MAGKS

Joint Discussion Paper
Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 01-2019

Julika Herzberg

Protection and Profit: Empirical Evidence of Governmental and Market-based Forest Policies

Coordination: Bernd Hayo • Philipps-University Marburg
School of Business and Economics • Universitätsstraße 24, D-35032 Marburg
Tel: +49-6421-2823091, Fax: +49-6421-2823088, e-mail: hayo@wiwi.uni-marburg.de

Protection and Profit: Empirical Evidence of Governmental and Market–based Forest Policies

Julika Herzberg

January 5, 2019

Abstract

In this paper, I study the effectiveness of privately managed FSC certified forests and public sustainability reserves distributed over the entire Brazilian Amazon from 2002-2015. The paper uses high-resolution data on forest cover derived from satellite images and organized in a grid of 1 km^2 cells. Using a difference-in-differences estimator in a regression discontinuity environment, I find an increase in deforestation of an annual area of 8,057 ha in FSC forests after the certification. Public sustainability zones' impact on deforestation is also positive but declines over time. The effectiveness of both type of zones improves if they are located closer to (export) markets or existing infrastructure.

JEL-codes: J43, O13, O14, Q15, Q17

Keywords: deforestation, commodity prices, sustainable forest management

1 Introduction

Tropical forestlands are gaining increasing attention due to their various beneficial characteristics, especially the manifold environmental aspects associated with forests such as biodiversity, water regulation or sequestering carbon. However, economic development close to forests is often related to environmental damage and illegal deforestation due to the extension of agriculture, mining and infrastructural projects. Conservation policies face the challenge of simultaneously achieving deforestation reduction and poverty alleviation. Moreover, local forest policies are at risk of leakage since in large forest areas deforestation activities could be shifted to other spots which are less monitored. One integrative solution is seen in Sustainable Forest Management (SFM), which is a concept involving social, economic and environmental principles in the management of forest resources. The implementation of this concept could be politically or economically motivated. While the former is realized by governmental control and management support, the latter is voluntarily adapted by firms or communities, often motivated by an expected pay-off on environmental-conscious markets. The empirical literature provides quite mixed results on the effectiveness of both governmental and private, certified SFM projects. [1] However, to the best of my knowledge, a comparison between the two, based on a geo-referenced panel data analysis, has not been studied before.

This paper argues that for the identification of the effects of such conservation projects, various aspects such as spatial and temporal trends have to be taken into account. I provide evidence on how these parameters influence the policy outcome of the SFM zones and furthermore consider geographical heterogeneity and economic incentives by using international commodity prices. To do so, a data set is used consisting of 70 governmental and private-run sustainable-use zones distributed over the entire Brazilian Amazon from 2002-2015. As public zones[2] I consider extractive reserves (*Reservas Extravistas, RESEX*), which are implemented as part of the Brazilian conservation policy. These public reserves are dedicated to traditional populations, who generate a basic income mainly from small agriculture and the extraction of non-timber forest products (NTFP).
As private zones, certified forest management units are studied, which have to comply to sustainability standards prescribed by the Forest Stewardship Council (FSC)[3] in order

[1]See on the success of sustainable forest management among others: Bacha and Rodriguez (2007); Blackman (2015); Rico et al. (2018).

[2]For the sake of simplicity "public zone" will be used for extractive reserves reserves and "private zone" for describing FSC certified forests. However, this should not disguise the fact that not all FSC zones are private properties but are also managed by local communities. Table A.2 gives an overview of the tenure of the FSC certified zones.

[3]Competing systems of forest certification exist. Some are industry driven (e.g. PEFC) or state organized (e.g. Malaysian Timber Certification Council, CFLOR), others are developed by NGOs (e.g.

to pass a regular third-party audit. Promoted as a non-regulatory conservation tool, forest certification marks forest products extracted in a sustainable manner. The label provides information to conscious consumers about the compliance of the company to certain management standards that guarantee the preservation of the forest.

Existing studies on the production side of FSC zones are often limited to specific cases (Rockwell et al., 2007; Kalonga et al., 2016; Rico et al., 2018) or based on qualitative data (Ulybina and Fennell, 2013; Araujo et al., 2009). Studies implementing a quasi-experimental approach are e.g. Nordn et al. (2016), considering forest certification in Sweden, and Blackman et al. (2018), studying the outcomes of FSC certified areas in Mexico. Both studies use a propensity score matching method and both find very small or insignificant effects of certificated zones on deforestation. In this paper I argue that propensity score matching has a number of shortcomings which impede the estimation of the total effect. Since the control group is formed by units of forests distributed all over the country and matched by a limited number of covariates, propensity score matching is quite weak in capturing local effects such as spillovers to areas close to the certified forest units.

In contrast to strictly protected conservation zones, sustainable-use zones are affected by human activity and are by definition part of the economic system in the region. Therefore, it is essential to take local heterogeneity, time and market trends as well as spillover effects into account to evaluate their effectiveness in reducing deforestation.

This paper uses a novel geo-referenced panel data set for FSC zones in the Brazilian Amazon. For the empirical estimation, I use two variants of a difference-in-differences method in a regression discontinuity environment. The advantage of this approach is that it deals with the non-randomness nature of the treatment and that it accounts for direct and indirect spillovers on adjacent forests. Additionally, I offer a conceptual framework which highlights theoretical mechanisms of localization, institutional ownership and economic incentives of sustainable-use forests on the variable of interest i.e. the deforestation rate. The results provide evidence that certification of private zones significantly increases deforestation in the certified forest, which leads to additional 8,057 ha per year deforested area. The time trend model shows that this increase in deforestation rates is especially high in the first 5 years after the certification date and that around 3-4 years before the main audit deforestation rates decline sharply. This result is robust to all specifications in this study. Accounting for local heterogeneity reveals that the increase in deforestation rates is driven by FSC zones located further away from markets and infrastructure. Moreover, I find evidence that under high timber prices the deforestation on the surrounding areas decreases.

