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MASTER THESIS

DEFORESTATION IN BRAZIL

An empirical evaluation on the effectiveness of the Soy Moratorium

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ABSTRACT

This dissertation is designed to explore the lamentable destruction that is taking place in the Amazon rainforest and further conduct an analysis with the aim of evaluating if abiding the Soy Moratorium of 2006 had any impact in curbing deforestation during the post-period of inception, 2006. The SoyM is a voluntary agreement purposing to hinder the demolition of forests related to soy plantation; this contract solely applies to the Amazon biome and calls all companies operating in the supply chain of the soy commodity to cease trading soybean resourced from deforested areas effectively after July 24, 2006.

In order to discover the impact of the programme, we formulate a research question as follows, "did the Soy moratorium caused a reduction in deforestation in the Amazon biome?" That is to say, do companies that signed the policy truthfully adhere the principle and contribute in lessening deforestation? This question initiates the path to discover whether the Amazon biome experience less deforestation compared to neighbouring biomes following companies' signage of the voluntary agreement.

We investigate the entire Amazon biome encompassing 177 municipalities and use 206 municipalities from the Cerrado biome as a control, which are located at the geographical border between the two biomes: a total of 383 municipalities. This paper covers a time span of 14 years, from 2003 to 2016, and therefore the longitudinal dataset contains 5362 observations for each variable of interest.

We employed a difference-in-differences approach, with both municipality and year fixed effect, to examine if the SoyM have generated a genuine causal effect in decreasing both soy and territorial deforestation in the Amazon biome. Applying mentioned strategic approach, we acquire two different results. First, a general broad approach, conducted on the assumption of the Cerrado biome as a control factor, produces an insignificant impact of the SoyM. Whereas, applying a more specific model, which also consider the role of signatory companies in a given municipality, the empirical results suggest that the SoyM had a significant causal effect in decreasing soy deforestation and territorial deforestation as well, in the Amazon biome.

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CHAPTER 1. INTRODUCTION

The Amazon biome, one of the six Brazilian continental biomes, seriously suffered from a growing level of deforestation in the past decades, predominantly for a massive expansion of the agricultural sector and especially the soybean operations (Nepstad et al. 2006, FAO report 2016). In response to these blameworthy circumstances, on 24 July 2006, two associations of farming companies signed the Soy Moratorium (SoyM), which obligated their associate members to not trade soybeans grown on crops deforested after that date (Gibbs et al. 2015). As the membership to these two association is voluntary, only signatory companies are committed in combating for a reduction in the soy deforestation rate.

The objective of this thesis is to assess the effectiveness of the SoyM and particularly the research question pursues to evaluate the causal impact of Soy Moratorium on the level of soy deforestation and territorial deforestation in the Amazon biome after 2006. Thanks to the specific features of the panel dataset employed in the empirical strategy, our research exhibits an original characteristic, considerably differentiating from previous investigations. We perform a counterfactual analysis on the efficacy of the SoyM through a difference-in-differences estimation, considering as principal dependent variable the level of soy deforestation, and not only the whole level of territorial deforestation. Furthermore, another innovative aspect derives from the source of the data; in fact, we employed a recently updated longitudinal dataset obtained from the Trase database, which provided us information on 383 Brazilian municipalities, 177 from the Amazon biome and 206 from the Cerrado biome.

Besides our main empirical strategy research, we also analyse the interaction between Soy Moratorium and another anti-deforestation policy: the Critical County Program, commonly known as Blacklist. The environmental policy, entered into force in 2008, functions in both restricting the access to agricultural credit and increasing the monitoring on the ground (Cisneros et al. 2015). This enrichment of the econometric model strengthens our analysis and helps regression output to be unbiased.

From the results emerges a meaningful impact of SoyM: first, signatory companies contributed to decrease the level of soy deforestation, up to a rough maximum amount of 110,000 ha per year. On the contrary, non-signatory companies responded in an opposite manner, such as augmenting forest clearing for soy production, approximately to a maximum level of 12,000 per year ha. The Blacklist significantly entrusted as well to reduce soy-linked deforestation. The SoyM and the Critical County Program also remarkably impacted in lessening the overall level of territorial deforestation; for example, companies committed with the moratorium contributed with a reduction up to 550,000 ha every year, from 2006 onwards.

Lastly, we extend the investigation for both dependent variables (soy deforestation and territorial deforestation) to evaluate the combined efficacy of SoyM and the Critical County Program for blacklisted municipality after 2006. The objective is to find a possible proof of a stronger reduction in deforestation as a consequence of two combined policies; however, we obtained opposite results. First, we receive no prove for a lower soy deforestation due to double monitoring in those municipalities; then, more surprising, we found out that in a municipality, the simultaneous presence of the two policies could lead to an increase in the level of different-originated deforestation, in other words not soy-related deforestation.

In conclusion, we provide an adequate technique to proof the robustness of our framework, contemplating a possible violation of the homoscedasticity assumption and receiving a confirmation of the quality of the results.

CHAPTER 2. BACKGROUND

This chapter is aimed to introduce various factors that are closely related to our research paper. This includes geographic and political background of Brazil, deforestation in Brazil and the forces behind the destruction, soy commodity in Brazil and related moratorium (the Soy Moratorium of 2006). This chapter will also introduce the main research question of this thesis and present other regarded policies that are separate from the SoyM.

2.1. OVERVIEW

This section embodies a presentation of Brazil and addresses a general overview of deforestation occurring in the country.

2.1.1. BRAZIL

Brazil is the largest country in Latin America and the fifth in the world for both extension area and population. The political subdivision of the Federal Republic of Brazil is given by 27 Federative Units. For a clear comprehension of the subsequent analysis, it is important to point out that only seven of them are part of the Amazon biome: Amazonas, Acre, Rondonia, Amapá, Pará, Mato Grosso and Roraima.

Figure 1 presents map of Brazil with consideration of State divisions.

Figure 1: Political Division of Brazil by States. (Source: Wikipedia)

From a geographical point of view, Brazil comprises six continental biomes namely in alphabetic manner: Amazon, Atlantic Forest, Caatinga, Cerrado, Pantanal and Pampa (refer Figure 2).

Our main focus of analysis, the Amazon biome, is the largest biome that covers almost half of Brazil (IBGE 2004). Representing 49.29% of the Brazilian territory, the Amazon biome accounts for one third of the global tropical rain forest, which encompasses over 10% of the world's highly esteemed but also endangered fauna and flora species. For instance, the biome hosts up to 60,000 flora species of which 30,000 are in endemic condition (Dubey 2015). Besides its biodiversity coverage, the biome encompasses abundant types of soil, moist climate, extensive river basin and fruitful geographic layer (Albagli 2001). In that sense, the Amazon biome has been naturally employed as a climatic stabilizer, biodiversity repository and also a means of subsistence to 350 different ethnic groups inhabiting in the area (Simon and Garagorry 2005).

Figure 2 presents map of Brazil with consideration of biome divisions.

Figure 2: Geographical Division of Brazil by biomes. (Source: Wikipedia)

2.1.2. DEFORESTATION

The Amazon biome has suffered an increasing level of deforestation in the past decades (FAO report 2016) and nowhere in the world recorded such magnitude of deforestation. According to FAO's report, an average annual rate of 25,540 km^2 deforestation occurred in Brazil between 1990 and 1995, of which the majority was scored in the Amazon biome (Andersen 2002). From 1996 to 2005, an average 16,600 km^2 of forest was cleared in the frontier states of Mato Grosso, Rondônia, and Pará that accounted for 85% of all Amazon deforestation (Macedo et al. 2012).

Brazil lost an area equal to 27,200km^2, an area equivalent to the size of Belgium due to the 2003-2004 deforestation. On average, this will split to a loss of an area equivalent to a FIFA recommended football pitch in every ticking eight seconds (Teixeira 2005). In reflection to such indecency, recent studies claimed the Amazon rainforest as "the arc of deforestation" and alike research as "the front line of destruction" (Douglas et al. 2006, Greenpeace 2006, Macedo et al. 2012).

As a consequence of such deforestation, Brazil has been ranked among the top of the world's largest climate polluters (MST 2004), which placed the country ahead of developed nations such as UK and Germany (CAIT 2005). For example, 75% of the country's greenhouse emissions derive from deforestation, in which the clearing and burning of the Amazon plays a huge role (Greenpeace 2006).

2.1.3. CAUSES OF DEFORESTATION

It was significantly difficult to monitor and thereafter take effective precautions against the removal of forest, because two-thirds of deforestation carried out to clear land for agriculture has been conducted illegally (Stickler et al. 2008). Nevertheless, the causes and dynamics of deforestation have been repeatedly and thoroughly studied over the past 30 years.

A prominent study argues that the key role of deforestation originates from operations and activities that provide advantageous economic of scale and largely dependent on speculative gains or government subsidies (Margulis 2004). Predominantly, the primary drivers of Amazon deforestation are beef (cattle ranching) and soybean industries (Nepstad et al. 2006). High-ranked pollution in Brazil was purely the result of an imbalanced supply of cheap agricultural commodities, such as soya and meat industry (Greenpeace 2006). The possible role of soybean export as a cause of deforestation is our subject of study, therefore this section proceeds discussing the industrial expansion and the succeeding deforestation harm that emanate from the soy commodity.

The soybean operations in Brazil have been one of the major drivers of deforestation in the Amazon biome. In Santarém and Belterra municipality, for instance, the commodity contributed to 15,000 to 28,000 hectares of deforestation from 2002 to 2004 (Cohenca 2005).

The main reason of the upscaling deforestation in the Amazon biome is nothing but a pure consequence of an immense agro-industrial expansion that had begun in the late 1990's (Nepstad et al. 2006). Perhaps, studies bestow different reasons behind the growth of the operation. Among them, new varieties of crops that are capable of tolerating the moist and hot Amazon were generated (Fearnside 2001) and global increase in demand of animal-feed protein pushed soy prices (Brookes et al. 2005).

The United States have been a long-established leading soy supplier to the European and Asian demand market (Dros 2004). Following the restriction of genetically modified soy (GM-soy) by the European Commission, resulted from European consumers opposition, occurred a simultaneous decline of US market share of European soy imports and an increasing demand for Brazil's soy production, as GM-soy is severely restricted in Brazil (ISAT Mielke 2004).

Growing demand of soybeans, added with competitive land prices and improved infrastructure of logistics and transportation roads, attracted a flow of potential investments from global key players in agricultural commodities (Diaz et al. 2006) and hence production increased 15% per annum from 1999 to 2004 (Nepstad et al. 2006). In 2003 for example, approximately 6 million tonnes, equivalent to 50 percent of total European Union's soy import, was traded internationally from Brazil (LMC International 2003).

In addition to the EU ban imposition, explosive growth of the Chinese economy was another phase of reinforcement for international demand of soy (Nepstad et al. 2006). China experienced an average 9% GDP growth per year since 1999; as a result, China's soy consumption increased leading to a rapid growth in demand for soy-fed pork and poultry (Naylor et al. 2005). In the Amazon biome, for example, the volume of soy export to China increased from 76 thousand tonnes in 2003 to approximately 5.4 million tonnes in 2016. Therefore, the share of soybeans that is exported to China from the Amazon biome significantly increased from 3.3% to 44% in our study period (Trase 2019).

Such an increase in the export of soy commodity might sound like a promising growth from the Brazil's economic side perspective. However, studies argue that such growth came at the cost of environmental destruction in hand. First, soybeans cause more damage comparing to other crops, in a sense that they require huge infrastructural transportation means, which lead to a direct and indirect chain of destruction to land and natural habitat (Fearnside 2001). Second, growing demand for soybeans, due to a potential increase in agricultural output prices, also increased deforestation (Verburg et al. 2014).

Coherently with above-mentioned findings, other studies concluded that there is a strong correlation between commodity markets, specifically beef and soybean, and deforestation (Barona et al. 2010, Laurence et al. 2011). Infrastructural and transportation projects associated with soybean farming, for instance, are primary resources of illegal deforestation (Laurence et al. 2011); a finding supported by Albernaz et al. (2006) in which pavement projects, resulted from speculative investments, lead to rapid but imbalanced use of land, triggering to deforestation increase.

2.2. SOY COMMODITY OVERVIEW

This section attempts to give a review of the Soy commodity and linked conservative moratorium introduced in 2006.

2.2.1. SOY COMMODITY EXPLORATION

Brazil produced over 50 million of soya commodity in the year of 2004-2005 across the Amazon biome, in approximately an area that is equivalent to the size of United Kingdom, numerically about 23 million hectares (IBGE 2006). Succeeding, the government added the crop to the top list of its export commodities and reported that the country's real GDP growth rate reached 5.1% in the same year (Morais 2005). Under those circumstances, it was not a late cry out for environmental groups and local natives to knock the world and object in public, requesting urgent amendment procedures to heal the wounds of a suffering habitat, the Amazon biome.

2.2.2. THE SOY MORATORIUM

In 2006, environmental groups from a prominent non-governmental organization, Greenpeace, and local protestors ram the terminal dock of giant Cargill in Santarém, Brazil (Gibbs et al. 2015). Previously and in the same year, the organization accused the world top three agricultural commodity traders namely Cargill, Archer Daniels Midland (ADM) and Bunge as the criminals to the destruction of the Amazon rainforest. In their thorough report “Eating up the Amazon” Greenpeace described soya monoculture operation as the slow death of the Amazon (Greenpeace International 2006).

As a consequence of these resounding protests, on 24 July 2006 the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the Association of Cereal Exporters in Brazil (ANEC) signed the Soy Moratorium (SoyM), a voluntary agreement which committed their associate companies to not trade soybeans grown on crops deforested after that date. The two associations, which consolidated companies accounted for purchased 90% of the soy produced (Gibbs et al. 2015), tried to preserve the reputation of the soy industry, supporting a sustainable supply chain striving for a reduction of the deforestation rate.

The SoyM therefore does not present any monetary incentive neither for the participant companies nor for the buyers, because it operates as a “market exclusion” policy, in other words non-commitment producers lose the access to the market (Brannstrom et al. 2012, Gibbs et al. 2015).

It is important to highlight two specific features of the SoyM. Even though deforestation results from several commodity operations in the whole Brazilian territory, the SoyM is biomic-center and commodity-specific; meaning that it applies only in Amazon biome and to soy commodity (Gibbs et al. 2015)

Initially the agreement was valid until 2008, for a period of two years, subsequently it was renewed annually until in 2016 (Gibbs et al. 2015), when it was declared indefinite. (Greenpeace International 2016). In addition, an important modification of the original version was made when, in coherence with the approval of the new Forest Code on 25 May 2012, the reference date of the SoyM was shifted to 22 July 2008 (ABIOVE 2018).

The implementation and the monitoring of the SoyM involves both the private sector, through delegates of company member of ABIOVE and ANEC, and the civil society, which together form the GTS (Grupo de Trabalo da Soja, Soy Working Group) (ABIOVE 2018). Since 2008, also the Brazilian government joined the GTS; the Ministry of the Environment (MMA) started to collaborate to the fulfilment of the SoyM and the Brazilian Institute for Space Research (INPE) was charged to recognize plots of land where soy was planted on areas deforested after the cut-off date (Gibbs et al. 2015).

The scope of monitoring the SoyM is to identify year-by-year eventual presence of soy crops in plots of land deforested after the reference date, mainly through the utilization of satellite images. The monitoring analysis becomes effective if two minimum requirements are fulfilled: the first regards municipalities with soybeans plantation more than 5,000 ha in the current or precedent year (or expected to be grown in the following year) and the second requires deforestation events equal or higher than 25 ha. Any deforested property below 25 ha is recognized as a "small deforested area" and it will be considered in the assessment once the total deforested area reaches 25 ha, after the deforestation of adjacent portions. (ABIOVE 2018).

The verification process occurs in different phases: it starts to identify the destination use of deforested areas, thanks to the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery, then lands with planted crops are re-analysed with higher-resolution Landsat and Resourcesat imagery to assure the presence of soybeans (Gibbs et al. 2015). Finally, in the wretched case in which a property is not compliant with the SoyM, its name is added to a list, managed by the GTS, to make the infraction evident to soy traders.

2.3. COMPLIANCE AND EFFECTIVENESS OF THE SOY MORATORIUM

This section presents, respectively, strengths and weaknesses of SoyM.

2.3.1. POSITIVE ASPECTS OF THE SOY MORATORIUM

Although the underpin of this thesis is to investigate whether the implementation of SoyM had a significant effect in reducing deforestation level in the Amazon biome, it is critical to reflect on previous studies done vis-a-vis this matter and obtain claimed effectiveness of the moratorium.

According to Gibbs et al. (2015), Soy Moratorium functions efficiently better than related law enforcements put in place, because it specifically regulates the proportion where only soy is grown and exclude supervising the whole property. In Mato Grosso, for instance, about 627 properties were recorded, during the SoyM period, for violating the Forest Code and clearing the forest illegally while only 115 properties suffered exclusion from soy trade as a result of violating the SoyM.

In a similar manner to above findings, there exists an instinct difference between compliance to SoyM versus the legal enforcement. The Forest Code, for example, does not require the implementation of an agreement between producers and traders. The SoyM, on the other hand, not only requires visitation and signing agreement between soy traders and farmers, but also warns that a violation of SoyM would cost the latter to lose access to the international market. With the help of ANEC, ABIOVE, IBAMA, Greenpeace and related Brazil's environmental governmental and non-governmental agencies, the moratorium utilizes all available mechanisms in hand including satellite data, field visits and other legal enforcements to successfully attain its goal. In other words, the SoyM scheme took advantage from different governmental and non-governmental institutions, which some of them were created initially to build the Brazilian national state (Brown and Koeppe 2012).

