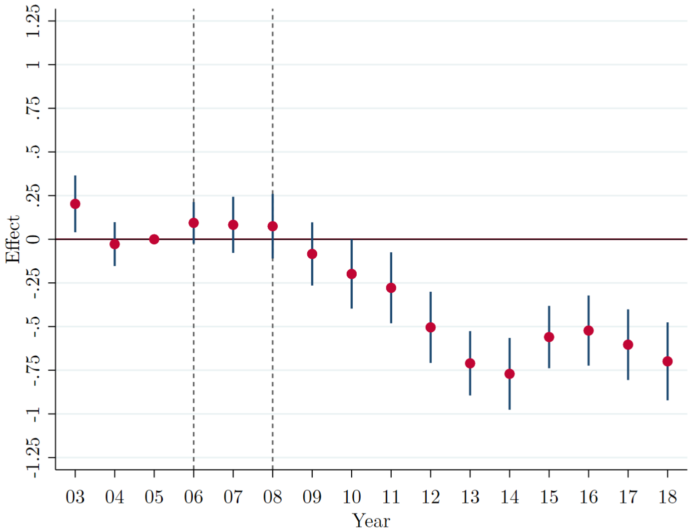
Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.15: Emissions: No transformation on the dependent variable



Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural and land and forest use change in municipality i and year t. The dependent variable is only divided by 1000. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

Figure A.16: Emissions: No concurrent conservation policies



Notes. All results are expressed in percentage points. The figure shows the Net GHG emissions results without controls. Data are provided at the municipality-year level. Vertical dotted lines indicate the two prominent events, SoyM and Resolution 3545. The dependent variable is the net GHG emissions by agricultural, and land, and forest use change in municipality i and year t. The dependent variable is transformed into $log + 1$. Standard errors are clustered at the municipality level. Confidence intervals: 95%.