FSC). The FSC label is the best known label (on the consumer side) and is present in over 80 countries. Comparing the FSC and PEFC system reveals that FSC has stricter rules on banning pesticides and on the introduction of exotic species (Rametsteiner and Simula, 2003)

Regarding the public zones, deforestation increase as well but at a lower rate. The spatial estimations do not show a significant treatment effect at the border of the zone and suggest that in the long term trend deforestation rates decrease. Higher prices for non-timber forest products further reduces deforestation activities in this extractive reserves. The results allow to draw several conclusions. First, whether the zone is governmental or privately established, its location plays an important role. If a SFM zone is established where the forest industry has not arrived yet, its implementation could open up access into intact forest lands which might finally increase overall deforestation. Second, private sustainable forest management organizations such as the FSC should ensure that firms do not increase deforestation after the successful certification and that financial incentives do not overlap envriomental principles. Finally, governments are supposed to take overall effects on the region into account and could increase the effectiveness of extractive reserves by supporting the production of non-timber forest products.

The paper contributes to the literature in several ways. While there exists a range of studies examining the acceptance of ecolabels on the consumer side [4], evidence on the producer side is very thin. One reason for this is the lack of available data on FSC certified zones which incorporate time and spatial dimensions. This paper helps filling the gap by studying the deforestation in the presence of voluntary and mandatory conservation policies, by (i) using data at a high spatial resolution; (ii) covering the entire Brazilian Amazon; and (iii) by disentangling the effect with respect to various determinants. The paper also contributes to the broader literature of evaluating conservation zones and forest certification in consideration of heterogeneous effects within regions. Finally, it also provides new evidence for the growing literature on the relationship between environmental degradation and increasing commodity prices.

The paper is structured as follows. Section 2 discusses findings of the existing literature and elaborates a conceptional framework that underpins the empirical analysis. Section 3 provides data resources and pre-tests on geographical and political parameters in the control and treatment group. Section 4 states the empirical strategy. Section 5 presents the estimation results on the effect of certification and designation of SFM zones on deforestation rates and how it varies with local characteristics and volatility in exogenous prices. Finally, section 6 presents the conclusion.

2 Existing evidence and conceptual framework

While in the last decade of the 20th century small-scale settlers, gold diggers and a dominant timber industry were the main drivers of deforestation in the Brazilian Amazon,

[4]See, for instance, D'Souza et al. (2006); Aguilar and Vlosky (2007); Atkinson and Rosenthal (2014)

nowadays the largest threat is the transformation of forest into pasture (Margulis, 2004), soy fields (Morton et al. (2006); Nepstad et al. (2014)), and other crops (Harding et al., 2018). Since the early 2000s, the Brazilian government launched a battery of different conservation policy tools to decrease deforestation rates dramatically. One of the most impressive interventions is the establishment of new conservation zones which now cover over 44% of the legal Amazonian territory (Verissimo et al., 2011).

2.1 Conservation Zones

In contrast to the Brazilian zoning policy in the 1970s and 1980s, when most zones were centrally administrated top-down policies with only restrictive access for the local population or tourism, a large part of the recent implemented zones are decentrally-managed sustainable-use projects. The Convention on Biological Diversity[5] defines sustainable use as:
"...the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations."(CBD, 2018)

The effectiveness of the implementation of sustainably managed forestry compared to strictly protected areas or compared to no policy intervention, has been discussed in an ongoing debate over many years. An argument for the denying of human activity in protected forests is a higher level of biodiversity and less degradation of primary tropical forests (Zimmerman and Kormos, 2012). Opponents of strictly protected parks that completely prohibit any human use of forest resources, would argue that the reduction of deforestation is more probable if local communities are involved in the decision-making and monitoring process (Ostrom, 2010). They could efficiently contribute with their knowledge about local resource management to the conservation of the forest lands (Hayes, 2006).
A recent discussion about the effects of SFM zones was induced by a study by Brandt et al. (2016) on deforestation rates in the Congo Basin after the implementation of a new SFM law. According to the study, deforestation in forests with a sustainable management plan stayed the same or even increased in the six concessions of their study. The main reason for this is seen in the extension of the road network and increasing settlements close to SFM zones, which further increase deforestation. In Karsenty et al. (2017) a group of 20 researchers comments on this article. Besides pointing on methodological

[5]The Convention on Biological Diversity was founded at the 1992 Rio Earth Summit and signed by 150 states. It is dedicated to promote sustainable development and to elaborate practical tools to realize the principles of Agenda 21.

shortcomings and limitations of the data used, the researchers emphasize that sustainable forestry projects are coming with a long time horizon. Thus, for a valid evaluation, longer observation periods are necessary and time trends have to be taken into account. Nevertheless, a related study on the development of roadless space in Congo's forests, by Kleinschroth et al. (2017), concludes that within FSC certified concessions roadless space has been continuously lost. The only forests without a loss of roadless space are found in strictly protected national parks.
An empirical study by Pfaff et al. (2014) assesses public conservation zones in the Brazilian state Acre and finds that although forest loss is higher in SFM zones compared to strictly protected areas, the impact in the reduction of deforestation is larger as well. The authors attribute this result to the fact that sustainable use zones are in average located closer to human settlements and roads. This seems to be rational since the production of sustainable timber is reliant on infrastructure that makes transport to domestic and international markets possible.
Another point researchers consider as important for the evaluation of SFM projects is their economic purpose. Naturally, if economic considerations overlap ecological principles, deforestation increases as soon as it pays off for the forestry managers or owners. For instance, Rasolofoson et al. (2015) compare different forms of forest management and find that only in those without permission of commercial timber extraction deforestation is significantly reduced.