Further, a previous research, using vegetation index data from MODIS (Moderate Resolution Imaging Spectroradiometer), conducted to analyse spatial dynamics of agricultural land use post-deforestation in Mato Grosso, concluded a sharp decline in deforestation related to soy production, in which partial of the effectiveness was granted to SoyM. The maximum deforestation rate post-SoyM in 2009, which was 344,748 ha/year, is 60% smaller than the minimum pre-SoyM deforestation rate of 561,185 ha/year, recorded in 2002 (Kastens et al. 2017). Although this research finding encompasses a well-reasoned empirical fact of the impact of SoyM, there exists a potential flaw on some principles of the analysis. Mato Grosso comprises three biomes: the Pantanal, the Cerrado and the Amazon. Since the study has investigated the annual deforestation rate of Mato Grosso by comparing post-SoyM (2007-2014) to pre-SoyM period (2001-2006), the common practice in DID estimation is to check for the parallel trends prior to treatment effect. Yet, this study did not conduct the test to confirm the existence of parallel trend. Another flaw is the fact that the main assumption of this study is based on the fact that any cropland detected with MODIS is most likely soy plantation. Our paper, however, confirms the existence of parallel pre-trends between areas of study which satisfy the difference-in-differences unbiased estimation (Chapter 5 and 6) and also gather a dataset of variables of interest that are directly linked to soy production (Chapter 3).

Assunção et al. (2012) carried out an empirical research to investigate deforestation decline in reflection to changes in prices and policies. This analysis was aimed specifically to exclude the effect that could emerge as a result of the 2008 crisis and clearly see effect of the latter change. Such analysis finding concluded that the SoyM resulted in significant effect against deforestation level and forest clearings even after controlling for factors of price variations, municipality fixed-effects and common time trends effect. Based on a panel data conduct in the Amazon municipality from 2002 to 2009, this paper finds out that SoyM avoided deforestation level of 73,000 km^2 in the time period of 2005 to 2009, which is equivalent to 2.7 billion tonnes of carbon dioxide or 13.2 billion US dollars (Assunção et al. 2012).

2.3.2. NEGATIVE ASPECTS THE SOY MORATORIUM

In spite of the previously mentioned successes in reducing deforestation in the Amazon biome, produced by soy plantation, the SoyM presented some failures and still maintains weak points. For example, in the state of Mato Grosso during the period between 2009 and 2016, 54 municipalities were identified as non-compliant with the agreement (Silva and Mendelson 2018). Of the total deforestation occurred in that period (481,893 ha), the amount originated by a transformation to soy crops was equal to 12.45% (59,972 ha).

Another limitation of this policy is its "biome centric" and "commodity-specific" feature, as its application only involves the Amazon biome and soy commodity (Brown and Koeppe 2012), leaving all the other Brazilian biomes and commodity operations unprotected by the risk of deforestation. The immediate consequence could be an indirect incentive to move soy production and therefore deforestation to the adjacent Cerrado biome.

Furthermore, as companies are not allowed to sell crops from new deforested lands, they might be forced to expand soy production to already-cleared areas, mainly coming from previous land used for pasturing. Subsequently, this replacement might induce to an indirect deforestation in the cattle sector (Gibbs et al. 2015).

Overall, we evidence that the SoyM has indeed some positive effects in decreasing the deforestation level that was soaring in the early 2000's; however, such effect solely targets operation regarding to soy production, and as a result, limitations becomes vivid if we further attempt to curb deforestation level by utilizing the same moratorium in other commodities or biomes as well.

In conclusion, for a comprehensive solution of the wide deforestation problem, one single policy, even though individually efficient, is not resolved. It is therefore requested a broad collaboration between different production sectors, companies and governments because the realization of the ambitious objective to put an end to deforestation can be achieved only by monitoring, together, all different causes of deforestation: from soy crops to oil palm production, from new infrastructure to new pasture land.

2.4. MAIN THESIS RESEARCH QUESTION

The aim of this paper is to further investigate the effectiveness of the Soy Moratorium in the Amazon Biome through a counterfactual analysis, differentiating from previous studies for three reasons.

The first novelty consists in the use of a recently updated longitudinal dataset provided by the Trase database (https://trase.earth/, 2019). We used information of 383 municipalities, 177 placed in the Amazon biome and 206 in the Cerrado biome, on two main variables of interest: soy deforestation and territorial deforestation. The observation period is 14 years, from 2003 to 2016; thus we have 5362 observations for each variable and 3 years pre-SoyM and 11 years following SoyM implementation (2006-2016).

The second original contribution derives from the empirical method applied in the thesis: a difference in differences approach, through which we primarily attempt to find a causal relation between the adoption of the environmental policy and the level of soy deforestation after 2006 in the Amazon biome. However, by applying the same empirical strategy, we are equally interested in studying the impact of SoyM on a second dependent variable, territorial deforestation. In addition, in the graphical description of the data, we present an interesting and meaningful overview of the path of soy production and soy land use over the same study period (2003-2016).

As a third innovative aspect, after insightful and rigorous analysis, we decide to perform an empirical study with the establishment of specific soy deforestation as dependent variable. To the best of our knowledge, no such identical study has been conducted as a subject of research before, which further grants the originality to this paper. In fact, although an equivalent aspect of study was conducted by two follow students from NHH, which investigated the causal impact of SoyM through a counterfactual analysis (Savhn and Brunner 2018), in their thesis the dependent variable of interest was only territorial deforestation and not soy deforestation. In addition to this first main distinction, there are other and equally important dissimilarities between the two papers. First, their dissertation do not contemplate firm status, distinguishing between signatory and non-signatory companies, an essential aspect for a proper evaluation of the moratorium; secondly, they employed a scarce number of municipalities (only 39) and obtained data from a different source, the "Programme for the Estimation of Deforestation in the Brazilian Amazon" (PRODES).

In conclusion, even though the Amazon deforestation argument was repeatedly examined, our empirical investigation presents some qualifying and peculiar aspects, worthy of attention.

2.5. OTHER POLICIES TO REDUCE DEFORESTATION

As the deforestation problem is wide and involves a large number of factors, from soy and oil palm production to pasture, answers are equally multiples and diversified. In this section are presented the main policies, different from Soy Moratorium, but with the same objective of reducing deforestation.

2.5.1. FOREST CODE AND CAR (ENVIRONMENTAL PROPERTY REGISTRATION)

This section discusses briefly how the Brazilian government actively implemented federal enforcement and environmental codes to curb deforestation. Without the SoyM in effect, federal enforcement would be the primary intervention acting to limit deforestation from the soy supply chain (Gibbs et al. 2015). The primary legal enforcement applied in Brazil was the Forest Code (Law no.12.651), which has been actively in force since 2012 (Forest Code 2016). The Forest Code requires landowners in Amazon biome to preserve 80% of their land for native vegetation, and landowners in other biomes to preserve 20-35% of their property for the same reason (Soares 2014).

The Code is chiefly aimed to achieve three principal goals of environmental factors: first restrain deforestation, then ensure environmental compliance, such as reducing greenhouse gas emission, which is the third objective (Forest Code 2016).

Carlos Nomoto, Secretary General of the WWF-Brazil, on the annual report of the Forest Code 2016 addresses that the main aim of the Code is to combat against deforestation and ensure environmental compliance (Forest Code 2016). His strong beseech to maintain the efforts in fighting deforestation was chiefly pointed to assist in putting an end the illegal and careless destruction of the tropical forest.

The main components of the Forest Code are: Information on environmental rural registry (Portuguese acronym, CAR), Areas of Permanent Protection (APP) and Legal Reserves. One of the advanced feature of the Forest Code is the CAR (Forest Code 2016).

The CAR, Rural Environmental Registry, is a transparency tool that connects landowners and state environmental agency in a registry of environmental boundaries and adequacy; in addition, it assists in assessing to whether the Legal Reserve and APPs requirements are adequately fulfilled

(ABIOVE 2014). The main aim of CAR is to provide a transparent information database to municipalities, states and federal government about registered property's environmental condition in order to control, monitor and analyse environmental damage, and further conduct environmental safety planning (CAR 2019). Operated by Brazil's environmental protection agency, IBAMA, the CAR system supplies satellite data, including high-resolution images that efficiently allow landowners to locate and report updated condition of their property (Gibbs et al. 2015).

Such initiative of property registration solely, however, does not protect the forest. Azevedo et al. (2017) conclude that a complete comply with the CAR registry is not effectively reducing illegal deforestation as the cost of adhering the Code outweighs the economic benefits that could be obtained from it. Farmers faced a cost of restoration ranging from US $1.6 billion in the Mato Grosso to US $7.9 billion in Pará. Exposed to this estimated value, some farmers from the registered area confessed in violating the Code through clearing small areas (<10 ha), in a hope that such small-scale would escape satellite detection or field visit by prosecutors.

Research findings further conclude that field-based enforcement (inspection) is cost-effective but comes at high opportunity cost for landowners, meaning that environmental services could compensate spending from regulator's point of view; however, farmers also face costs associated to forgoing production and maintaining the implementation. Therefore, field-based inspection strategy, that simultaneously combines incentives and disincentives-based policy, is not feasible and compatible both economically and socially (Börner et al. 2014). As a result, deforestation events are still active in the Amazon biome each year, making difficult to achieve the enforcement (Börner et al. 2014, Gibbs et al. 2015).

In that sense, implementation of the Forest Code and in turn the CAR in Brazil had remained low and ineffective in curbing deforestation. Legal enforcement in place did not properly succeed the aim of protecting water and natural vegetation, causing illegal land use and deforestation to go widespread (Sparovek et al. 2010).

2.5.2. THE CRITICAL COUNTIES PROGRAM

The Critical Counties Program – commonly called Blacklist – belongs to the set of policies aimed to reduce deforestation and it was originated and promoted by the collaboration between the Brazilian Central Bank and Environment Ministry (Nepstad et al. 2014).

It became effective from 2008, after the passing of Presidential Decree 6,321 in December 2007, where are contained the following objectives: controlling illegal deforestation and preventing land degradation, evaluation made for each county (*município*) geographical unit (Cisneros et al. 2015, Nepstad et al. 2014).

The municipality-level monitoring represents a distinguish characteristic. In fact, it differs from all the others ongoing policies, thus even from the one we are evaluating in this thesis, the Soy Moratorium, which monitors each property individually (Nepstad et al. 2014).

The three criteria followed to insert a municipality into the Blacklist, presented in Cisneros et al. (2015), are:

1. the total deforested area,
2. the total deforested area in the previous three years and
3. the increase of deforestation of minimum three out of the past five years. Based on the mentioned parameters, the list is annually updated referring to the official deforestation statistics reported by the IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources) and the INCRA (National Institute for Agrarian Reform) (Cisneros et al. 2015).

For those municipalities, with high deforestation rates, added to the Blacklist, the immediate consequence is the suspension of the access to agricultural credit and a successive increase in the monitoring (Nepstad et al. 2014). Consequently, the policy should strongly stimulate the effort to reduce deforestation.

Although the decline in deforestation could be addressed to many programs, especially as they overlap both temporally and geographically, there is common evidence of the effectiveness of this specific policy. There are many researches, among them (Assunção et al. 2015; Cisneros et al. 2015, Nepstad et al. 2014), which confirm the success of the program in reducing deforestation.

Due to the positive impact in declining deforestation of the after-mentioned policy, as better explained in the dedicated Chapter 5, we introduce in the estimation models an addition independent variable, to capture the effect of the Program and thus prevent the possibility of biased results.

2.5.3. THE CATTLE MORATORIUM

In 2009, Greenpeace along with the Federal Public Prosecutors office in Para state (Ministerio Publico Federal MPF-Para) and related NGO's, all in cooperation, initiated a legal enforcement connected to illegal deforestation and pressured key traders in beef, leather and meat packing companies (Gibbs et al. 2015). 4th October of 2009 came with another milestone attainment: four of the world's largest cattle producers (JBS-Friboi, Bertin, Minerva and Marfrig) certified the implementation of the Cattle Moratorium. They pledged to modify their beef supply chain and ensured any of their productions not to be sourced from new forest clearings (Mongabay 2009).

The Cattle Moratorium comprises six criteria aimed at affecting the industrial cattle operations in the Amazon biome (Greenpeace 2009):

1. zero deforestation in the supply chain;
2. rejection of invasion of indigenous lands and protected areas;
3. rejection of slavery work;
4. rejection of land grabbing and land conflicts;
5. a monitorable, verifiable and reportable tracking system;
6. implementation of the supply chain commitments;

Despite the implementation, the Cattle Moratorium showed a limited significance in forest conservation (Alix-Garcia and Gibbs 2017), as the current enactment lacks effective monitoring and clear assessment of large segments of the cattle supply chain (Walker et al. 2013). This loophole opens an opportunity for laundering activities in-between complaint and noncompliant properties, ignoring indirect parts of the supply chain, and grants a leakage of cattle from non-complaint properties to slaughterhouses with no monitoring system of supplying sources (Gibbs et. al. 2015).

2.5.4. ZERO DEFORESTATION COMMITMENT

From the above-presented "pros and cons" assessment of SoyM, it should be evident the insufficient power of the moratorium in the noble intent of reducing deforestation. For this reason, it is becoming more and more fundamental to introduce other global instruments such as Zero

Deforestation Commitment (ZDC), where companies and countries are committed in removing commodities associated with deforestation from their entire supply chain.

Recently, four major companies of the Brazilian soy sector – Amaggi, ADM, Bunge and Cargill, which represent half of the export in the period between 2006 and 2016 – undertook a ZDC. As a result, 42.2% of all Brazilian soy export in 2016 (28 million tonnes) was covered by a ZDC (Trase 2019).

An example of ZDC is the New York Declaration on Forests (NYDF), a voluntary statement of intentions promoted by companies, states and the civil society (Trase 2019). Signed in 2014, its first two goals are the following. First, "at least halve the rate of loss of natural forests globally by 2020 and strive to end natural forest loss by 2030" and then "support and help the private-sector goal of eliminating deforestation from the production of agricultural commodities such as palm oil, soy, paper and beef products by no later than 2020" (NYDF 2014).

2.5.5. THE BOLSA VERDE PROGRAM

The Bolsa Verde program began in 2011 aiming to successfully address multidimensional differences connected to social and environmental issues across different regions of Brazil (United nations 2019). Under the official name "Program of Support to Environmental Conservation", the four main pillars of the program are:

1. Promote and encourage the conservation of ecosystems (caring for the environmental and sustainable use of resources).
2. Promote conscientious citizenship and improve living conditions.
3. Increase the income of the population living in extreme poverty that carries out activities of conservation of natural resources in rural areas, and
4. Encourage the participation of the beneficiaries in actions of environmental, social, technical and professional qualification.

The Ministry of Environment (MMA) is the key actor governing the Bolsa Verde and further steers the program's guiding Committee. Other members of the program include: Presidency's Chief of Staff Office, Ministry of Social Development, Special Secretariat for Family Agriculture and Agrarian Development, Ministry of Finance and Ministry of Planning, Development and Management (WWP 2017).

Families living under extreme poverty conditions (monthly income below R$ 85.00 per capita) and contributing towards a beneficial, conservative and sustainable environmental schemes are directly registered as recipients of the Bolsa Verde Program Fund (United Nations 2019).

Since its inception, the Bolsa Verde Program was able to improve environmental conservation in territories where recipient families live, assess the conditions of the Program and its contribution to enhance the living conditions of assigned families and as a result eradicate the danger of environmental destruction.

With the support of the Program and new equipment, beneficiary families were able to identify the significance and its beneficial effect to the welfare and environmental prevention. Further, they boosted their productivity and exercised precaution strategy to identify the main threats to conservation, that are fire and deforestation. However, they still lack infrastructural access to a water supply, sewage network and garbage collection system and also lack capacity-building courses aimed to enhance their involvement with the environment (WWP 2017). With that in mind, the Ministry of Environment identified the challenges and constructed new activities to enhance future social and environmental development. These activities are:

- Increasing agro-extractivist activity with improved technical assistance conditions, training and access to microcredit, as well as better production chain structures.
- Establishing joint efforts with other federal and state programs in order to improve household infrastructure and access to public services.
- Improving Bolsa Verde information outreach to beneficiary and non-beneficiary families and the general population.
- Keeping a constant enrollment of families in territorial units, as well as indigenous lands, quilombola lands and other traditional population territories.
- Developing and improving monitoring on a continuous basis, including deeper scales and perspectives of spatial analysis.

CHAPTER 3. DESCRIPTION OF THE DATA

This chapter outlines, in the first section, the origin and the structure of data, whereas the second section contains a detailed graphical description of the variables of interests.

3.1. PRESENTATION

The first section contains information regarding the provenance of data, followed by an illustration of issues we faced during analyses and the subsequent conclusion.

3.1.1. SOURCE

This paper uses a panel dataset with a time span of 14 years from 2003 to 2016. The source of our dataset is Trase (Transparency for Sustainable Economies) database, which is assembled by a partnership between the Stockholm Environment Institute (SEI) and Global Canopy, both in collaboration with Vizzuality, the European Forest Institute (EFI) and other affiliated organizations and individuals (Trase database 2016).

Trase seeks to provide a go-public supply chain information system regarding to major forest-risk commodity operations, such as soy, beef, palm oil, timber, pulp and paper, coffee, cocoa and aquaculture. Trase cooperates with different organizations such as the Produção Agrícola Municipal (the Municipal survey on the Production of Agricultural goods) and the Brazilian Bureau of Statistics (IGBE) to obtain data information such as soy production, land use and related annual agricultural survey.

Trase platform presents transaction of commodities using Sankey diagrams (Trase database 2019). The Sankey diagram outlies production of soy flows including information on exporting company, importing company and the country of destination. Further, it allows users to customize the diagram to discover commodity flows according to point of origin (e.g. municipality, biome, state), the source of export (either by company or port); all these transactions can be viewed based on different characteristics related to the commodity flow (e.g. trade volume, land-use, territorial deforestation, soy deforestation risk, land-based CO_2, CO_2 emissions risk from soy deforestation).

3.1.2. PROBLEMS

Our initial aim was to collect deforestation data at company level. Ideally, as some companies signed the moratorium in 2006, the subsequent hypothetical analysis scheme was to differentiate between treated companies and controlled companies based on both the year of implementation (2006) and the private decision of companies to sign the moratorium. Following this strategy, we aimed to analyse the causal impact of the moratorium in deforestation level in the Amazon biome using counter-factual empirical strategy at a company level.