A further important determinant of the effectiveness of zones in reducing overall deforestation rates are spillover effects. This refers to the policy effect on the non-treated areas. In principle the effect can have three potential outcomes: First, no spillover effects could be detected, which means that the policy did not influence the deforestation patterns outside of the area targeted by the policy.
Second, spillover effects can be positive, which means deforestation rates outside the treated area are reduced. By the implementation of sustainable-use zones monitoring efforts in the region could increase in general and thereby also decrease deforestation rates in forests outside of the protected zone. Anecdotal evidence suggests that sustainable forestry increases the awareness of intact forests as an economic and social value in the affected regions (Schelhas and Pfeffer, 2005).[6] The presence of SFM projects could also create new jobs and increase financial stability in a municipality and therefore decrease illegal activities in the forest (Bacha and Rodriguez, 2007). Moreover, if they are economically successful and demand is high enough, SFM practices could diffuse throughout the entire sector and have effects on the overall compliance of the industry (Foster and Gutierrez, 2013).

[6] Moreover forests systems themselves have numerous positive externalities: Fertile soil, climate and rainfall regulation, provision of nutrition and medical plants (Sims and Alix-Garcia, 2017)

Finally, spillovers could be negative or the policy could come with leakage. Literature shows that the construction of new roads other infrastructure in forest areas is highly correlated with deforestation (Mertens et al., 2002; Pfaff et al., 2007). Thus, if the implementation of SFM zones is connected with the extension of the road network in a region, it reduces opportunity costs of deforestation and opens access for illegal deforestation as well (Brandt et al., 2016; Kleinschroth et al., 2017).

Forms of leakage could be observed when the decrease in deforestation in a country, region or municipality leads to an increase in deforestation in neighbouring forests, as for instance shown by Alix-Garcia et al. (2012). Channels for leakage are multiple. It could be that lumbers who are operating -or who would operate in the future- in the protected area shift their activity to land outside of the conservation zone (Aukland et al., 2003). Moreover, leakage is especially observed where alternative land uses are present and deforestation pressure is high. If the establishment of a conservation zone leads to a restriction of land available for agriculture, then deforestation on unprotected land accelerates (Armsworth et al., 2006; Fisher et al., 2011; Delacote et al., 2016). Finally, restriction of the timber production due to the limited harvest rates in sustainable forestry, may increase prices. This motivates new firms to enter the market leading to an increase in deforestation

The effectiveness of sustainable-use zones may also be different if the introduction of sustainable management practices is a voluntary adoption by individual firms or communities or if it is a obligatory requirement by the state. Since this is one of the main focuses of this paper, the conceptual differences are elaborated in the following subsection.

2.2 Governance in sustainable forest management projects

Sustainable-use zones implemented by the government are usually supported and monitored by public institutions. Thus, not surprisingly the effectiveness of such anti-deforestation policies is correlated with institutional quality and the executive power of a state (Arcand et al., 2008; Culas, 2007). Blackman (2015) emphasizes that the lack of effectiveness of conservation zones is nonetheless due to the limited governmental enforcement and monitoring of strictly protected areas in (developing) countries.

However, it is also mentioned by several studies that the limited success in reducing deforestation might be a result of not locating them at the hot spots of deforestation, close to the large agriculture companies and farms, but rather to remote areas, where they do not impede economic growth (e.g. Joppa and Pfaff (2009); Nolte et al. (2013)).

In contrast to state-owned and controlled SFM zones, the certification of forests is widely considered as a market-based instrument for lowering deforestation rates. The aim of

ecolabelling forest products is to increase the value of timber production, which is in line with environmental goals, and to encourage the market to financially appreciate sustainably produced wood. With this approach, private certification generally goes beyond or around governmental regulation, taking consumer responsibility into account (Sundstrom and Henry, 2017).
Product labelling is often considered as a tool to deal with asymmetric information on the market. The lack of information about a company or a production process yields inefficiencies for the consumer (search costs, adverse selection etc). To solve these issues a label has to provide valuable and credible information. This means that a consumer should be familiar with the production criteria associated with a certain label and that the assessment of a firm has to be executed by an independent agency (Roe et al., 2014). Researchers have identified at least four reasons why participating in a voluntary environmental program in the forest sector could be beneficial for private agents.[7]