However, after a thorough investigation of the report, followed by a looped communication with colleagues from Stockholm Environment Institute and Global canopy, we discovered a potential flaw on how Trase allocate to companies the amounts of soy deforestation, territorial deforestation, soy production and land use. In particular, we discovered a discrepancy in the values that are in excel file (E-file), which is available for download, versus the profile section (P-section) where you can view individual municipality report for each year.

The first complication is that the soy-production data reported in the E-file represent only a partial amount (linked to a known exporter), whereas the values presented in the P-section represent the whole amount, regardless of the key trader. It implies that the E-file reports values lower than the real amount (as in the P-section), in other words only a percentage of the total value of soy production.

In addition, the E-file presents lower values than the P-section of the three other variables (soy deforestation, territorial deforestation and land use) for two reasons:

1. The soy production in year (t) is linked to territorial deforestation, soy deforestation and land use of year (t-1), which is the previous year.
2. Their values are reported in the E-file not in real terms but applying the same percentage found for soy production in year (t) with a known destination.

A further critical point is how, for a given municipality in year (t), data of territorial deforestation, soy deforestation and land use of year (t-1) are attributed to different companies operating in that municipality in year (t). As it was not possible to identify the specific-company exact amount of territorial deforestation, soy deforestation and land use, Trase first divided the total amount of each variable based on the soy production in year (t), and then attributed to companies the respective amount of those variables. Meaning that a certain percentage of soy production in year (t) implied the responsibility for the same percentage of territorial deforestation, soy deforestation and land use in year (t-1). A thorough example of such disparity is presented in the case of municipality Cabixi in Appendix 5.

3.1.3. STANCE AND SOLUTION

For the reasons described above, we consider data of soy deforestation, territorial deforestation and land use, attributed to companies, to be unsuitable for our original purpose. It crosses the fundamental principal of an empirical research to directly link the percentage of these three variables to the amount of soy production. How can one ensure if, following the example in Appendix A5, Bunge caused 15% of soy deforestation, why not 10% or 20%? Therefore, we decided to consider data of deforestation and land use only at municipality level and abandon original strategy of a SoyM assessment based on data at company level. However, data on soy production and its company contribution level remain coherent and therefore, we will utilize them in one of our empirical studies.

In order to obtain a complete and trustable data of soy production, territorial deforestation, soy deforestation and land use, we decided to manually create, by ourselves, a dataset using the P-section of the Trase website as a source. We collected data of the 177 municipalities, all of them included in the Amazon biome, from 9 States (Acre, Amapá, Amazonas, Maranhao, Mato Grosso, Para, Rondonia, Roraima, and Tocantins). As the time period spans from 2003 to 2016, this new longitudinal dataset contains 2478 observations for each variable.

The Cerrado biome encompasses about 800 municipalities. In such a case, it would be infeasible to collect a manual data of all municipalities. Further, intuitively the deforestation level, both territorial and soy, of the entire Cerrado biome would be comparatively higher than the Amazon biome. In that sense, in order to have a comparable number of observations in both biomes, it makes a coherent sense to focus only on a restricted area of Cerrado thus not on the entire biome. In order to resolve this situation, we decided to focus on 206 municipalities of three States, namely Mato Grosso, Maranhao and Tocantins, located at the border between the Amazon and Cerrado biomes.

Also, we contacted associates from SEI and Global Canopy to assist us in the matter of Cerrado biome data collection. With their help, we obtained a full dataset of variables of our choice study for 206 municipalities with the same time span from 2003 to 2016 containing 2884 observations for each variable.

3.2. GRAPHICAL OVERVIEW OF DATA

In this section, we briefly present a graphical description of the data, highlighting the relevant features of our analysis. In particular, we focus our attention to four important aspects: soy deforestation, a comparison between soy deforestation and territorial deforestation, the similar evolution between soy land use and soy production, and the relation between soy land use and soy deforestation.

3.2.1. SOY DEFORESTATION

In order to better explain the path of soy deforestation over the period, we decide to take as a reference a prominent paper by Nepstad et al (2014) which divided the Brazilian deforestation process into three phases:

1. Agro-Industrial Expansion (1990-2004).
2. Frontier Governance (2005-2006).
3. Territorial Performance (2006-2014).

1. In the first phase, during the 1900's and early 2000's, an increase in global demand for soy commodity caused a high level of soy deforestation in the Amazon biome (Nepstad et al. 2006). Coherently, Figure 3 shows that the highest level of soy deforestation in both biomes was recorded in that time period (2003 and 2004). Therefore, Amazon deforestation become more sensitive to global commodity market conditions and consequently a large scale of soy expansion and deforestation occurred in the area (Nepstad et al. 2014). Overall, during this time period, soy production, driven by higher prices, and usage of cleared forests showed an immense increment; as a result, soy deforestation reached its spike.

2. The decline in the following phase, from 2004 to 2005, could be ascribed to two reasons. Firstly, a plunge in the profitability of soy production caused a retraction in the commodity supply chain. Secondly, the Brazilian government launched law enforcement measures aimed to control the increasing capacity level of deforestation. As part of this program, the Detection of Deforestation in Real Time (DETER), the Plan for Protection and Control of Deforestation in the Amazon (PPCDAm), Forest Code, Legal Reserve project and other concerned control measurements, contributed to a soy deforestation decline (Nepstad et al. 2009, Macedo et al. 2012, Nepstad et al. 2014).

3. In 2006 the Greenpeace-led attack succeeded in the Soy Moratorium inception and in this year starts the third and last phase of the deforestation chapter. This is the period we are investigating, that is if the SoyM has a causal impact in curbing the deforestation level in the Amazon biome.

From Figure 3 clearly emerges that the lowest level of soy deforestation for both biomes was recorded in 2006 but thereafter the path for the two areas had a different evolution. While in the Amazon biome the level of soy deforestation remained constant and close to zero, on the other hand, there was an upscaling increase of soy deforestation in the Cerrado biome just after the initiation of the moratorium (2007-2008); later, the rate remained always higher in comparison to the Amazon biome, including the lowest amount recorded in 2006. This contrasting trend could be a counter effect of the Amazon biome-based agreement; in other words, the absence of the policy (moratorium) implies that some key supplier of soy commodity might relocated their field operation to the Cerrado biome to escape the contract.

Figure 3 presents a comparative overview of Soy Deforestation for Amazon and Cerrado biome

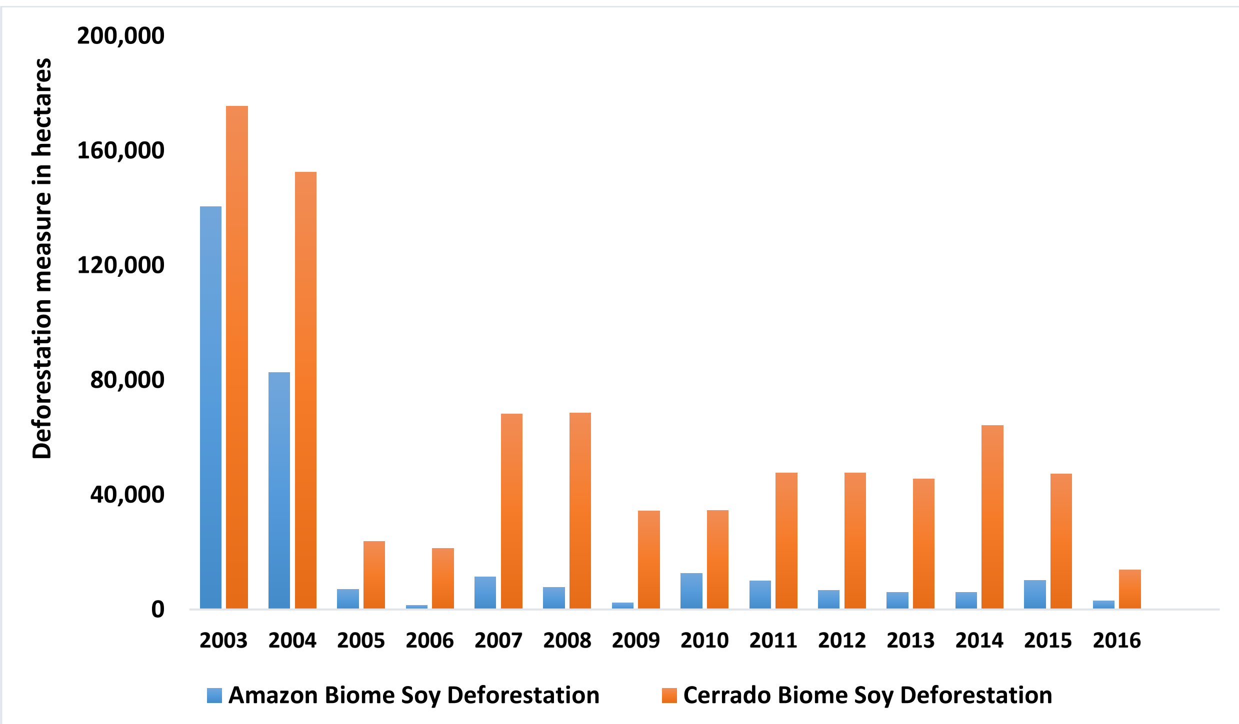

Figure 3: Soy Deforestation in the Amazon and Cerrado biome. (Source: P-section available in: Trase 2019).

3.2.2. RELATIVE WEIGHT OF SOY VS TERRITORIAL DEFORESTATION

Figures 4 and 5 outline soy versus territorial deforestation for the biome Amazon and Cerrado respectively. From the graphs, we can briefly obtain two important facts:

1. Soy deforestation contributes only to a small share of territorial deforestation in both areas. This transmits an assured confirmation that there are many other factors attributing to the forest clearing

in the Brazilian biomes. Both figures exhibit that soy deforestation, measured in the right-hand scale in hectares, contributes to a small amount of territorial deforestation, measured in the left-hand scale in hectares as well.

2. A supporting paper by Azevedo et al. (2017) found out that some farmers cleared comparably tiny areas (<10 ha), in a hope that due to the small scale they would escape foot prosecution or satellite detection. In that sense, some of the soy plantation in the Amazon and Cerrado biome could be practically operating in hidden lands or perhaps illegal fields. Therefore, as we briefly outlined in section 3.1.3. to collect manual data from Trase at the municipality level, both figures only present officially reported data of annual deforestation level of both variables; that is to say the soy deforestation might be higher than what it is displayed in the figures. This assumption could be practical in the case that a fully transparent data report would be available in Trase, from all municipalities that allow any type of soy production in their land.

Figure 4 presents Amazon biome regarded deforestation (Soy and Territorial).

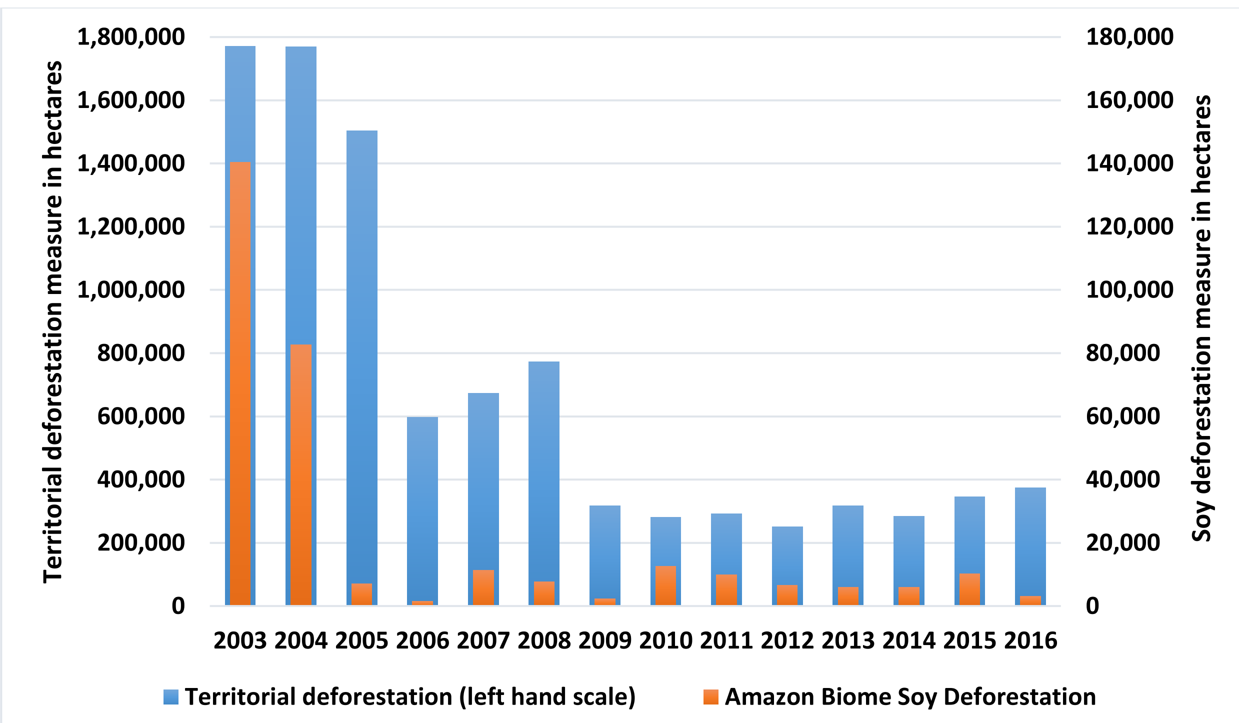

Figure 4: Comparison of Soy vs Territorial deforestation (Amazon biome). (Source: P-section available in: Trase 2019).

Figure 5 presents Cerrado biome regarded deforestation (Soy and Territorial).

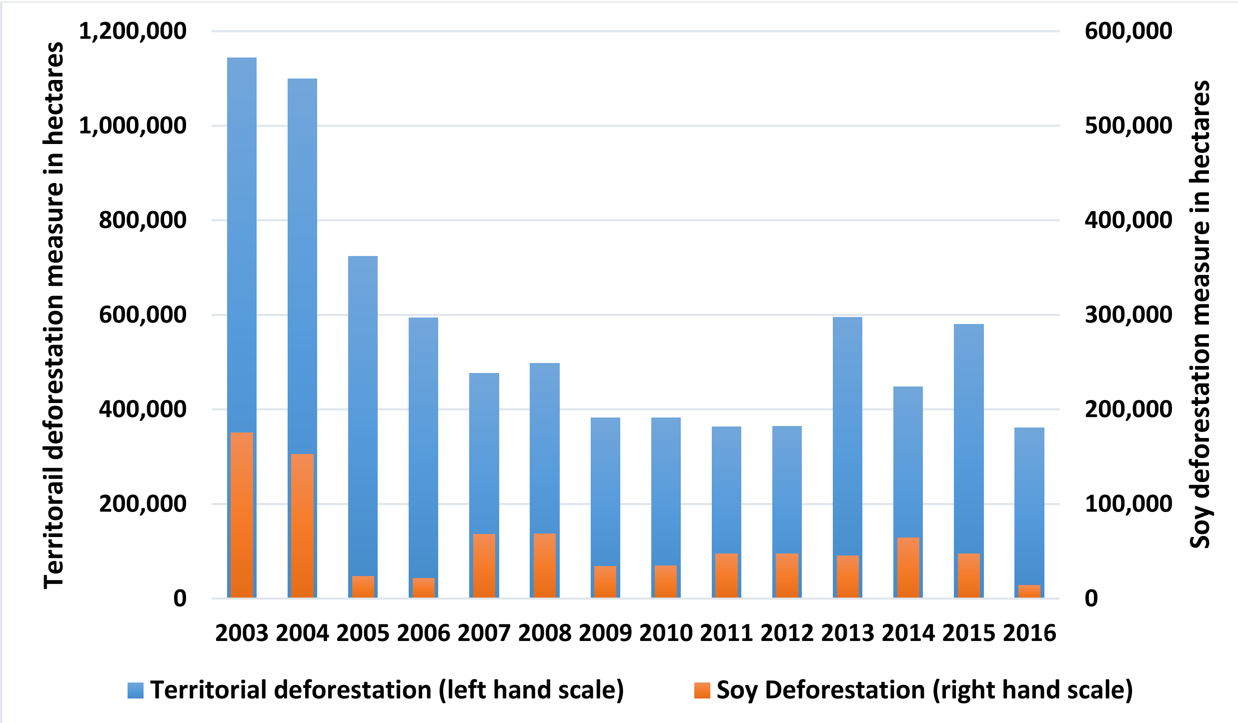

Figure 5: Comparison of Soy vs Territorial deforestation (Cerrado biome). (Source: P-section available in: [Trase 2019]).

3.2.3. GRAPHICAL OUTLOOK OF SOY LAND USE AND SOY PRODUCTION (EFFICIENCY)

Furthermore, Figures 6 and 7 outline a brief summary of soy production and soy land use in the Amazon and Cerrado accordingly. As both biomes exhibit an increasing level of soy production and available land use for production, we conducted a graphical analysis of such variables of interest to investigate if the increase in soy production derives from a gain in efficiency, meaning the existence of productivity growth, or from a proportional increase in land used. The answer is unequivocal because the efficiency level remained stable throughout the interval time of study. Referring to Figures 6 and 7 accordingly, the level of soy production, measured in the right-hand scale (in tonnes), is three times the land use level measured on the left-hand side scale (in hectares). Meaning, for both biomes, the amount of soy produced per hectare of land was approximately 3 tonnes over the entire period. Therefore, this finding proves that the higher level of soy production was linked to a proportional increase in land use and not to productivity growth.

Figure 6 presents Annual Land use and Soy production in the Amazon biome.

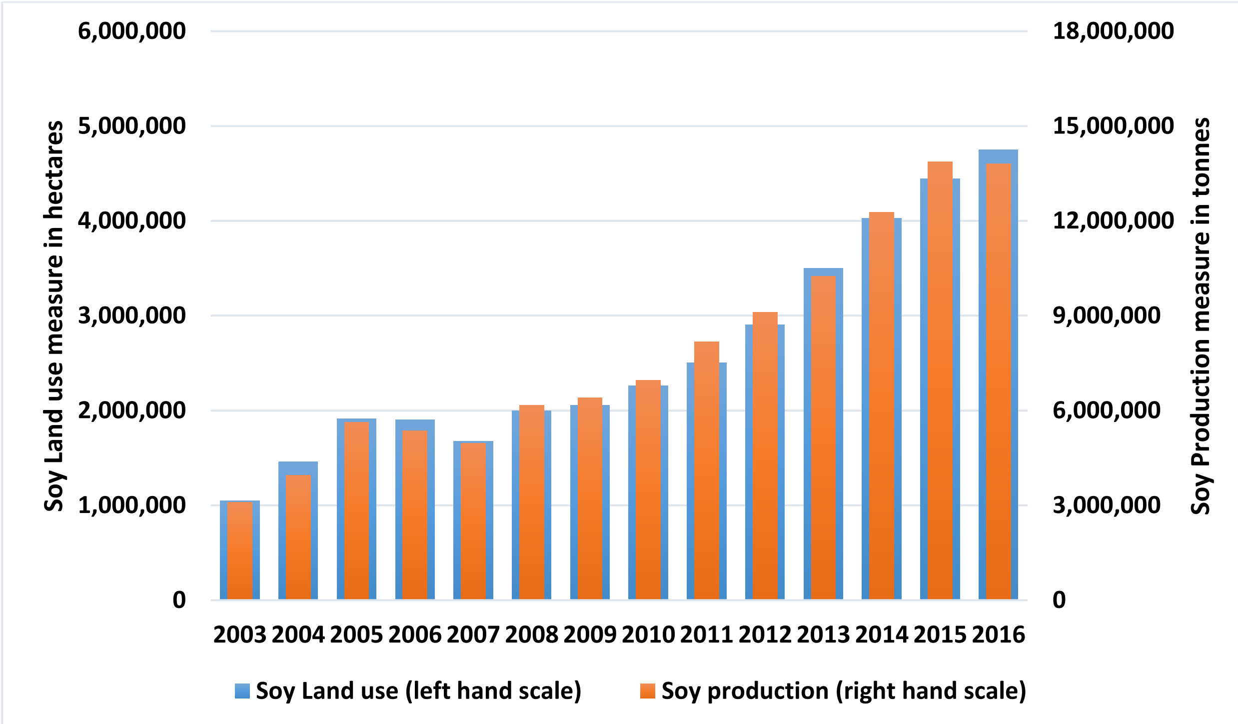

Figure 6: Comparison of soy land use and soy production, Amazon biome. (Source: P-section available in: Trase 2019).

Figure 7 presents Annual Land use and Soy production in the Cerrado biome.

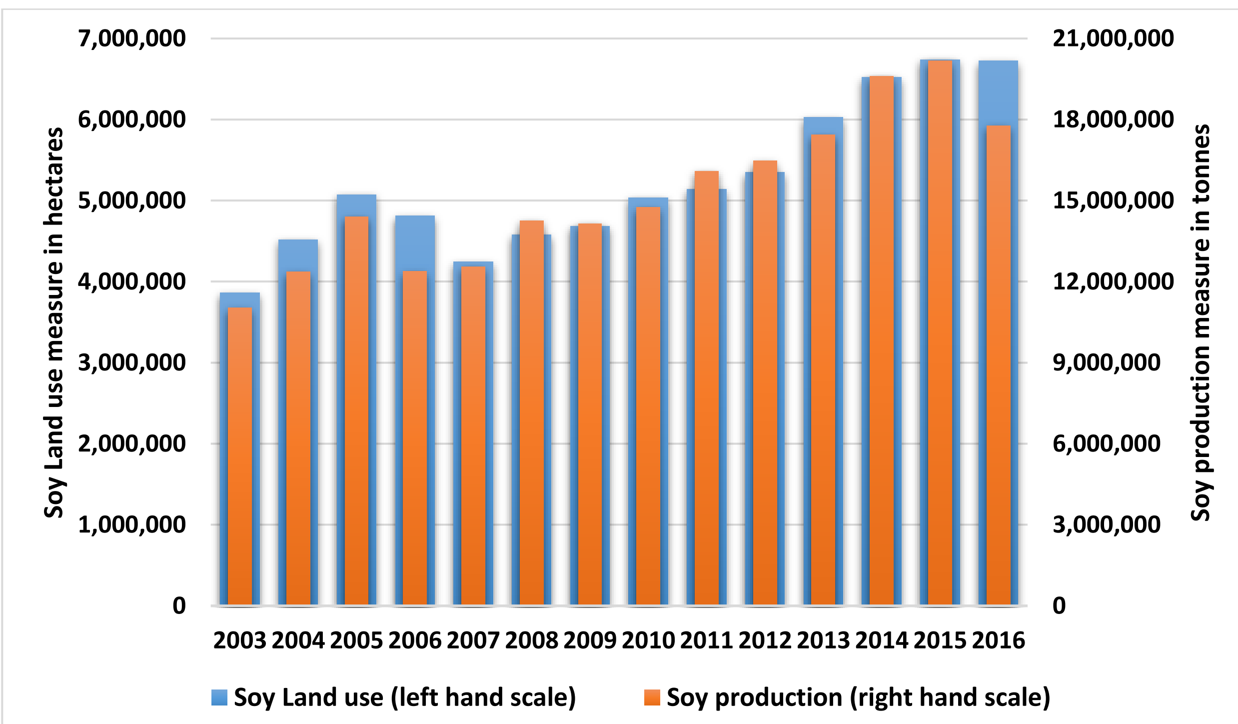

Figure 7: Comparison of soy land use and soy production, Cerrado biome. (Source: P-section available in: Trase 2019).

3.2.4. CONTRIBUTION OF LAND USE AND SOY PRODUCTION TO SOY DEFORESTATION

To summarize all reported figures, even if the level of soy deforestation declined post-SoyM, the land use for soy and resulting soy production has increased in the same time period and was even much higher than the deforestation rate immersing from soy production recorded. Such scenario clearly explains that the increase in soy land or soy production is not directly related to an equal level of deforestation. In other words, there is no direct linkage between factors of soy commodity and direct soy deforestation. Consequently, most of the “new” land used for soy production might came from a replacement of an already cleared area, primarily aimed for other types of operation (cultivation) and economic activities in the area (pastureland is a good example in this case) or purely from uncultivated land.

CHAPTER 4. EMPIRICAL STRATEGY

This chapter describes the empirical strategy applied in the thesis, which enables to answer the research question. First, we explain the theoretical approach then we present the consequential econometric model and finally we list the correspondent specific equations.

4.1. THEORETICAL APPROACH

The description of the data in Chapter 3 highlighted how both levels of deforestation significantly dropped in the Amazon biome after 2006, such as after the implementation of the SoyM. As we stated in the research question, our aim is to empirically assess the effectiveness of the moratorium in reducing deforestation (from soy and territorial) in the Amazon biome. In order to answer our research question, we elaborate two different strategies, both aimed to evaluate this policy but constructed from a different prospective. It follows a general presentation of the two strategies, which will be employed for soy deforestation in Chapter 5 and territorial deforestation in Chapter 6.

4.1.1. FIRST EMPIRICAL STRATEGY

The first empirical strategy evaluates the overall impact of SoyM on the level of deforestation, after 2006, in municipalities of the Amazon biome. We construct a model with a program participation dummy variable ($policy\_biome_{it}$) as independent variable, which reflects the characteristic of the SoyM: it applies only in the Amazon biome and after 2006. Therefore, 177 Amazon municipalities after 2006 compose the group affected by the policy and the consequent value of the dummy variable is 1, while it is zero before 2006. On the other hand, 206 Cerrado municipalities represent the control group and the consequent value of the dummy variable is zero. In fact, as we specified before in the description of the policy, SoyM is a biome-specific measure, meaning that it applies only in the Amazon biome, therefore systematically awarded as a treatment group (exogenous effect); consequently, it allows analysing the policy using municipalities in the Cerrado biome as a control group.

To be fair, we are aware that considering the entire Amazon biome as a treated area could be inappropriate because the SoyM does not force every company to operate overall, but it is a voluntary and independent decision made by each company. Nevertheless, this strategy can remain valid as the key traders of soy commodity signed the moratorium and therefore almost the entire amount of soy was traded by those companies (Gibbs et al. 2015). For this reason, we can advisedly but only temporarily, assume in the first strategy the Amazon biome to be entirely affected by SoyM.

From this strategy, we expect the coefficient of $policy\_biome_{it}$ to be negative, signifying that the implementation of the SoyM implicated a reduction in the level of deforestation in municipalities of the Amazon biome after 2006.

4.1.2. SECOND EMPIRICAL STRATEGY

The second empirical strategy is equally aimed to assess the effectiveness of the SoyM. As the first strategy considers the Amazon biome being completely involved in the SoyM, without taking into consideration the role of signatory and non-signatory companies, this strategy, on the other hand, includes the specific company's private choice of whether or not agree with the moratorium.

As we described in section 2.2, two association of agricultural companies, ABIOVE and ANEC, signed the SoyM in 2006, committing their member to be compliant with the moratorium. To find the name of signatory and non-signatory companies, which is essential to build this strategy, we examined the websites of the two associations (http://www.abiove.org.br and https://www.anec.com.br), which contain the update lists of associated members.

To perform the analysis, we construct a model which contains two program participation dummy variables as independent variables, created as follows.

For the first independent variable ($policy\_percentage\_1_{it}$), we initially considered the amount of soy produced, by future SoyM signatory companies, in 2003, in each municipality of the Amazon biome. Thus, we obtained a percentage (of soy production of future signatory companies, for each municipality of the Amazon biome), which ranges from 0 (in case of complete absence of signatory companies) to 1 (if signatory companies produced the whole amount of soy). Then, each municipality of the Amazon biome is attribute 0 for the three years before the launching of the SoyM (2003, 2004 and 2005) and the aforementioned percentage value (between 0 and 1) from 2006 onwards. Finally, municipalities of the Cerrado biome is attribute 0 for the entire period.

The second independent variable ($policy\_percentage\_2_{it}$) is built in a simple way: from 2006 onwards, for municipality of the Amazon biome is attribute one minus the value of the first independent variable while always 0 for the previous years (2003, 2004 and 2005). To complete the dataset, each municipality of the Cerrado biome is still attribute 0.

As we stated in section 3.1, data regarding soy production and its subdivision to companies, reported in the E-file, do not present any complication since they are carefully recorded, therefore we can safely construct the two above-described variables.

The choice of 2003 as a reference, correspondent to the first year of our dataset and therefore the further ahead from the launching of SoyM, permits to avoid the endogenous effect of the moratorium in the soy productions shares. In addition, this year precedes the introduction of a series of environmental policies and law enforcement implemented under Lula's presidency (Nepstad et al. 2014).

Based on how the two-program participation dummy variables are constructed, the approach of this strategy is to assess the effectiveness of SoyM, taking as a reference the relative weight of production of future signatory companies in each municipalities of the Amazon biome in 2003. Municipalities of the Cerrado biome are considered again as a control group.

The hypothesis design is targeted to assess the following:

1. In municipalities of the Amazon biome with a higher percentage of soy produced by future signatory companies in 2003, the level of deforestation after 2006 should be lower. Therefore, the coefficient of the first independent variable ($policy\_percentage\_1_{it}$) is expected to be negative, implying a beneficial effect (in terms of deforestation) for almost treated municipalities. In other words, the higher the commercial-presence of signatory companies the lower the level of deforestation.
2. In municipalities of the Amazon biome with a lower percentage of soy produced by future signatory companies in 2003, the level of deforestation after 2006 should be higher. Therefore, the coefficient of the second independent variable ($policy\_percentage\_2_{it}$) is expected to be positive, implying an exacerbating effect (in terms of soy deforestation) for those non-treated municipalities. In other words, the lower the commercial-presence of signatory companies, the higher the level of deforestation.

4.1.3. THE CRITICAL COUNTY PROGRAM

As reported in section 2.5.2., the Critical County Program (Blacklist) is another environmental policy aimed in reducing deforestation, which succeeded its noble objective, according to many academic studies, among them (Assunção et al. 2013, Nepstad et al. 2014, Cisneros et al. 2015).

Aware of the fact that the effectiveness of the Critical County Program could potentially bias our outcomes, we enrich and strengthen the previous empirical strategies including the explanatory variable $blacklist_{it}$ to control for the contribution of this policy. However, the blacklisting procedure is endogenous to deforestation because a given municipality faces the registry protocol after breaching or failing to observe the code of conduct related to deforestation; therefore, it is not possible to directly estimate the casual effect of this policy and the coefficients will represent as an indicator of the correlation between the Program and deforestation. In other words, this strategy boosts as a way to control for another policy that have a mutual connection with SoyM and also as an overall indication of the effect.

The independent variable $blacklist_{it}$ is a program participation dummy variable, which acquires the value one only when a municipality is listed under the Critical County Program, otherwise the value is zero. A clarifying example could be the municipality of Alta Floresta, which belonged to the Blacklist from 2008 to 2012, therefore for that period the dummy variable is one; consequently, from 2003 to 2007 and from 2013 to 2016 the value is zero.

In order to correctly and precisely create the variable $blacklist_{it}$, we referred to the website of the Brazilian Ministry of Environment (http://www.mma.gov.br, Ministério do Meio Ambiente) obtaining a complete and updated list of municipalities, currently or previously involved in the Critical County Program. In particular, during the span of time analysed in this paper, from 2003 to 2016, 39 of the 383 municipalities included in our dataset were reported in the Blacklist. For the sake of completeness, the full list municipalities, and their respective year of entering and exiting, is presented in the appendix A4.

Consistently with previous researches, we predict the coefficient of $blacklist_{it}$ to be negative, underling a considerable role of the Blacklist in diminishing the forest clearing.

A different way to control for this environmental policy, in alternative to the introduction of the variable $blacklist_{it}$, consists in the introduction of a combined municipality-year fixed effect for the sole municipalities included in the Critical County Program, only for the period in which they are listed. Therefore, those municipalities would result excluded from the estimation; as a consequence, cancelling the impact of the Blacklist in the level of deforestation. In the estimations presented in the subsequent Chapters 5 and 6 we will present both modalities.

4.2. ECONOMETRIC MODEL AND ESTIMATION OF EMPIRICAL STRATEGIES

This section presents the consequential econometric and the appropriate estimation method to evaluate the two mentioned empirical strategies.

4.2.1. THE ECONOMETRIC MODEL

The proper econometric model to represent and assess our strategies is a two-way error-component regression model with program participation dummy variables as independent variables (Baltagi 2013).

A simple version of the model with a single explanatory variable is:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_i + \alpha_t + u_{it} \qquad i \in \{1 \dots N\};\ t \in \{1 \dots T\}\ (1)$$

Where:

y_{it}: dependent variable.

β_1: coefficient of interest.

x_{it}: independent variable.

α_i: unobserved individual effect which captures all unobserved and time-constant factors that affect y_{it}.

α_t: unobserved time effect which captures all unobserved and individual-constant factors that affect y_{it}.

$u_{it} \sim \mathcal{N}(0; \sigma_u^2)$: remained stochastic disturbance such as factors that change over time and over individual.

4.2.2. THE ESTIMATION METHOD

The fixed effect estimation is a technique of estimation that permit to remove the unobserved effects α_i and α_t from the original model: an important advantage coming from a peculiar characteristic of a panel dataset.

To see how this method works, consider again a simple version of the model with a single explanatory variable:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_i + \alpha_t + u_{it} \qquad i \in \{1 \dots N\}, t \in \{1 \dots T\}\ (1)$$

Now, we introduce the following transformations:

1. Averaging over time, for each individual i:

$$\bar{y}_i = \frac{1}{T}\sum_t^T y_{it} = \beta_1 \bar{x}_i + \alpha_i + \bar{u}_i\ (2)$$

2. Averaging over individual, for each time t:

$$\bar{y}_t = \frac{1}{N}\sum_i^N y_{it} = \beta_1 \bar{x}_t + \alpha_t + \bar{u}_t\ (3)$$

3. Averaging over individual and time:

$$\bar{y}_{it} = \frac{1}{NT}\sum_i^N \sum_t^T y_{it} = \beta_1 \bar{x}_{it} + \bar{u}_{it}\ (4)$$

Given the above transformations, we can eliminate the unobserved effects α_i and α_t subtracting from equation (1) equations (2), (3) and (4):

$$y_{it} - \bar{y}_i - \bar{y}_t - \bar{y}_{it} = \beta_0 + \beta_1(x_{it} - \bar{x}_i - \bar{x}_t - \bar{x}_{it}) + \alpha_i - \alpha_i + \alpha_t - \alpha_t + u_{it} - \bar{u}_i - \bar{u}_t - \bar{u}_{it} \quad (5)$$

We can simplify the expression (5) introducing the time-demeaned data of each component:

$$\ddot{y}_{it} = \beta_0 + \beta_1\ddot{x}_{it} + \ddot{u}_{it} \qquad i \in \{1 \dots N\}, t \in \{1 \dots T\} \quad (6)$$

We performed a fixed transformation or within transformation and the important result about equation (6) is that the unobserved effects (α_i and α_t) are disappeared. This suggests that we should estimate (6) by pooled OLS. A pooled OLS estimator that is based on the time-demeaned variables is called the fixed effects estimator or the within estimator (Wooldridge 2014).

The fixed effect estimator is unbiased if the independent variable is strictly exogenous, in other words if the remained stochastic disturbance u_{it} is uncorrelated with the independent variable in each period for each individual. Furthermore, for a correct OLS estimation, the remained stochastic disturbance u_{it} should be homoscedastic and uncorrelated across time (Wooldridge 2014).

4.3. SPECIFICATION OF THE EQUATIONS

It follows how we employ the described econometric model to both previously presented strategies.

4.3.1. FIRST STRATEGY

The following equations represent how we estimate the first strategy:

$$y_{it} = \pi_1(biome_i \times SoyM_t) + \pi_2 blacklist_{it} + \rho_i + \rho_t + v_{it} \quad (7)$$

$$y_{it} = \pi_1 policy\_biome_{it} + \pi_2 blacklist_{it} + \rho_i + \rho_t + v_{it} \quad (8)$$

The subscript t denotes the period of 14 years, from 2003 to 2016 while i refers to 383 municipalities, 177 from the Amazon biome and 206 from the Cerrado biome.

y_{it} is the dependent variable and it will represent the level of soy deforestation or territorial deforestation in hectares for each municipality for each year.