First, the *signalling mechanism* of the label could generate economic advantages if the costumer values the extra effort the firm takes to comply to environmental standards, and is willing to pay a higher price for the product.[8] Second, the signalling effect could also be positive for a firm's public reputation as it shows awareness of environmental responsibility (Overdevest and Rickenbach, 2006). A better image of a firm is, in turn, associated with higher sales figures, less marketing costs and easier access to capital. Third, in a survey among FSC certified companies in Brazil, Araujo et al. (2009) find that the main motive to apply for a certificate does not lie in a possible price premium, but in the access to knowledge and technology transfer. This *learning mechanism* corresponds to the expectation that certification comes with a technology transfer for ecological production provided by the NGO or monitoring agency (Overdevest and Rickenbach, 2006). Finally, especially for developing countries, access to environmentally conscious international markets in Europe or the US is an important incentive for firms to participate (Rico et al., 2018).
It is sometimes argued, especially by firms from developing countries, that ecolableing is used as an entry barrier to markets in developed countries or as a strategic instrument to decrease their competitiveness. Indeed, the presence of certificated forests is higher in developed countries in the northern hemisphere than in tropical regions, where forests are biologically most valuable. Reasons for this gap often lie in problems with land tenure, high cost of certification and the small demand from domestic markets for certified prod-

[7]This could be farmers, communities, local companies for timber or paper products, or large often multinational companies. Klooster (2010) finds that most of the FSC certified areas are owned by large forest management operations

[8]There is no fixed price paid for certified timber as it is, for example, for *fair trade* products. Estimations of average on price premia are mixed. Clark (2011) reports a 10-30 % higher producer price, while Yuan and Eastin (2007) only find a 1.5 -6% for China.

ucts (Sierra, 2001). Especially for small-scale producers, it is also a lot of paperwork and difficulties to get licenses for their land. Moreover, additional costs for the audit and the transformation of the production process have to be covered by extra market benefits. As a consequence only those firms with the lowest compliance costs, which mainly are already close to sustainable management, apply for the certification. This selection process into the voluntary environmental programs reduces their overall effect in the combat against deforestation (Foster and Gutierrez, 2013).
In general, the effectiveness of voluntary certification programs could be measured by taking the number of participants times the average effect per participant plus the spillovers the program has on other non-participating firms (Potoski and Prakash, 2005). This also applies for the evaluation of governmental programs with the difference that the number of participants (or here, forest area protected) is not exogenous but can be determined by the state. In the voluntary case, the number of participants will result from the direct and indirect costs of the participation and how harmful consumers' sanctions for non-participating are. The average effect depends on the label's criteria, the firm's willingness to comply and the frequency of the audits. Theoretical models show that voluntary environmental programs can dominate mandatory programs if governmental monitoring expenditures are higher than costs to incentivise a voluntary participation (Wu and Babcock, 1999) or if the market demand for products that meet environmental standards is high (Karl and Orwat, 1999).

The above stated facts and insights show that the final success of SFM projects in reducing deforestation depends on various parameters, which might also differ between voluntary and mandatory implemented conservation zones. The analysis in this paper considers the following aspects in regard to the effectiveness of sustainable-sue policies: *Where* is the SFM zone located? If a sustainable-use zone is located where deforestation and human activity is low, the implementation might be accompanied by an expansion of infrastructure which opens access into virgin forests and increases deforestation there. *Which* effects does a SFM zone have beyond its borders? If overall monitoring around the zone is augmented, deforestation rates could decrease even on unprotected forest lands. Implementation could also result in higher deforestation rates if deforestation activity is simply shifted to forest lands outside of the zone. *Who* does implement sustainable use practices and who does monitor and control the timber harvest in the zones? A community or forest company, which already uses quite long rotation rates in their management plans, might have less opportunity costs to comply with SFM certification standards or governmental requirements of sustainability, but will also be less effective in decreasing deforestation. Subsequentially, if a reasoned monitoring plan is missing or consequences of misbehaviour are not clearly communicated, full compliance to SFM regulations can-

not be expected.
Why is the SFM zone implemented? If a SFM project has mainly commercial ends and mainly produces for export markets, it will be more vulnerable to volatilities in price and demand than if the priority lies on conservation and poverty alleviation.
In the following sections, all these parameters will be carefully analysed to examine if the SFM zones substantially and statistically significant reduce deforestation rates.

3 Data

This section describes the data sources and explains the data preparation. Geographical and socio-economic covariates are pre-tested to illustrate parallels and differences between treatment and control group.

3.1 Data Sources

Deforestation rate and Remaining Forest — My main dependent variable is the annual deforestation rate in a grid cell of 1 km^2 size. The deforestation rate is defined as:

$$df_{rate} = \frac{fr_{t-1} - fr_t}{fr_{t-1}} \quad (1)$$

where fr_t is the remaining forest in year t and fr_{t-1} is the remaining forest cover in the previous year. In order to calculate the annual change in remaining forest, I use data based on NASA satellite images which have been processed at the Brazilian National Institute for Space Research (*INPE (2017) - Instituto Nacional de Pesquisas Espaciais*). The data cover the entire legal Amazon, an area of about 5 million km^2. The data are organized into 1 km^2 grid cells and to each such cell the annual deforestation is assigned. For the control group, I use grid cells located outside the conservation zone within different buffers where the largest is 60 km.
The forest data are coded from August to July. This means that deforestation in year 2002 actually measures forest loss from August 2001 to July 2002. In order to have at least one year before and one year after the implementation date of a zone, I include only zones that where implemented after July 2002. An overview over the certification dates and size of the FSC zones is given in table A.2 and for the implementation date of the RESEX zones in table A.3. Note, that in the sample for both types of zones, the initial year in the data set is changed to the next year to adapt the time dimension to

the deforestation rates.[9] I further restrict the sample by excluding all grid cells without any forest cover left in 2002. Cells that are part of a protection zone of another type than RESEX or FSC zones are excluded from the sample to avoid a bias in the dependent variable. Geographic covariates are used to check for systematic differences between treatment and control group. For instance, these covariates are: distance to the next river, road, municipality borders and cities. A detailed overview of dimension and source of all variables used in this paper is available in table A.1.