$biome_i$ represents the treatment dummy-variable and its value is one for municipalities located in the Amazon biome whereas is zero for municipalities located in the Cerrado biome.

$SoyM_t$ represents the time dummy-variable and its value is one for years following the implementation of the SoyM (2006-2016) whereas is zero for years before its launch (2003-2005).

$policy\_biome_{it}$ is the first independent variable in equation (8). It denotes the program-participation dummy variable, deriving from the multiplication of the treatment dummy-variable and the time dummy-variable. Its value is 1 for municipalities of the Amazon biome from 2006 to 2016 and zero otherwise.

$blacklist_{it}$ is the second independent variable in equation (8). The program participation dummy variable is one only for the period in which a municipality belongs to the Critical County Program, otherwise is zero.

π_1 is the first coefficient of interest, expected to be negative. It represents the average treatment effect of SoyM on deforestation in municipalities of the Amazon biome from 2006, considering the biome as a benchmark (Woodridge 2014).

π_2 is the second coefficient of interest, predicted to be negative as well. It indicates a correlation between the Blacklist and level deforestation in municipalities included in the program.

ρ_i indicates the unobserved municipality effect, ρ_t the unobserved time effect and $v_{it} \sim \mathcal{N}(0; \sigma_v^2)$ the remained stochastic disturbance.

4.3.2. SECOND STRATEGY

The following equations represent how we estimate the second strategy:

$$y_{it} = \phi_1(percentage_i \times SoyM_t) + \phi_2[1 - (percentage_i \times SoyM_t)] + \phi_3 blacklist_{it} + \sigma_i + \sigma_t + w_{it} \quad (9)$$

$$y_{it} = \phi_1 policy\_percentage\_1_{it} + \phi_2 policy\_pergentage\_2_{it} + \phi_3 blacklist_{it} + \sigma_i + \sigma_t + w_{it} \quad (10)$$

The subscript t denotes the period of 14 years, from 2003 to 2016 while i refers to 383 municipalities, 177 from the Amazon biome and 206 from the Cerrado biome.

y_{it} is the dependent variable and it will represent the level of soy deforestation or territorial deforestation in hectares for each municipality for each year.

$SoyM_t$ represents the time dummy-variable and its value is one for years following the implementation of the SoyM (2006-2016) whereas is zero for years before its launch (2003-2005).

$percentage_i$ represents the first treatment dummy-variable. For municipalities of the Amazon biome, the value corresponds to the percentage of soy produced, by future SoyM signatory companies, in 2003, in each municipalities of the Amazon biome. For municipalities of the Cerrado biome the value is zero.

$policy\_percentage\_1_{it}$ is the first independent variable in equation (10). It denotes the first participation dummy variable, deriving from the multiplication of the first treatment dummy-variable and the time dummy-variable. Its value corresponds to $percentage_i$ for municipalities of the Amazon biome after 2006 and zero otherwise.

$1 - percentage_i$ represents the second treatment dummy-variable. For municipalities of the Amazon biome, the value corresponds to one minus the value of the first treatment dummy-variable ($percentage_i$). For municipalities of the Cerrado biome the value is zero.

$policy\_percentage\ \_2_{it}$ is the second independent variable in equation (10). It denotes the second participation dummy variable, deriving from the multiplication of the second treatment dummy-variable and the time dummy-variable. Its value corresponds to $1 - percentage_i$ for municipalities of the Amazon biome after 2006 and zero otherwise.

$blacklist_{it}$ is the third independent variable in equation (10). The program participation dummy variable is one only for the period in which a municipality belongs to the Critical County Program, otherwise is zero.

ϕ_1 and ϕ_2 are coefficients of interest, the first expected to be negative whilst the second coefficient expected to be positive. They represent the average treatment effect of SoyM on deforestation in municipalities of the Amazon biome from 2006, considering the percentage of soy produced, by future SoyM signatory companies, in 2003, in each municipalities of the Amazon biome as a benchmark (Woodridge, 2014).

ϕ_3 is the third coefficient of interest, predicted to be negative. It indicates a correlation between the Blacklist and level deforestation in municipalities included in the program.

σ_i indicates the unobserved municipality effect, σ_t the unobserved time effect and $w_{it} \sim \mathcal{N}(0; \sigma_w^2)$ the remained stochastic disturbance.

CHAPTER 5. SOY DEFORESTATION

This chapter presents the empirical results of the causal relationship between SoyM and soy deforestation. First, we conduct the parallel trends test to confirm the difference-in-differences empirical approach is valid in this manner; second, we introduce the models and present the outcomes of the two strategies, following the formulation outlined in the precedent sections 4.3.1. and 4.3.2. In this and subsequent chapters, we perform all computations and data analysis employing the statistical software Stata, version 15.1 (StataCorp, 2018).

5.1. PARRALEL TRENDS ASSUMPTION

In this section, we examine the necessary assumption of common trends between the treatment and control biomes, to safely proceed with the estimation phase. In that sense, we first conduct a graphical overview of the observed soy deforestation values, followed by an empirical parallel trends test: all from the period between 2003-2005 (pre-treatment period of the SoyM).

5.1.1. GRAPHICAL ASSESSMENT OF SOY DEFORESTATION TRENDS

A crucial pre-condition to construct properly a counter-factual analysis, feasible for establish a causal relationship, is the presence of common trends, between the treated group and the controlled group, before the cut-off date. In our case, the level of soy deforestation in the Amazon biome and in the Cerrado biome, before 2006, such as before the introduction of the SoyM, should present the same trend.

Figure 8 presents soy deforestation in both biomes, examining the parallel trends assumption.

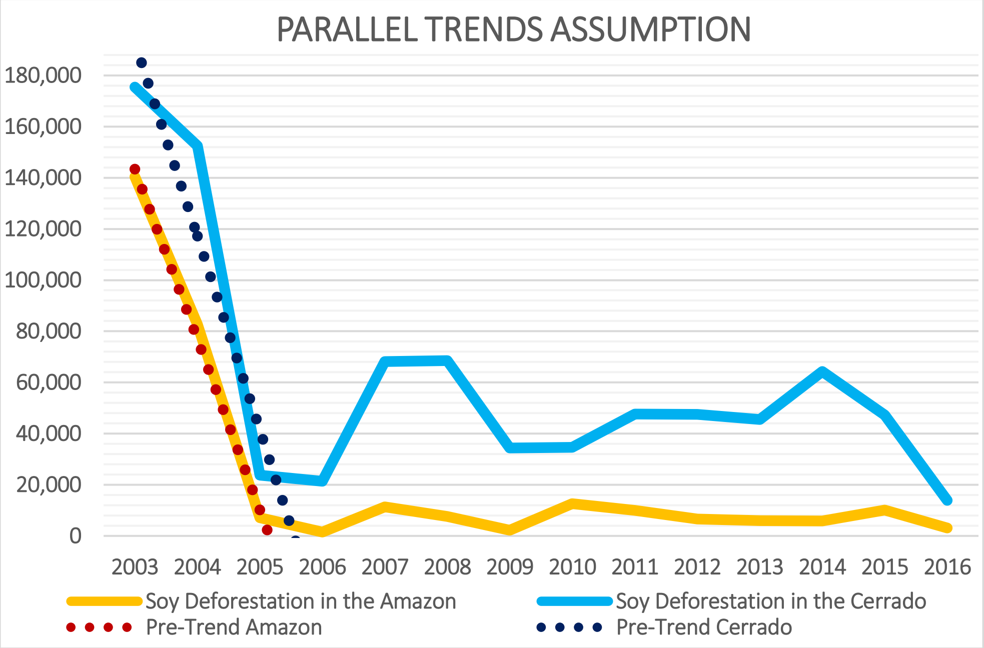

Figure 8: Parallel Trends Assumption – Soy Deforestation (Source: P-section available in: Trase 2019).

As illustrated in Figure 8, this fundamental assumption is fulfilled for our variable of interest, in the period from 2003 to 2005.

5.1.2. EMPIRICAL TEST OF THE PARALLEL TRENDS: SOY DEFORESTATION

This section further investigates the pre-treatment trend of observed values of soy deforestation and examines if the common trends assumption is on hold, reflecting to both the Amazon and Cerrado biome.

To conduct the test, we built equation (1), to test the pre-treatment soy deforestation trend.

$$soy\ deforestation_{it} = \alpha_1 + \alpha_2(biome_i \times year_t) + \varphi_i + \varphi_t + \eta_{it} \ (11)$$

Where $biome_i$ is a biome dummy variable that is equal to 1 for Amazon biome and 0 for Cerrado biome and $year_t$ is a year dummy variable that observes the change in the soy deforestation level from 2003 to 2004 and also from 2004 to 2005. To obtain the change in the observed values of deforestation variable, we assigned the years 2003-2005 with numbers 1-3 accordingly.

Following the above equation, α_2 is the coefficient of interest, constructed by the interaction term between the biome dummy variable and the year dummy variable.

Table 1 presents the parallel trends assumption test of SoyM.

Test for Parallel Trends Assumption
Dependent Variable: Soy Deforestation

	(1)	(2)	(3)	(4)
Biome_trend	-141.4***	-374.4***	-60.0	-6.18
	(47.6)	(70.44)	(49.9)	(94.1)
Municipality FE	No	Yes	No	Yes
Year FE	No	No	Yes	Yes
Constant	636.2***	748.9	850.4***	326.9
	(69.9)	(780.2)	(95.9)	(766.1)
Observations	1152	1152	1152	1152
R^2	0.0076	0.0093	0.030	0.032
F -statistics	8.84	5.41	11.7	9.33

Standard errors in parentheses: *p<0.10, **p<0.05, ***p<0.01

Table 1: Test for Parallel Trends Assumption – Soy Deforestation

Table 1 presents the results developed following above equation of parallel trends test. Here the null hypothesis is that $\alpha_2 = 0$, the growth of soy deforestation was the same in both biomes, whereas the alternative hypothesis is $\alpha_2 \neq 0$, the growth of soy deforestation was not the same even before the treatment (SoyM) was effective.

In reference to Table 1, column (4) resembles equation (11) in which both municipality and year fixed effects are controlled properly. The result amplifies the coefficient of interest (α_2) to be insignificant and therefore assures that the key parallel trends assumption is on hold.

Overall, both the graphical analysis and the empirical test confirm the parallel trends assumption to hold; consequently, we can move forward with the estimation of the models

5.2. EMPIRICAL RESULTS OF SOY DEFORESTATION: FIRST STRATEGY

In this section, we present results of the first empirical strategy formulated in section 5.2.1. The main framework of study (dependent variable) is soy deforestation.

5.2.1. MODEL

The first strategy evaluates the overall effectiveness of SoyM taking as a reference the difference between Amazon biome and Cerrado biome, as it is represented in equation (12):

$$soy\ deforestation_{it} = \pi_1 policy\_biome_{it} + \pi_2 blacklist_{it} + \rho_i + \rho_t + v_{it} \quad (12)$$

Where $soy\ deforestation_{it}$ is the dependent variable and computes the level of soy deforestation in hectares per municipality for each year, π_1 is the coefficient of interest that captures the effect of SoyM on soy deforestation in the Amazon biome post inception of the moratorium, after 2006, and π_2 is the coefficient of interest that signifies the correlation between the Critical County Program and soy deforestation, in municipalities inserted in the Blacklist.

5.2.2. ESTIMATION

Table 2 exhibits regression outputs, including both municipality and year fixed effect.

Difference-in-Differences Estimation: First Strategy *Dependent Variable: Soy Deforestation*			
	(1)	(2)	(3)
Policy_biome	-42.5 (54.1)	24.9 (54.9)	38.7 (54.0)
Blacklist		-483.8*** (76.0)	
Constant	824.7*** (41.4)	824.7*** (41.3)	824.7*** (40.4)
Observations	5362	5362	5362
R^2	0.071	0.078	0.17
F Statistics	27.0	28.1	3.07
Standard errors in parentheses: *p<0.10, **p<0.05, ***p<0.01			

Table 2: Difference-in-Differences Estimation: First Strategy - Soy Deforestation

Column (1) presents a simplified version of the equation (12), excluding the dummy variable of Critical County Program ($blacklist_{it}$) from the first strategy. The result shows a negative, but not significant at 10% level, impact of the moratorium in the level of soy deforestation: the average treatment effect of the SoyM in the Amazon biome (per municipality per year) is 42.5 ha of decrease in soy deforestation compared to Cerrado biome.

Column (2) presents the complete first empirical strategy, as represented in equation (12). The inclusion of the independent variable $blacklist_{it}$ do not substantially modify the previous outcome for the coefficient of the variable $policy\_biome_{it}$. The coefficient π_2 of the variable $blacklist_{it}$, on the other hand, results a significant value, interpreting a strong correlation between SoyM and Blacklisting and their accordance in the manner of soy deforestation.

In Column (3) we present the first empirical approach with a vital alteration, as discussed in section 4.1.3., regarding the modality of the Critical County Program. We omit the variable $blacklist_{it}$ and introduce a combined municipality-year fixed effect for sole municipalities enlisted in the study time interval period; in this case, we substitute $blacklist_{it}$ with a new component $\gamma_{year\#municipality}$. The result interprets the average treatment effect of the SoyM in the Amazon biome (per municipality per year) is 38.7 ha of reduction in soy deforestation compared to Cerrado biome, although this regression result is not significant at 10% level.

5.2.3. FIXED EFFECT INCLUSION TEST – F TEST

For the complete estimation of equation (12), as estimated in column (2) of Table 2, we perform an F test to verify the presence of unobserved factors and, consequently, to confirm the necessity to insert fixed effects in our model. In particular, we conduct three F tests: for municipality FE, for year FE and the last for municipality and year FE together.

F Test: First Strategy		
	Soy Deforestation	
Municipality FE	*Year FE*	*Municipality & Year FE*
F(382, 4964) = 6.00	F(13, 4964) = 21.63	F(395, 4964) = 6.53
Prob > F = 0.0000	Prob > F = 0.0000	Prob > F = 0.0000

Table 3: F Test: First Strategy – Soy Deforestation

Results, presented in Table 3, are unambiguous: time and/or individual invariant factors are present in the study period and therefore we need to control for them.

Therefore, the SoyM exhibits no effect in declining soy deforestation when we compare the Amazon and Cerrado biome as treatment and control group respectively; in fact, this regression output does not ensure the SoyM to be significantly effective. However, the graphical analysis in Chapter 3 vividly shows a slump of the soy deforestation, specifically after the 2000's; for instance, the Amazon biome witnessed a scenario where the destruction of soy deforestation declined starting from 2005 and stayed at low or almost close to zero in post-SoyM periods.

Overall, the SoyM appears not successful or, perhaps, this wide approach is not able to capture the real capacity of the moratorium properly: the first strategy might be a broad approach of estimation to calculate a significant impact of SoyM to soy deforestation. The SoyM systematically identifies the Amazon biome as a treatment group because it is an exogenous effect and this provides an assumption that the Cerrado biome is a control factor. On the contrary, the first strategy does not systematically control companies that operate under these biomes and neither it controls the share of production amounted by companies who sign and promise to oblige the moratorium. For this reason, it is significantly clear, at this point, to identify firm status and properly differentiate the condition between signatory and non-signatory companies to obtain a solid impact of the moratorium. This is where the second strategy becomes effective.

5.3. EMPIRICAL RESULTS OF SOY DEFORESTATION: SECOND STRATEGY

In this section, we present the framework and the results of the second empirical strategy, as formulated in section 4.3.2., considering soy deforestation as dependent variable.

5.3.1. MODEL

The second strategy assesses the influence of SoyM based on the level of soy produced, by future signatory and non-signatory companies in 2003, in municipalities of the Amazon biome. The aim of this estimation, presented in equation (13), is to evaluate the following three assumptions.

$$soy\ deforestation_{it} = \phi_1 policy\_percentage\ \_1_{it} + \phi_2 policy\_pergentage\_2_{it} + \phi_3 blacklist_{it} + \sigma_i + \sigma_t + w_{it} \quad (13)$$

First, municipalities of the Amazon biome, with soy production in 2003 predominantly managed ("dominated") by future signatory companies, should present after 2006 a reduction in the level of soy deforestation, implying that the commercial activity of those companies fostered reduction in soy deforestation and therefore we suppose ϕ_1 to be negative.

Second, on the contrary, municipalities of the Amazon biome, with soy production in 2003 predominantly managed ("dominated") by future non-signatory companies, should present after 2006 an increase in the level of soy deforestation, implying that the commercial activity of those companies caused an increase in soy deforestation and therefore we suppose ϕ_2 to be positive.

Third, the coefficient ϕ_3, referring to the correlation between the Critical County Program and soy deforestation, is expected to be negative as well.

5.3.2. ESTIMATION

Table 4 displays second strategy regression results including municipality and year fixed effect.

Difference-in-Differences Estimation: Second Strategy

Dependent Variable: Soy Deforestation

	(1)	(2)	(3)	(4)	(5)
policy_percentage_1	-613.5*** (123.3)	-520.3*** (123.8)	-475.1*** (124.8)	-644.1*** (131.5)	-609.8*** (133.4)
policy_percentage_2	65.6 (57.9)	125.5** (58.5)	134.6** (57.9)		
Blacklist		-468.5*** (75.9)		-492.6*** (77.5)	
Constant	824.7*** (41.3)	824.7*** (41.2)	824.7*** (40.3)	405.4*** (41.1)	402.7*** (40.4)
Observations	5362	5362	5362	5362	5362
R^2	0.076	0.083	0.17	0.085	0.17
F Statistics	27.1	27.9	3.14	16.5	3.07

Standard errors in parentheses: *p<0.10, **p<0.05, ***P<0.01

Table 4: Difference-in-Differences Estimation: Second Strategy – Soy Deforestation

Column (1) presents a simplified version of the second empirical strategy, where we exclude the variable $blacklist_{it}$. In this estimation, the coefficients of interest correspond to the assumptions discussed above. The coefficient of $policy\_percentage\_1_{it}$ shows an average treatment impact of 613.5 ha of reduction in soy deforestation after the implementation of the moratorium, presenting as well a level of statistical significance at one percent; the coefficient of $policy\_percentage\_2_{it}$ exhibits a positive soy deforestation level post SoyM even though it does not present an appropriate level of significance.

Column (2) presents the complete second strategy model, as represented in equation (13), including the independent variable $blacklist_{it}$ and exhibits interesting features. The variable $policy\_percentage\ \_1_{it}$ maintains a negative and significant coefficient: an average treatment effect of 520.3 ha of decrease in soy deforestation for each municipality from 2006 onwards. Considering the whole panel of municipalities of the Amazon biome in the dataset, the annual maximum level of saved forests is 92,093.1 ha (520.3 × 177) thanks to the SoyM.

Besides, the coefficient ϕ_1 in Column (2) is slightly lower than in column (1): reasonably, the Blacklist policy introduced in the model could capture some soy deforestation effect, shrinking the impact of the SoyM. However, the most important aspect is reaffirmed: signatory companies played an important role in decreasing soy deforestation, even after including and controlling for the Critical County Program.

The variable $policy\_percentage\ \_2_{it}$ confirms a positive coefficient, but more relevant, from column (1) to column (2) it turns significant, at 5% level. This modification constrains to revise the conduct of non-signatory companies and then consider the existence of a counter-effect of the SoyM. In fact, they were potentially responsible for an average increase of soy deforestation up to 125.5 ha in each municipality, every year after the introduction of SoyM. Applying the same comparison, non-signatory companies could have caused, on average, a maximum increase in level of soy deforestation equal to 22,213.5 ha (125.5 × 177) every year after 2006.

In line with the hypothesis, the coefficient (ϕ_3) of the variable $blacklist_{it}$ also exhibits a negative value. This result reaffirms the correlation between SoyM and Blacklisting and their mutual correspondence in terms of soy deforestation.

Column (3) presents a regression output with the following proper modification of the econometric model. We first remove the independent variable $blacklist_{it}$, then we insert a new component: a combined municipality-year fixed effect ($\delta_{year\#municipality}$), for the sole municipalities included in the Critical County program, only for the period in which they are listed. The proposal of this examination is to check the goodness of our previous results, especially the unbiasedness of the coefficients; thus, we control for blacklisted municipalities in order to extract them from the estimations and then obtain a solid answer on the effectiveness of the SoyM.

In that manner, the coefficient $policy\_percentage\_1_{it}$ results an average treatment effect of 475.1 ha of decrease in soy deforestation in each municipality, every year following the inception of SoyM. This result is statistically significant at 1 percent. Whereas the coefficient $policy\_percentage\_2_{it}$ (significant at 5% level) reveals that non-signatory companies could have contributed, on average, to an increase of 134.6 ha in soy deforestation in each municipality.

In the following two regression outputs of Column (4) and Column (5), we also modify the econometric model as follows: both regression output are estimated with the exclusion of the variable $policy\_percentage\ \_2_{it}$ and a new parameter $\sigma_{year\#biome}$ take the place of σ_t. The latter switch of the variables allows the study to control year specific and biome specific effect and under this strategy, both biomes manifest particular year effects related to its geographic division. While Column (4) encompasses the variable $blacklist_{it}$, Column (5) presents a regression output substituting that variable with the above-mentioned component, the municipality-year fixed effect $\delta_{year\#municipality}$.

In Column (4), the coefficient $policy\_percentage\_1_{it}$ presents a negative impact that is statistically significant at one percent level. Signatory companies contribute to an average treatment effect of 644.1 ha reduction in soy deforestation in a given municipality. In this case, the SoyM has lessen soy deforestation in the Amazon biome by a maximum amount of 114,005.7 ha (644.1 × 177) per year. The variable $blacklist_{it}$ also reveals a significant result that boost the implication of a strong correlation between the Blacklist and soy deforestation in municipalities included in the program.

Column (5) also produces an average treatment effect of 609.8 ha of decrease in soy deforestation per municipality; this result is statistically significant at 1 percent. This result add up to 107,934.6 ha reduction in soy deforestation per year (609.8× 177).

5.3.3. FIXED EFFECT INCLUSION TEST – F TEST

Following the same principle applied for the first strategy, we perform a series of F tests to prove the existence of unobserved factors and therefore the goodness of the model represented in equation (13) in trying to control for fixed effects. Again, results, presented in Table 5, ensure the presence of invariant factors over time and over municipality and then confirm the reasons to control for fixed effects.

F Test: Second Strategy		
	Soy Deforestation	
Municipality FE	*Year FE*	*Municipality & Year FE*
F(382, 4963) = 6.09	F(13, 4963) = 21.73	F(395, 4963) = 6.62
Prob > F = 0.0000	Prob > F = 0.0000	Prob > F = 0.0000

Table 5: F Test: Second Strategy – Soy Deforestation

5.4. EXTENSION OF THE SECOND STRATEGY: SOY DEFORESTATION

This section proposes an expansion of the second empirical strategy as presented in this chapter; the novelty introduced regards the insertion of an additional independent variable in the original econometric model represented by equation (13).

The new extended model results in equation (14).

$$soy\ def_{it} = e_1 policy\_percentage\_1_{it} + e_2 blacklist_{it} + e_3 policy\_interaction_{it} + z_i + z_{year\#biome} + s_{it} \quad (14)$$

The supplementary explanatory variable $policy\_extention_{it}$ simply derives from the multiplication between two other independent variables respectively $policy\_percentage\_1_{it}$ and $blacklist_{it}$; in other words, an interaction program participation dummy variable that assume the value of $policy\_percentage\_1_{it}$ only if and when a municipality is involved in the Blacklist. The model contains also a year-biome fixed effect ($z_{year\#biome}$), to control for unobserved factors occurring either in the Amazon or Cerrado biome in different years.

Coherently with its construction, in theory the variable $policy\_extention_{it}$ should capture the combined effect on deforestation of the Critical County Program and the SoyM. Therefore, the magnitude of the coefficient e_3 exhibits the level of soy deforestation in municipalities with a double supervision. Consequently, we expect those municipalities to have a higher reduction in level of soy deforestation due to a stronger monitoring.

Table 6 presents estimation results from the extension of the second empirical strategy.

Difference in Differences Estimation: Extended Second Strategy
Dependent Variable: Soy Deforestation

	(1)	(2)
policy_percentage_1	-644.1***	-626.0***
	(131.5)	(136.1)
Blacklist	-492.6***	-466.1***
	(77.5)	(93.1)
Policy_Extension		-126.2
		(245.1)
Constant	405.4***	405.3***
	(41.1)	(41.1)
Observations	5362	5362
R^2	0.085	0.086
F Statistics	16.5	16.0

Standard errors are in parentheses: *p<0.10, **p<0.05, ***p<0.01

Table 6: Difference-in-Differences Estimation: Extended Second Strategy - Soy Deforestation

For completeness, Column (1) presents the model excluding the new interaction variable, as it was represented in column (4) of Table 4, and column (2) exhibits the above-presented enriched model as represented in equation (14).

The attention is immediately focused on the value of the coefficient e_3. Although negative, it does not present a sufficient level of statistical significance, contradicting our initial assumption. Thus, municipalities involved in a double scheme, SoyM through companies and Blacklist though the government, do not reveal a particularly lower reduction level of soy deforestation. Finally, the other three independent variables closely display the same well-known results.

Overall, this intriguing extension of the second empirical strategy do not lead to a solid conclusion on the interaction effect between SoyM and Blacklist but reaffirms the separated goodness of the two programs.

5.5. EVENT STUDY ANALYSIS: SOY DEFORESTATION

To extend and enrich our investigation, we include in the paper an event study analysis for the second empirical strategy, constructed through the equation (15).

$$soy\ deforestation_{it} = \beta_{2003}X_{it}^{2003} + \dots + \beta_{2016}X_{it}^{2016} + u_i + u_{year\#biome} + \gamma_{it} + \varepsilon_{it} \quad (15)$$

The regressors are dummy variables, which confer to municipalities of the Amazon biome the value of the variable $percentage_i$, but only for the respective year and zero for the remaining years. To be clear, for example, the variable X_{it}^{2003} has positive values only for the year 2003 and, subsequently, zero for all the others. Completing the description, municipalities of the Cerrado biome remain as a control group, maintaining the value zero for all the independent variables.

To control for unobserved factors, the model contains also municipality fixed effect (u_i) and year-biome fixed effect ($u_{year\#biome}$); the letter is aimed to capture any shock, occurring over the analysed period, in both the Amazon and the Cerrado biome. Finally, it is inserted a municipality-year fixed effect γ_{it} for the sole municipalities involved in the Blacklist, to control for the Program.

The objective of this study is to examine from a different prospective, employing an alternative empirical method, our original proposal: evaluating the effectiveness of the SoyM in reducing soy deforestation. Coherently with the above-illustrated framework, we expect the coefficients of the independent variables preceding the introduction of the SoyM to be aligned and close to zero; in fact, we take as a reference year (and thus as reference coefficient) 2005, the year preceding the introduction of the moratorium. On the other hand, coefficients from β_{2006} to β_{2016}, referring to the period of activity of the SoyM, are supposed to be negative.

Figure 9 reports the results of the event study analysis for soy deforestation.

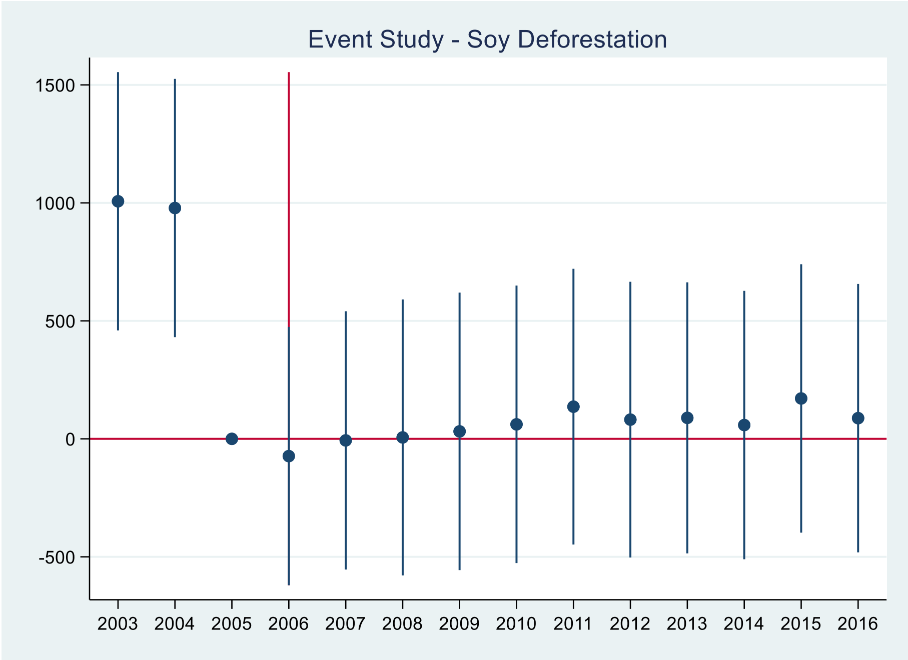

Figure 9: Event Study – Soy Deforestation

Results are not in line with the expectations as the coefficient β_{2005}, referring to the year precedent to the introduction of the moratorium, is aligned with the coefficients referring to years under it adoption, meaning an unexpected effectiveness of the SoyM, one year in advance. However, this phenomenon cannot be attributed to other policies, since we properly controlled for them through the year-biome fixed effect ($u_{year\#biome}$), but possibly to a self-decision of companies to commit themselves in reducing deforestation, even without signing a contract. For this reason, we are not sufficiently confident to state a manifest effectiveness of the SoyM in reducing soy deforestation and to have more support for a conclusion pronouncement, we proceed the investigation analysing, following the same empirical structure, the impact of the moratorium on the level of territorial deforestation.

CHAPTER 6. TERRITORIAL DEFORESTATION

Conscious of the complications emerging from the analysis on soy deforestation, this chapter further investigates the role of the SoyM, through an assessment of its impact on the overall level of deforestation. Adopting for simplicity and clarity the same structure of the previous chapter, we first verify the assumption for performing a DID approach, then we present and comment the outcome of the estimations. The chapter contains as well an extension of the second strategical approach and an event study in support of the results.

6.1. PARALLEL TRENDS ASSUMPTION

This section, as performed for soy deforestation in the previous chapter, presents the fundamental assumption of common trends between the treated and the controlled biomes, in order to have a green light for the execution of empirical estimations for territorial deforestation as well. It is initially illustrated in a graphical analysis and then through a formal test.

6.1.1. GRAPHICAL ASSESSMENT OF TERRITORIAL DEFORESTATION TRENDS

The presence of common trends between the treatment group (Amazon biome) and control group (Cerrado biome) in the period preceding the implementation of the moratorium (2003-2005) is an existential pre-condition to find a causal relationship between SoyM and territorial deforestation. It follows a graphical analysis to confirm this assumption.

Figure 10 presents territorial deforestation, examining the parallel trends assumption.

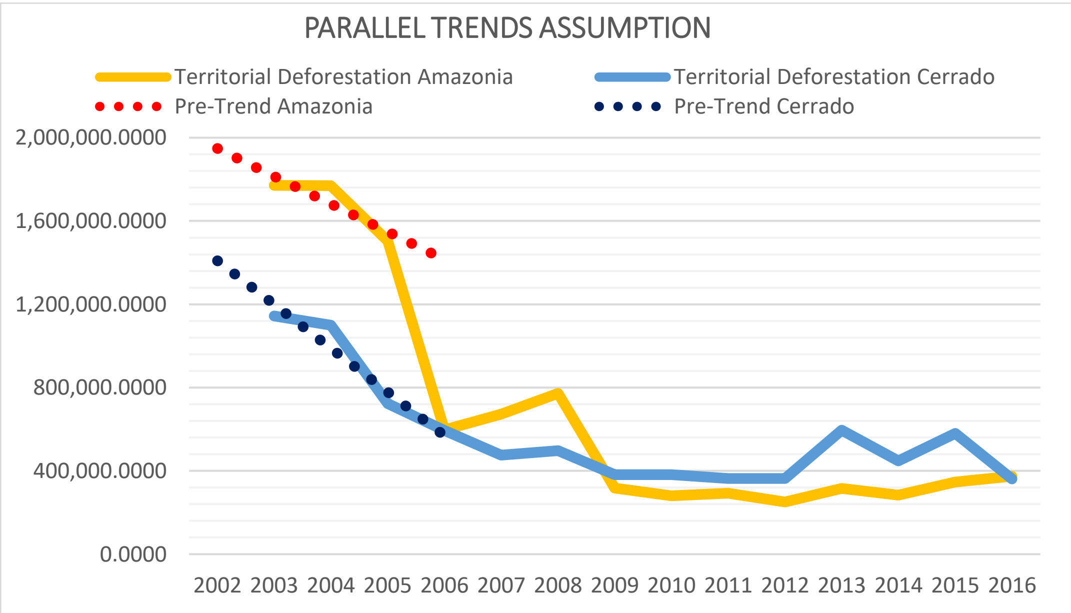

Figure 10: Parallel Trends Assumption – Territorial Deforestation (Source: P-section available in: Trase 2019).

Figure 10 demonstrates how the fundamental assumption is fulfilled for our variable of interest, in this case territorial deforestation, in the period from 2003 to 2005.

6.1.2. EMPIRICAL TEST OF THE PARALLEL TRENDS: TERRITORIAL DEFORESTATION

As we attempt to reflect the impact of SoyM in the overall measure of territorial deforestation through its contribution of lessening soy deforestation, it is important to exam that the pre-treatment trends of observed values of territorial deforestation is correspondent and confirm the parallel trend holds. To analyse the pre-treatment territorial deforestation trend, we construct equation (16).

$$territorial\ deforestation_{it} = \delta_1 + \delta_2(biome_i \times year_t) + \vartheta_i + \vartheta_t + \mu_{it} \quad (16)$$

Where $biome_i$ is a biome dummy variable that is equal to 1 for Amazon biome and 0 for Cerrado biome, $year_t$ is a year dummy variable that observes the change in the territorial deforestation level from 2003 to 2004 and also from 2004 to 2005 and δ_2 is the coefficient of interest, formulated by the interaction term between the $biome_i$ dummy variable and the $year_t$ dummy variable. Besides, in order to calculate the change in the observed values of deforestation variable, we give the years 2003-2005 values of 1-3 accordingly.

Table 7 reports the empirical results following equation (16).

Test for Parallel Trends Assumption

Dependent Variable: Territorial Deforestation

	(1)	(2)	(3)	(4)
Biome_trend	1594.8***	-749.7***	2029.9***	270.0
	(258.0)	(256.0)	(270.7)	(344.2)
Municipality FE	No	Yes	No	Yes
Year FE	No	No	Yes	Yes
Constant	5476.2***	2080.7	6650.5***	803.2
	(379.4)	(2835.3)	(520.5)	(2804.0)
Observations	1152	1152	1152	1152
R^2	0.032	0.85	0.053	0.85
F- Statistics	38.2	11.3	21.4	11.6

Standard errors in parentheses: *p<0.10, **p<0.05, ***p<0.01

Table 7: Test for Parallel Trend Assumption – Territorial Deforestation

A valuable point to discuss is that the test is based under the null hypothesis that $\delta_2 = 0$, meaning that the growth of territorial deforestation was the same in both biomes (parallel trends) and the alternative hypothesis is $\delta_2 \neq 0$ which rejects the null hypothesis of parallel trends assumption. In reference to Table 7, column (4) presents equation (16) in which both municipality and year fixed effects are controlled properly. The results convey that the coefficient of interest (δ_2) turns out to be insignificant and guarantees that the parallel trends assumption holds in this matter.