Public Zones RESEX Data — The first RESEX zone was implemented in 1990 in memorial to the famous resistance fighter and rubber collector Chico Mendes. Their primary objective is to clear property rights distribution over the land and serve local communities as a protected habitat. These communities are not indigenous but have traditional knowledge on the extraction of non-timber forest products, such as fruits or rubber, as well as substantial agriculture production. The central idea behind the implementation of these zones is that traditional forest users may have the most responsible interaction with the resource their livelihood depend on. Thus, extractive reserves are only designated to those local populations that can exhibit a history of sustainable forest use (Da Silva, 2004). In this spirit, more and more extractive reserves were designated such that 92 exist until today; 35 in my period of observation, 53 before and additional 4 in 2018. The establishment of RESEX zones comprise three principal steps. First, a formal request of the local population is necessary, which has to contain descriptions of the social, economic and environmental conditions of the area where the zone should be implemented. This first request is often accompanied and supported by an environmental NGOs (Koziell, 2002). Thus, their placement is not a top-down decision but requires a bottom-up request by the communities themselves. Second, the Brazilian Envriomental Institute (IBAMA) has to approve the request and elaborate a plan for the sustainable use of the resources of the area. Finally, the plan has to be translated into action and should be steadily improved to guarantee long-term efficiency (Da Silva, 2004).
Data on implementation date, localization and size of the RESEX areas are acquired from the Brazilian ministry of environment, *Ministerio do Meio Ambiente* (MMA, 2017). The sample contains 35 RESEX zones, where the smallest is about 28 square kilometres and the largest is about 12887 square kilometers. Table A.3 lists all RESEX zones contained in the sample and gives information about size and the municipalities in which they are located. Figure A.7 maps the location of the zones and shows the proximity to agricultural frontier, the so called arc of deforestation [10] and, thus, illustrating the distance to

[9] Of course only if the designation or certification occurred in the last four months of a year. For instance the initial year of a zone certified in November 2004, appears in the sample as 2005.

[10] The arc of deforestation describes a region at the southern edge of Brazil's Amazon, where most of the deforestation takes place and the frontier between cleared land and dense forest is located. Each

the forest which is probably most affected by recent deforestation.

Private Zones FSC Data — The Forest Stewardship Council is a non-governmental organization that was founded in 1993 with the objective of establishing a voluntary system for sustainable production and of providing a market-based solution to the timber industry. [11] Since then, the number of certificates and the size of the area certified have increased steadily.
The main concept is to limit the annual maximum yield in a clearly defined area: a so-called Forest Management Unit (FMU). The certification is executed by a third-party audit agency at the level of those FMUs. Usually, there is one main audit at the beginning of the certification followed by reassessments every 5 years if the firm applies for an extension of the certificate. Additionally, a short audit report is provided by the agency each year to confirm the compliance with the FSC standards. Beyond regulations on harvesting and regeneration of forests, the FSC imposes formal principles to ensure a socially beneficial, economically viable and environmentally sustainable management plan (FSC, 2015).
For the FSC zones, there is no data set available that gives information about the exact geographical localization, the size, the operating company, and the duration of the certificate. Documents on this first assessment (to obtain the certificate) are available from the FSC webpage (info.fsc.org) and they provide information on GPS coordinates, size of the certified areas, maps, timeline and report changes in the scope of certification. By using the Brazilian land register (CAR, 2017), where private agents have to register their land since 2012, it was possible to identify the areas. Careful examination and comparison of companies' maps and the CAR shape file made it possible to get the exact geo-referenced location and border of the certified area. The detailed process of the creation is described in A.1.1. Furthermore, I run several sensitivity tests with variation of years in the pre- and post-treatment period in order to increase reliability.
It is important to notice that many of the FSC certified forests could not be part of the sample, since they are secondary forests [12] or plantations. However this is a form of

year it moves further into the forest, revealing a boom and bust pattern (Rodrigues et al., 2009).

[11] Initially, the label mainly addressed the timber industry and commercial lumber companies. For small-scale loggers and communities it is much more complicated to receive the certificate due to economies of scale and often less experience in commercial forestry. However, in 2013 the Smallholder Fund was found by the FSC to financially help smallholders with the certification costs and with other obstacles in the certification process.

[12] Secondary forest is forest that is re-grown on woodland that was once cleared and hence differs in its biodiversity. While natural forests contain many species, re-grown forests usually have only one or two species, commonly fast growing ones like e.g. eucalyptus, with rotation cycles as low as 7 years for paper and pulp production. Thus, rules for the management of native forests are more stringent than those for plantations (Blaser, 2011)

reforestation and thus, not the objective of this investigation. After these adjustments, my data set contains 35 FSC zones with geographic references in 28 municipalities. The smallest zone is 12 km^2 and the largest is 8777 km^2. A list of all certified FSC zones is given in the appendix A.2.

There are several limitations of the FSC data sets that should be taken into account for the interpretation of the results. First the geographical allocation was not possible for all FSC certified forests in the Amazon due to missing documents or a lack of information in the documents. Timber harvest in FSC certified forests is supposed to follow a management plan which divides the area into parcels that are harvested in one year and fallowed for several years afterwards in order to give nature time for recover. I do not have information about which parcels are harvested in which year but only know location and certification dates for the entire zone.[13] This could be an issue when harvesting is systematically higher or lower close to a zone's border, which could especially bias the results of the spatial estimation and regression discontinuity figures. There is no reason to assume that deforestation should be higher or lower closer to the border on average. However, to meet this concern, I run the regression with different distances to the border within and outside the zone.

Several FSC zones are located in public forests for which the certification holders possess a license for forest use. Therefore, I cannot completely rule out that these areas are additionally supported or monitored by governmental forces. However, the decision to certificate their land, the cost of certification and the income from the sold timber are solely determined by private agents.

International Prices — As basis for the construction of the price index of corn and cattle, I use annual commodity prices by the World Bank (WB, 2017). Figure A.15 shows the development of these prices from 2002 to 2015. Especially the price for corn increased about 2.5 times between 2010 and 2013 and declined rapidly afterwards.

For timber, I use tropical sawnwood prices published by the International Tropical Timber Organization (ITTO, 2018) which collects the data on tropical timber prices and production in collaboration with the FAO and the World Bank. The organization also provides data on plywood and roundwood, but I use sawnwood here due to two main reasons. First, because in terms of tropical timber, sawnwood is the product with the highest export figures in Brazil in the regarded period. It makes about 67 % of all tropical timber exports from Brazil. Second, sawnwood exports are mainly delivered to environmentally conscious markets such as Japan, the US and the EU-28, which are the target markets for sustainable produced timber (Blaser, 2011).

[13] Similarly to the data Blackman et al. (2018) use in their paper on FSC certified areas in Mexico, the data which do not provide information on which part of the zone is deforested in which year.

Furthermore, I consider the three most important non-timber forest products: rubber, açaí and brazil nuts. Rubber is the only commodity of those three for which the international price is available, again published by the World Bank. For Açaí and Brazil nuts I take average prices from South Brazilian states, which do not produce them but are often a stopover to international markets. For each of the commodities, prices are normed on the year 2002. These prices are the time-varying component of the price index. Cross-sectional variation is achieved by using the heterogeneity of the economic importance of a commodity in a municipality since each grid cell is located in a municipality, the commodity weights of the municipalities are automatically attributed to the grid cell. The weight w for the price index is calculated as follows:

$$w_{j,i,2002} = \frac{v_{j,i,2002}}{\sum_{j=1}^{n} v_{i,2002}} \tag{2}$$

where $v_{j,i,2002}$ is the output value of commodity j in municipality i in the year 2002. This value is divided by the aggregated value of all agricultural and forest commodities produced in municipality i in the initial year 2002. The output value of the commodities are published in the annual report Produção Agrícola Municipal and the Produção da Extração Vegetal e da Silvicultura at the Brazilian Statistical Institute (IBGE, 2017).

Figure A.11-A.14 presents a map that shows how each price intensity is distributed over the Amazonian municipalities. While timber intense municipalities seem to be smoothly distributed over the whole area, there are two regions to highlight: First, the south of the Amazon, mostly the state of Mato Grosso, where timber intensity is low, agricultural business is large, and not much forest is left. Second, the north east of the Amazon, where municipalities with high timber intensity cluster. Municipalities there, for instance are Paragominas or Dom Eliseu in northern Pará, which are located close to big harbors like Belém or São Luiz, from which timber can be exported to the US, Europe or China. At the same time the conversion into agricultural land there is not at the same advanced stage as it is in the south. However, in the South part there is hardly any production of NTFP, which is most intense in the North parts where forest is more dense and intact than in areas close to the agricultural frontier. I control for these clusters by including robustness checks, which account for spatial autocorrelation.

3.2 Covariates

This section examines whether geographical and socio-economic covariates are significantly different in the treatment and the control group before the zones are implemented.

Different pre-trends of the dependent variables are tested separately in section 4.3.
A critical assumption for a difference-in-differences estimation with a geographical threshold (here the borders of the zones) is that the subjects of observation (grid cells) do not differ systematically around this threshold, such that the only fact which makes them different is the implemented policy. For an assessment of this smoothness around the border the upper panel of table 1 compares geographical characteristics at the grid level and focuses at a 10 kilometer buffer around a zone's border. All variables are either measured before 2002 (Distance to Sawmill, City and Road) or are time invariant (Non-Forest Area, Soil Quality and Distance to River). Since data on socio-economic covariates are only available on the municipality level, the lower panel compares these characteristics between municipalities which host a SFM zone and non-affected neighbouring municipalities.

Table 1: Pre-test on Covariates

	Private (FSC)			Public (RESEX)		
	Inside	Outside	tStat	Inside	Outside	tStat
			Geographical Variables			
Non-Forest Area (%)	0.02	0.07	(-1.08)	0.08	0.09	(-1.03)
Soil Quality (1-5)	1.82	1.76	(0.20)	1.40	1.53	(-0.54)
Distance to Sawmill (km)	122.98	108.21	(0.30)	218.56	216.43	(1.52)
Distance to City (km)	65.08	62.78	(1.01)	82.1	76.8	(1.91*)
Distance to River (km)	21.39	21.66	(-1.26)	14.56	15.19	(-1.03)
Distance to Roads (km)	24.51	19.27	(0.48)	66.12	60.7	(1.67)
Observations	14,126	19,218		212,135	206,476	
			Municipality Variables			
Deforestation (km2)	58.5	80.9	(0.87)	57.6	51.9	(-0.38)
Population (2000)	40130	43688	(0.16)	46823	30893	(-1.06)
GDP per capita (in Tsd R$)	4.3	4.1	(-0.31)	3.6	4.1	(1.30)
Extraction Fuelwood (m3)	31426	24089	(-0.77)	30083	20804	(-1.62)
Extraction Acai (tons)	185.8	748.1	(0.98)	245.9	564.2	(1.05)
Extraction Brazil Nuts (tons)	271.8	106.5	(1.96*)	145.6	52.02	(2.16**)
Extraction Rubber (tons)	32.7	19.3	(0.37)	22.3	7.5	(2.23**)
Accessibility	3.19	3.31	(0.98)	3.44	3.19	(1.99*)
Cattle	71182	97987	(1.00)	57283	82753	(1.73*)
Corn (in Tsd R$)	1095	671	(-1.12)	621	826	(0.70)
Observations	40	110		108	165	