6.2. EMPIRICAL RESULTS OF TERRITORIAL DEFORESTATION: SECOND STRATEGY

As stated in Chapter 5, the first strategical approach resulted to be enabled to capture the effective impact of the SoyM; for this reason, the empirical analysis on territorial deforestation is performed only through the second strategy. In addition, to properly control for the effect of other policies or events occurring in the Amazon or Cerrado biome, the model contains a year-biome fixed effect; in this manner, the impact of the SoyM would result purified from other phenomena and thus unbiased.

6.2.1. MODEL

The equation (17) represents the consequent model to estimate:

$$territorial\ deforestation_{it} = \kappa_1 policy\_percentage\ \_1_{it} + \kappa_2 blacklist_{it} + \tau_i + \tau_{year\#biome} + \eta_{it} \quad (17)$$

Where the independent variable $territorial\ deforestation_{it}$ represents the level of territorial deforestation in hectares for each municipality for each year and the parameter $\tau_{year\#biome}$ represents the year-biome fixed effect. The coefficient of interest κ_1 exhibits the yearly average treatment effect of SoyM on territorial deforestation in municipalities of the Amazon biome, after its launching in 2006, while κ_2 indicates how the Critical County Program and territorial deforestation are correlated.

6.2.2. ESTIMATION

Table 8 presents results of the second strategy employed for territorial deforestation.

Difference-in-Differences Estimation: Second Strategy *Dependent Variable: Territorial Deforestation*		
	(1)	(2)
policy_percentage_1	-3192.6*** (596.8)	-4009.3*** (580.2)
policy_percentage_2		
Blacklist	-8828.5*** (352.0)	
Constant	5613.9*** (186.8)	5565.7*** (175.8)
Observations	5362	5362
R^2	0.36	0.47
F Statistics	98.4	12.8
Standard errors in parentheses: *p<0.10, **p<0.05, ***p<0.01		

Table 8: Difference-in-Differences Estimation: Second Strategy - Territorial Deforestation

Column (1) presents the estimations of the model represented in the above equation (17). The coefficient of interest κ_1 of the variable $policy\_percentage\ \_1_{it}$ is negative and statistically significant at 1%, signalling an annual reduction in territorial deforestation up to 3,192.6 ha, in every municipality of the Amazon biome, after 2006. The other coefficient of interest κ_2 of the variable $blacklist_{it}$ is negative and statistically significant at 1% as well, indicating an overall effectiveness of the environmental policy in reducing territorial deforestation.

Column (2) differs from column (1) for the modality on how the Critical County Program is considered; in particular, we exclude the variable $blacklist_{it}$ and introduce a municipality-year FE for blacklisted municipalities. Even in this case, the coefficient of the variable $policy\_percentage\ \_1_{it}$ exhibits a statistically significant and negative value, a maximum decrease of 4009.3 ha of territorial deforestation from 2006 onwards, in each year and in each Amazon municipality. In this second estimation, the coefficient κ_1 is slightly higher, highlighting that the impact of SoyM was on average more pronounced in municipalities not involved in the Critical County Program.

Overall, from both estimations clearly emerges an evident effectiveness of the SoyM in shirking the whole forest clearing; to give a concrete idea, multiplying the coefficient κ_1 from column (1) for the number of municipalities in the Amazon biome (3,192.6 ha ×177), the moratorium had an impact in reducing territorial deforestation of a maximum 565,090.2 ha every year from its implementation.

6.2.3. FIXED EFFECT INCLUSION TEST – F TEST

For the estimation illustrated in equation (17) we perform an F test to verify the presence of unobserved (municipality specific and year-biome specific) factors. The objective is to confirm the necessity to insert fixed effects on our model and thus we conduct three F tests: for municipality FE, for year-biome FE and the last for municipality and year-biome FE together. Results, presented in Table 9, are straightforward: time-biome and/or individual invariant factors are present and therefore we need to control for them.

F Test: Second Strategy		
	Territorial Deforestation	
Municipality FE	*Year#Biome FE*	*Municipality & Year#Biome FE*
F(382, 4951) = 18.69	F(26, 4951) = 40.78	F(408, 4951) = 22.22
Prob > F = 0.0000	Prob > F = 0.0000	Prob > F = 0.0000

Table 9: F Test: Second Strategy - Territorial Deforestation

6.3. EXTENSION OF THE SECOND STRATEGY:TERRITORIAL DEFORESTATION

Following the same principle utilized for soy deforestation, we propose an equivalent extension of the second strategical approach for territorial deforestation as well. Again, the innovative aspect lies in the introduction of a supplementary independent variable, aimed at capturing the combined effect of the SoyM and the Blacklist, as represented in the equation (18).

$$territorial\ def_{it} = q_1 policy\_percentage\ \_1_{it} + q_2 blacklist_{it} + q_3 policy\_interaction_{it} + k_i + k_{year\#biome} + v_{it} \quad (18)$$

The additional control variable $policy\_extention_{it}$ exhibits the same features described in the previous chapter: it results from the multiplication between $policy\_percentage\ \_1_{it}$ and $blacklist_{it}$. Even for this estimation, we include a year-biome FE ($k_{year\#biome}$) with usual role of capturing annual and biome specific disturbances.

In line with the design of the model, the compounded effect of the SoyM and the Blacklist on territorial deforestation should be captured through the variable $policy\_interaction_{it}$ and exhibited by the coefficient of interest q_3, which is expected to be negative since in those municipalities act two environmental policies and thus an higher level of monitoring.

Table 10 illustrates the results of the extended second strategy for territorial deforestation.

Difference-in-Differences Estimation: Extended Second Strategy *Dependent Variable: Territorial Deforestation*		
	(1)	(2)
policy_percentage_1	-3192.6***	-3921.6***
	(596.8)	(616.5)
Blacklist	-8828.5***	-9895.9***
	(352.0)	(421.5)
Policy_Extension		5086.2***
		(1110.5)
Constant	5613.9***	5619.5***
	(186.8)	(186.4)
Observations	5362	5362
R^2	0.36	0.36
F Statistics	98.4	96.1
Standard errors are in parentheses: *p<0.10, **p<0.05, ***p<0.01		

Table 10: Difference-in-Differences Estimation: Extended Second Strategy – Territorial Deforestation

Column (1) presents the same estimation as in column (1) of Table 8, controlling the Critical County Program through the variable $blacklist_{it}$ and excluding the novel interaction variable; on the other, column (2) presents the estimation of the complete above equation (18). The coefficient q_1 of the variable $policy\_percentage\_1_{it}$ still exhibits a strong statistical significance and remains close to the precedent value: in every municipality of the Amazon biome from 2006 to 2016, the SoyM could reduce the territorial deforestation up to 3,921.6 ha. Likewise, the coefficient q_2 of the variable $blacklist_{it}$ confirms an overall negative impact of the Critical County Program on the level of territorial deforestation. On the other hand, the coefficient q_3 of the variable $policy\_interaction_{it}$ exhibits a surprising result, turning to be positive.

Therefore, the SoyM and the Blacklist confirm their individual effectiveness in reducing territorial deforestation; however, a possible explanation of last counter-intuitive outcome is that, in municipalities simultaneously involved in both policies and thus under an intense monitoring for soy deforestation, there could be a leakage in terms of other types of deforestations. In other words, the moratorium and the Critical County Program, if implemented together in a municipality, could lead to a smaller reduction of the territorial deforestation due to an increase in the level of deforestation different from soy.

Overall, from the equivalent section of the previous chapter we discovered how a double monitoring does not further positively affect the reduction in the level of soy deforestation, while from this extension section we found a potential negative impact of a combination between SoyM and Blacklist for the decrease of territorial deforestation.

6.4. EVENT STUDY ANALYSIS: TERRITORIAL DEFORESTATION

With the same purpose of complement and reinforce the empirical analysis, we perform an event study for territorial deforestation as well, constructed as follows.

$$territorial\ deforestation_{it} = \alpha_{2003}X_{it}^{2003} + \ \dots \ + \alpha_{2016}X_{it}^{2016} + \epsilon_i + \epsilon_{year\#biome} + \varphi_{it} + \ \omega_{it} \quad (19)$$

The model's framework reproduces the same employed for soy deforestation: independent variables are dummy variables, which confer to municipalities of the Amazon biome the value of the variable $percentage_i$, but only for the respective year and zero for the remaining years. On the other hand, municipalities of the Cerrado biome remain as a control group, maintaining the value zero for all the independent variables.

The inclusion of a year-biome FE ($\epsilon_{year\#biome}$) is aimed to remove from the estimation the frequently mentioned unobservable events occurring in the two biomes over the study period, while the specific municipality-year fixed effect φ_{it} controls for municipalities involves in the Critical County Program.

Using this different empirical approach, the purpose of the investigation is to have additional support in claiming the effectiveness of the SoyM in reducing territorial deforestation. Therefore, in line with the described design, we expect an alignment close to zero of the coefficients of the first three independent variable ($\alpha_{2003}, \alpha_{2004}$ and α_{2005}), since the year preceding the introduction of the moratorium (2005) is adopted as a reference; on the contrary, coefficient from α_{2006} to α_{2016}, linked to treated years, are prevised to be negative.

Figure 11 reports the results of the event study analysis for soy deforestation.

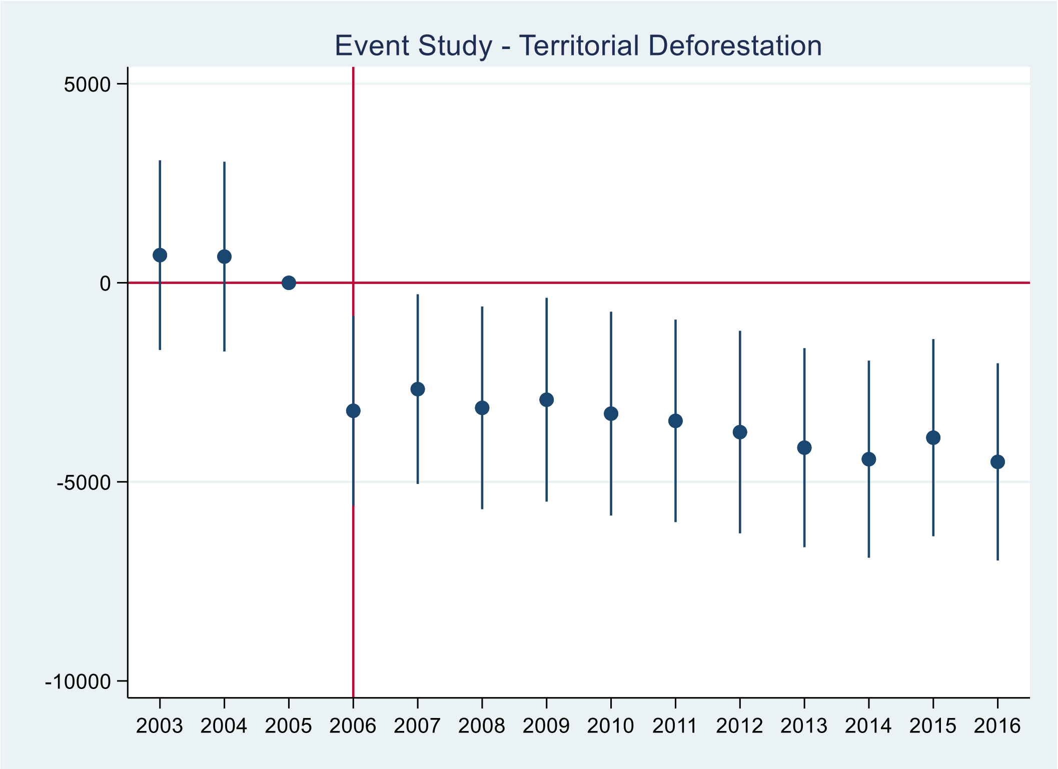

Figure 11: Event Study – Territorial Deforestation

Differently from soy deforestation, the outcome corresponds to the expectations, since now coefficients of variables referring to years before the introduction of the SoyM are aligned close to zero. Therefore, results clearly highlight how the moratorium contributed to decrease territorial deforestation from 2006 onwards, coherently with the year of its launching; thus, during the period 2003-2005, the SoyM had a null or negligible role in diminishing forest clearing, in line with its non-existence.

Therefore, the unexpected reduction in 2005, as reported in the previous event study analysis for soy deforestation in section 5.5., disappears for territorial deforestation. Consequently, we have a validation on how the SoyM begun to be efficacious after 2006, as predicted; thus, we are now able to amend the previous uncertain statement on the success of the moratorium. In fact, the evidence from this event study allows us to argue more confidently that the SoyM, after all, was effective in reducing deforestation; hence, the earlier drop in soy deforestation in 2005 (as presented in Figure 9) could only be ascribed to a private decision of companies and it does not have anything to do with the moratorium.

CHAPTER 7. DISCUSSION OF EMPIRICAL RESULTS

This chapter is constructed to recapitulate our findings on the causal relationship between soy moratorium and soy deforestation and reflect up on corresponding papers studied by other researchers.

Referring to previous Chapter 5 and Chapter 6, we present a comprehensive pronouncement of the moratorium effect in lessening soy deforestation and territorial deforestation, post the inception period of 2006. The average treatment effects in decreasing soy deforestation and territorial deforestation per year are roughly 106,000 ha and 565,000 ha, respectively.

These findings mutually correspond to several papers that claimed SoyM had a positive reduction effect in diminishing soy deforestation (Assunção et al. 2012, Gibbs et al. 2015, Kastens et al. 2017).

Gibbs et al. (2015) outlined that the inception of SoyM in 2006 contributed to a successful decline of soy deforestation and only a small portion of soy production occured in newly deforested areas. Soy farmers, under the SoyM scheme, are five times less likely to violate the contract, compared to legal enforcements, to mention the Forest Code.

Moreover, Kastens et al. (2017) also conceded with our findings of SoyM effect. Their study summarizes that the policy has pressured in eliminating the use of newly deforested areas for soy bean production and comparatively post-SoyM deforestation rate scored five times smaller than of pre-SoyM deforestation rate; forest-to-soy conversion was twice in pre-SoyM than in the post SoyM period which is an identical findings to Gibbs et al. (2015).

Another homogenous paper is of Assunção et al. (2012), which finds a strong contribution of the SoyM to a sizeable diminishing of soy deforestation rate and therefore stopping far forest clearings. Specifically, the paper highlighted that changes to conservative policies between 2004 and 2008 had a significant hand out to the curbing of newly deforested areas.

Another fascinating discover of our thesis is the empirical finding resulting from section 5.3.2: non-signatory companies contributed to a significant, at 5 percent level, increase of soy deforestation post-SoyM period. In that sense, we could carefully assume that there was a counter-effect contribution of increasing soy deforestation stemmed from those non-signatory companies because the empirical result, following reliable data, produced a positive and significant coefficient. In other words, related non-signatory companies have increased soy deforestation post-SoyM period.

A closer attention to the magnitude, in absolute value, of the first two coefficients of interest (ϕ_1 and ϕ_2) from Column (2) and Column (3) of Table 4 underlines that the contribution in decreasing soy deforestation by signatory companies is higher compared to an increase by the non-signatory companies.

According to a paper by Dros (2004), which is also supported by the Greenpeace report (2006), Archer Daniels Midland (ADM), Bunge, Cargill and Louis Dreyfus (signatory companies) accounted for about 60% total financing of the soy production in Brazil. Furthermore, these international giant companies control 80% of soy crushing capacity in Europe, providing soya meal products as well as oil to the animal feed market. This factual overview of these signatory companies' financial summary gives a hint about the non-signatory company limitations in terms of access to the market or, in other words, being dominated in the soy production operation.

Hence, careful presumption follows: non-signatory companies might lack the opportunity to increase the land use and thus soy production in newly deforested areas to take advantage of the moratorium freedom. However, they could not actively employ this strategy if they have limited access to the export market, scarcity of economic strength (market power), and subsequently an inadequate possibility to produce more and export the commodity. With this perception, the increase of soy deforestation by non-signatory companies is comparatively less than the decrease contribution of the signatory companies.

With this in mind, another important beneficial aspect to discuss follows Nepstad et al. (2014) division of the Brazilian deforestation, which was briefly discussed in section 3.2.1. More specifically, during the Frontier Governance phase, in which several and mutually aimed law enforcements were put in force, the demand for new deforestation decreased, the risk associated with undesignated clearing of forest land increased and deforestation became a riskier venture to expand soy production. Overall, embargoes and related fines imposed on illegal deforestation might also restricted non-signatory companies from contributing expected higher level of soy deforestation.

Moreover, the variable $blacklist_{it}$ presented a strong negative value that is statistically significant at 1 percent. This empirical result reaffirms the strong correlation that exists between soy deforestation and the Critical County Program. We can carefully assume that both policies jointly attributed to a significant reduction of soy deforestation.

Cisneros et al. (2015) conducted a quasi-experimental evaluation study in regard to the contribution of municipality blacklisting and concluded that the anti-deforestation campaign has preserved a forest cover that corresponds to an equal average annual forest loss at the time of study. In 2014, the INPE statistics reported an average annual deforestation rate score of 4,828 km^2 in 2014 and above-mentioned study conducted at the same time period corresponded to an average reduction of soy deforestation ranging from 600 – 6,750 km^2, which on average amounts to 4,022 km^2 per municipality per year from 2008 to 2012.

In section 2.5.2, we briefly mentioned the consequence for a municipality of being recorded in the Blacklist: an immediate suspension of access to the credit line within the aspect of the agricultural market (Nepstad et al. 2014).

Assunção et al (2013) conducted a study research to investigate the impact of credit constraints and how such variation in access to credit market in different municipality, affects deforestation. Their final comments in the paper outline that the novelty of the credit policy assisted in restraining deforestation in the Amazon biome and such defined policy plays a significant role in avoiding potential adverse rebound effects of soy deforestation.

In conclusion, empirical results emerging in this thesis, regarding both the efficacy of the SoyM and the Blacklist, are in line with several findings from previous academic researches.