Note: Upper panel compares average values of geographical variables on the grid level for the first 10 km around a zone's border and documents a t-test for the difference between these values in brackets. All variables are time invariant. *Non-Forest Area* gives the % of area that is naturally not covered by trees (rocks, mountains etc.). *Soil quality* is a FAO measure giving the restriction of the soil with respect to agricultural fertility: 1= very low restrictions and 5=high restrictions. The lower panel reports average values of the year 2002 for socio-economic an geographical variables on municipality level. The population data stem from the demographic census in 2000 that is published every 7-10 years.

Column (1) reports the mean value of geographical variables for grid cells in a FSC zone and column (2) does the same for grid cells outside the zone. Column (4) shows values of grid cells within a RESEX zone and column (5) shows the values for the adjoining grid cells. Columns (3) and (6) show the t-statistic for the difference between them. Column (6) reveals that the only statistically significant difference on the grid cell level lies at a slightly higher distance to the closest cities in the RESEX sample. Note that when comparing public and private zones it becomes evident that private zones are in average

located about 100 km closer to sawmills, almost 20 km closer to cities and over 40 km closer to roads than public zones.
Another assumption for geographical-based DD is that zone borders are not following a specific intention but are rather randomly drawn. About 4% (7%) of borders of the public (private) conservation zones are identical to the administrative borders such as municipality or state borders. About 11% (5.8%) are defined by main rivers. Those are of great importance in the Brazilian Amazon because they serve as a main transport system, especially for timber. About 1.4% (4.2%)of the zone borders follow roads or highways. Only 9% (24%) of the borders are straight, which implies that the majority of the zone borders are defined by natural geography such as small rivers, mountains etc. rather than designed on a drawing board. Since the Brazilian Amazon is very humid and rich in all kinds of water bodies, borders following small rivers are less of a concern.
Additionally, figures A.8 and A.9, which plot several geographic characteristic 10 km inside and outside of the zones in 2002, illustrate that around the border variable values pass quite smoothly. This and the insignificant t-tests in table 1 indicate that systematic differences in geographical covariates between treated and non-treated grid cells could be ruled out.

As described above, the lower panel compares average values of socio-economic variables on a municipality level in the year 2002, before the zones are established. In columns (1) and (4) municipalities which host a SFM zone are regarded and in columns (2) and (4) average values for the neighbouring municipalities are shown. Again, columns (3) and (6) report results of the t-test which examines if differences are significant. The private zone sample shows that a higher amount of *Brazil nuts* is collected in treated municipalities, which indicates high extractive activity. All other variables do not significantly differ in the FSC sample.
As expected, extracting activity in RESEX municipalities is higher in respect to *Brazil Nuts* and *Rubber*, due to the traditional populations which are supposed to live in these municipalities. Moreover, the variable *Accessibility* measures the mean travel time from the municipality center to the closest city with more than 50,000 inhabitants. It is coded in an interval from 1 to 5. An accessibility value of 1 means that the travel time is less than 1 hour and a value of 5 corresponds to travel times of more than 24 hours. This value is significantly higher for RESEX municipalities than for their neighbours and also higher than in FSC municipalities. This fact, together with the larger distances to roads and sawmills, suggest that access to formal markets, especially export markets, is more limited for inhabitants of extractive reserves than for private forestry companies. Finally, fewer *cattle* is kept there, indicating fewer agricultural activities. These values are especially interesting in regard to the examination of the commodity price effect on deforestation in section 5.4. The individual weighting of the prices, which is explained

in section 3.1 ensures that the differences in the production volume of agricultural and extractive goods, which are shown here, do not bias the estimation results.

4 Empirical strategy

In general, the empirical evaluation of conservation zones has to take into account that they are not randomly assigned but that their location could be chosen intentionally or systemically, which makes it difficult to identify the real cause of any change in the outcome. In other words, one cannot simply compare treated with non-treated areas, since it is not possible to disentangle effects of the policy from other unobservable differences between the two. To deal with this challenge, quasi-experimental designs are a popular approach to study conservation zone polices. Their advantage is that they aim to select an adequate control group for the treated units to ensure an unbiased estimator.