CHAPTER 8. ROBUSTNESS

In this chapter, we conduct a precautionary inspection to verify the robustness of the second empirical strategy and its extension, providing estimates with standard errors robust to heteroscedasticity. As the strongest support in favour of the effectiveness of the SoyM derived from territorial deforestation, we decide to perform such type of additional investigation limited to this dependent variable. This safety control contemplates a possible violation of the homoscedasticity assumption attributed to the idiosyncratic error; in other words, the case in which the remained stochastic disturbance is not "independent and identically distributed". Even though the econometric model contains both year-biome FE and municipality FE, to control for constant factors over time and place, the presence of dependent errors (serial correlated or spatial correlated) is still a possible challenge to face. To overcome this problematic, we implement a two-way clustering method to calculate standard errors that are robust to simultaneous correlation across two dimensions, specifically year and municipality. We were able to perform this procedure on Stata thanks to the contribution of Correia (2017), who provided a command (`reghdfe`) that allows for intragroup correlation.

Table 11 presents results including robust standard errors for the second strategy referring to territorial deforestation and reflecting Table 8 of Chapter 6.

Difference-in-Differences Estimation: Robust Second Strategy
Dependent Variable: Territorial Deforestation

	(1)	(2)
policy_percentage_1	-3192.6**	-4009.3***
	(1312.3)	(1332.4)
policy_percentage_2		
Blacklist	-8828.5***	
	(756.4)	
Constant	3952.2***	4075.4***
	(105.1)	(108.1)
Observations	5362	5362
R^2	0.65	0.71
F Statistics	76.6	.

Standard errors in parentheses: *p<0.10, **p<0.05, ***P<0.01

Table 11: Difference-in-Differences Estimation: Robust Second Strategy – Territorial Deforestation

Table 12 presents results including robust standard errors for the extended second strategy referring to territorial deforestation and reflecting Table 10 of Chapter 6.

Difference-in-Differences Estimation: Robust Extended Second Strategy *Dependent Variable: Territorial Deforestation*		
	(1)	(2)
policy_percentage_1	-3192.6**	-3921.6***
	(1312.3)	(1305.4)
Blacklist	-8828.5***	-9895.9***
	(756.4)	(936.7)
Policy_Extension		5086.2**
		(2221.8)
Constant	3952.2***	3999.1***
	(105.1)	(108.1)
Observations	5362	5362
R^2	0.65	0.65
F Statistics	76.6	51.7
Standard errors are in parentheses: *p<0.10, **p<0.05, ***p<0.01		

Table 12: Difference-in-Differences Estimation: Robust Extended Second Strategy – Territorial Deforestation

Robust results from both tables confirm the statistical significance of all coefficients of interest, highlighting how the estimations maintain theirs validity and causal meaning, even in the case of violation of the homoscedasticity assumption.

In conclusion, even after allowing for the presence of heteroscedasticity in the idiosyncratic error, such as correlation across municipalities and years, results of the second strategy, both normal and extended, guarantee the goodness of out empirical framework.

CHAPTER 9. PROBLEM ENCOUNTERED AND POSSIBLE EXTENSION

The scope of this chapter is to underline problems faced during the writing of the thesis as well as to suggest a possible different way to continue the evaluation of the SoyM and its related deforestation issue.

An important remark to highlight is that, to properly assess the SoyM, given its peculiar characteristics, it is extremely important owing reliable data regarding the level of deforestation (both soy and territorial) and, particularly, the individual contribution of signatory and non-signatory companies. However, it is evidently complex to obtain such information, considered both practical reasons and its delicate nature: it is understandable that companies do not gladly publicize how much they are responsible for deforestation. Nevertheless, we overcame this complication through the second empirical strategy, as presented above, employing data of soy deforestation at municipality level, which remain applicable to pursue our objective, in conjunction with data of soy production – in 2003 in the Amazon biome – adequately subdivided between the two company categories.

A possible further extension of the analysis could be conducted considering as dependent variable the ratio of deforestation – for each municipality in each year – to the respective total administrative territory and therefore abandoning the level of deforestation, adopted in this thesis. Naturally, both quantities should be computed with the same unit of measurement, hectares or square meters for example. The advantage of this different approach could derive from dealing with relative quantities, then allowing a simpler and more precise comparison among municipalities and biomes. Furthermore, it would be possible to solve the problem of comparing a similar number of treated and controlled municipalities and therefore extending the dataset to the entire number of municipalities from Cerrado or other biomes as well.

CHAPTER 10. CONCLUSION

This paper analysed the establishment motivations of the Soy Moratorium in 2006 and its subsequent causal impact in lessening soy and territorial deforestation in the Amazon biome; in addition, it analysed the impact of another environmental policy, the Critical County Program, on the same variables of interest. To conduct a thorough investigation, we explored a total of 383 municipalities, divided in 177 and 206 municipalities from the Amazon and Cerrado biome respectively.

Over a studying period from 2003 to 2016, we have executed a difference in differences empirical evaluation to ascertain if the decline in the level of soy and territorial deforestation from 2006 to 2016 succeeded the presence of the SoyM and the municipality blacklisting occurrence. We constructed two empirical approaches to test the causal relationship between SoyM and deforestation, including the Blacklist as well. The first strategy did not splendid out the true effect of the SoyM, because that approach merely attempted to take advantage from the exogenous effect. In fact, the Amazon biome was entirely considered as a treatment group, ignoring a peculiar characteristic of the moratorium, such as being a voluntary agreement, individually signed by each company and thus not valid *erga omnes*. The second approach, however, properly contemplated the effective attributes of the moratorium, introducing the crucial company private choice; consequently, results magnified a substantial causal impact of SoyM in deforestation reduction. Finally, both strategies highlighted a fundamental role of the Blacklist in obtaining a decrease in the level of soy and territorial deforestation.

More specifically, empirical results indicate that the SoyM implied a maximum annual reduction, in the period 2006-2016, approximately equal to 106,000 ha for soy deforestation and 565,000 ha for territorial deforestation. In addition, the second strategy (when applied for soy deforestation) also evaluated the behaviour of non-signatory companies during the post-SoyM momentum, especially their tendencies to exploit the freedom circumstance. The findings clearly propose that non-signatory companies could have caused an annual increase in the level of soy deforestation post-SoyM roughly up to 22,000 ha.

A supplementary investigation of the study analysis was focused on municipalities facing both the SoyM and the Blacklist, aimed to discover a possible benefit from an higher supervision. In those double-monitored municipalities, the reduction in the level of soy deforestation did not result more pronounced, indicating the absence of a positive effect from stricter vigilance; differently, the decrease in territorial deforestation occurred to be lower than in other “ordinary” municipalities, signalling a negative effect of double monitoring. A plausible explanation of this surprising outcome is that a stronger pressure on soy deforestation controls led to a leakage in other types of deforestation, thus shrinking the overall reducing impact.

For robustness affirmation, the last part of the paper mannerly performed estimations introducing standard errors robust to heteroscedasticity, chiefly aimed to crown of credibility the investigated programs. This examination determines the accuracy of the empirical strategies of this thesis: the meaningful and the unbiasedness of the coefficients of interest.

All in all, this thesis exhaustively responded to the above-stated research question, underling how both SoyM signatory companies and the Critical Country Program greatly contributed to honourable pursue of lessening soy deforestation and territorial deforestation. At the same time, as soy production still leads to some deforestation, the issue is not completely resolved; however, this paper exhibited at least two different measures, whose implementation ensured an extraordinary effect and thus how fight to the very end this problem.

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APPENDIX:

A1: List of Variables

Abbreviation	Description	Unit	Time Variant
year	Period analysed, from 2003 to 2016.	-	Yes
biome_name	Name of the Biome to which each municipality belongs.	-	No
state	Name of the State to which each municipality belongs.	-	No
municipality	Name of the municipality.	-	No
territorial_deforestation	Level of territorial deforestation in each municipality each year.	Ha	Yes
soy_deforestation	Level of soy deforestation in each municipality each year.	Ha	Yes
soym	Time dummy variable of both empirical strategies.	-	No
biome	Treatment dummy variable of the first empirical strategy.	-	No
percentage	First treatment dummy variable of the second empirical strategy.	-	No
1 – percentage	Second treatment dummy variable of the second empirical strategy.	-	No
policy_biome	Independent variable of the first empirical strategy.	-	No
policy_percentage_1	First independent variable of the second empirical strategy.	-	No
policy_percentage_2	Second independent variable of the second empirical strategy.	-	No
blacklist	Independent variable in both strategies.	-	No
policy_extention	Independent variable in the extended second empirical strategy.	-	No

A2: List of Figures

A3: List of Tables

A4: List of municipalities involved in the Critical County Program

The 39 municipalities present in our dataset and included in the analysis are reported in bold.

Municipality	*Entering*	*Exiting*	*Municipality*	*Entering*	*Exiting*
Alta Floresta	2008	2012	**Santana Do Araguaia**	2008	2012
Altamira	2008	-	**São Félix Do Araguaia**	2008	2017
Aripuanã	2008	-	São Félix Do Xingu	2008	-
Brasil Novo	2008	2013	**Ulianópolis**	2008	2012
Brasnorte	2008	2013	**Vila Rica**	2008	2017
Colniza	2008	-	**Amarante Do Maranhão**	2009	-
Confresa	2008	2017	**Feliz Natal**	2009	2013
Cotriguaçu	2008	-	Itupiranga	2009	-
Cumaru Do Norte	2008	-	**Juara**	2009	-
Dom Eliseu	2008	2012	**Marabá**	2009	-
Gaúcha Do Norte	2008	-	**Mucajaí**	2009	-
Juína	2008	-	Pacajá	2009	-
Lábrea	2008	-	**Tailândia**	2009	2013
Machadinho D'oeste	2008	-	**Alto Boa Vista**	2011	2017
Marcelândia	2008	2013	Boca Do Acre	2011	-
Nova Bandeirantes	2008	-	**Cláudia**	2011	2017
Nova Mamoré	2008	-	**Grajaú**	2011	-
Nova Maringá	2008	-	Moju	2011	-
Nova Ubiratã	2008	2017	**Santa Carmem**	2011	2017
Novo Progresso	2008	-	**Tapurah**	2011	2017
Novo Repartimento	2008	-	Anapu	2012	-
Paragominas	2008	2010	Senador José Porfírio	2012	-
Paranaíta	2008	-	Apuí	2017	-
Peixoto De Azevedo	2008	-	Buritis	2017	-
Pimenta Bueno	2008	-	Candeias Do Jamari	2017	-
Porto Dos Gaúchos	2008	2017	Cujubim	2017	-
Porto Velho	2008	-	Itaituba	2017	-
Querência	2008	2011	Manicoré	2017	-
Rondon Do Pará	2008	-	Novo Aripuanã	2017	-
Santa Maria Das Barreiras	2008	2017	Portel	2017	-

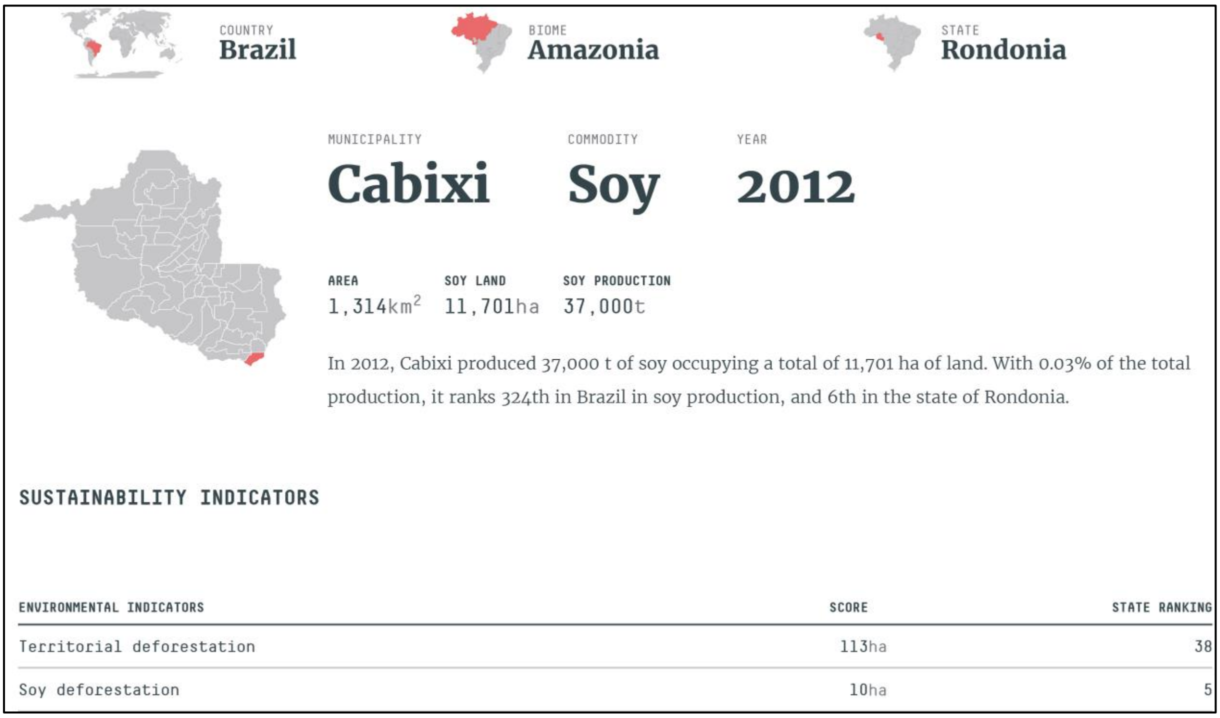
A5: The Case of Municipality Cabixi

A brief example of the discrepancy can be shown in the case of municipality Cabixi. Figure 12 exhibits a direct report of embedded factors related to the soy production in a given year (2012 and 2013). In that case, the P-section reports a precise level of land use, soy production, territorial deforestation and soy deforestation. The E-file, on the other hand, calculates soy deforestation and territorial deforestation in 2012, based on the soy production that they can allocate to known traders in 2013. The reason behind such lagged correlation is because plantation and subsequent export of soy takes at least one year and therefore soy deforestation and territorial deforestation in 2012 can be approximated based on the soy land use and soy production.

To describe more clearly, 43,500 tonnes of soy were produced in 2013, of which Trase were only able to allocate 38,064 tonnes, which is about 87% of total real production. Therefore, E-file only reported about 87% of the P-section that precisely recorded soy deforestation, land use and territorial deforestation in 2012. Consequently, E-file recorded respectively: not 10 ha but $0.87 \times 10 \approx 8.7$ ha, not 11,700 ha but $0.87 \times 11{,}700 \approx 10{,}238$ ha, and not 113 ha but $113 \times 0.87 \approx 98$ ha.

Furthermore, Trase in the E-file allocated adjusted 98 hectares to companies based on their proportion of their production level. For instance, as Bungee accounted for about 15% of the known tons exported ($5{,}479$ ha $\approx 0.15 \times 38{,}064$), therefore Bungee is directly responsible for an equivalent 15% of the recorded 98 ha of territorial deforestation (14 ha $\approx 0.15 \times 98$), 15% of the recorded soy deforestation (1.26 ha $\approx 0.15 \times 8.74$) and 15% of land use (1,472 ha $\approx 0.15 \times 10{,}238$).

Figure 12 presents the Profile section of Cabixi municipality available in [Trase 2019](#).



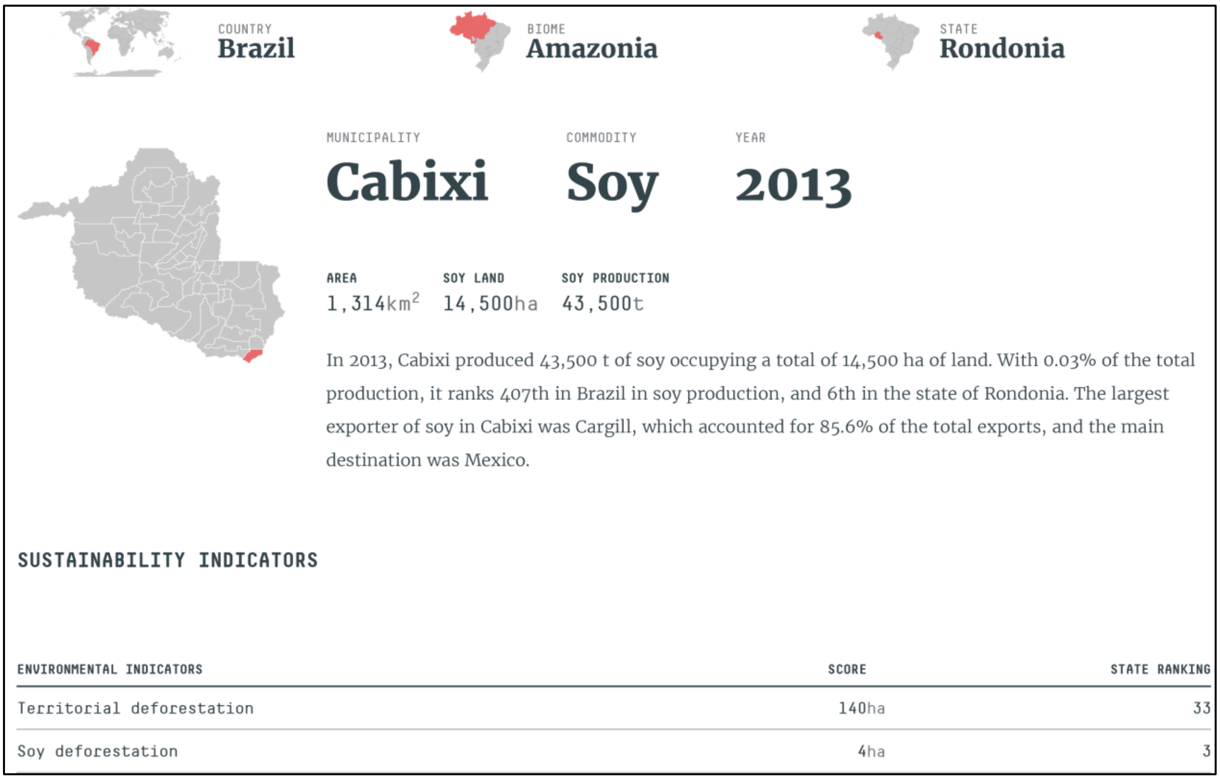


Figure 12: Example Municipality Cabixi (Source: [Trase 2019](#)).