This paper uses a difference-in-differences (DD) estimator in the spirit of a regression discontinuity design (RDD) to estimate the policy effect of sustainably managed forests on deforestation rates. This means that control groups are formed by the directly adjoining forests in different buffers around the zones. The analysis is based on the assumption that grid cells which are located close to each other are not only similar in terms of geographical characteristics and administrative and political parameters but also in unobservables which cannot be captured by controls or fixed effects in the regression. Following Ahlfeldt et al. (2017) the standard model is adapted to capture spatial heterogeneity and differences in time trends between treatment and control group. As baseline, I start with with a simple difference-in-differences model which estimates the average treatment effect for grid cells within a sustainable-use zones before and after the implementation. Grid cells located within 30 km outside the zone are used as a control group. However, I run various robustness checks including different specification of the control group. The baseline regression for is the following:

$$df_{it} = \alpha_j + \gamma_t + \beta_1 I_i + \beta_2 T_{it} + \beta_3 (I_i \times T_{it}) + \beta_3 X_i + \epsilon_{it}, \quad (3)$$

where the outcome variable df_{it} is the deforestation rate in grid cell i in year t. Zone fixed effects are captured by α_j and year fixed effects by γ_t. The inside dummy I_i is indicating whether a grid cell is located within a zone. The time dummy T is one if a year is equal to or higher than the year of the implementation of the zone to which grid cell i belongs. Note that for the FSC zones, the certificate either automatically expires after 5 years (if it is not extended) or it is suspended before the end of this period due to environmental or social misbehavior. For years following the termination of the certificate, the time

dummy T becomes 0 again.
The coefficient of interest is β_3 which measures the effect for the forest belonging to a grid cell that is located after a zone was successfully implemented. X_i is a vector of different time invariant geographical control variables which differ between the grid cells. ϵ_{it} is an error term, which is assumed to be independently and equally distributed.
To account for potential spillover effects the second specification of equation 3 takes grid cells located within 10 km around the zone as a second treatment group into the equation:

$$df_{it} = \alpha_j + \gamma_t + \beta_1 I_i + \beta_2 T_{it} + \beta_3 (I_i \times T_{it}) + \beta_4 O_i + \beta_5 (O_i \times T_{it}) + \beta_6 X_i + \epsilon_{it}. \tag{4}$$

The model is analogous to the first one but includes a dummy O_i which equals one for all grid cells located with a maximum distance of 10 km around a zone's border. β_4 captures the intercept of possible spill-over effects on close neighbor cells of the zone after the designation. Note that for the main model used in this paper η_i is included in order to account for cell fixed effects, which excludes all variables without between variation; in this case I_i, O_i and X_i.

4.1 Spatial difference-in-differences

An RDD approach in a geographical context assumes that political boundaries (cut-off point) split units into treatment and control areas (Keele and Titiunik, 2015). Analysts suppose that right at the cut-off point, characteristics between the units of observations do not differ systematically and could be used as a quasi experiment. Compared to the standard case where the selection into treatment and control group is based on whether their value for numeric rating falls above or below a certain threshold (Lee and Lemieux, 2010), the geographical boundary creates the threshold in the case of the spatial estimation. This basic assumption is translated to this study. The focus is taken precisely to those grid cells that are located close to a zone's border, since the probability that there is a systematic difference between the cells on both sides of a border becomes smaller (see table 1).
The spatial empirical model estimates the treatment effect of the implementation of a zone at different distances from the zone border as well as a possible discontinuity in deforestation rates around the border. The spatial DD model is estimated with the following

regression form:

$$df_{it} = \eta_i + \gamma_t + \beta_1 T_{it} + \beta_2(I_i \times T_{it}) + \beta_3(I_i \times D_i \times T_{it}) + \beta_4(O_i \times T_{it}) + \beta_5(O_i \times D_i \times T_{it}) + \beta_6(D_i \times T_{it}) + \epsilon_{it}, \tag{5}$$

again df_{it} is the deforestation rate in grid cell i at time t, η_i accounts for cell fixed effects and γ_t for time fixed effects. D_i measures the distance of cell i to a zone's boundary. In this specification β_2 gives the intercept of the treatment effect at the border and β_3 measures how it changes with respect to the distance from the border. In the full model of this specification, I also include interactions with an outside dummy O_i that measures the external effect of the treatment within the first 10 km outside of the border. Here β_4 captures the intercept of possible spill-over effects on close neighbor cells of the zone and β_5 shows whether these effects are changing with higher distance to the border (e.g. due to lower monitoring). The coefficient β_6 reports the effect the treatment has on grid cells which are located with higher distance from the zone, beyond the first 10 km after the border. Implementation of the zones occurred in different years during the sample period. The first year of official recognition as a RESEX zone counts as the first year of treatment. Equally, for the FSC zones, the first year of certification confirmation by the audit agency is the first year of treatment.

4.2 Time trend difference-in-differences

The spatial model described above assesses the effect of political or private protection effort on a pre-defined area and possible spillovers on the environment. However, it does not account for potential pre-trends in preparation of the treatment or changes in the effectiveness during the post-treatment years. Especially in the case of certification, the adoption of FSC standards is expected to start before the first audit that decides whether a FMU will be certified or not. To address these limitations, the time trend DD model focuses on trends in the years before and after the first year of certification or governmental protection, respectively. It takes the following regression form:

$$\begin{aligned} df_{it} = \alpha_i + \gamma_t + \beta_1 T_{it} + \beta_2(I_i \times T_{it}) + \beta_3(I_i \times YT_{it}) + \beta_4(I_i \times YT_{it} \times T_{it}) + \beta_5(O_i \times T_{it}) \\ + \beta_6(O_i \times YT_{it}) + \beta_7(O_i \times YT_{it} \times T_{it}) + \beta_8(YT_{it} \times T_{it}) + \epsilon_{it}, \end{aligned} \tag{6}$$

where the number of years before the implementation (negative values) of a zone and afterwards (positive values) are captured by YT. The year of implementation itself takes the value 0. The YT variable is interacted with the inside dummy to control for specific trends, which differ between treatment and control group, analogously, for the external treatment dummy O_i. In order to control for general post-treatment trends, an interaction between YT and T accounts for trends in deforestation that changes in the control group after the the zone was implemented. Taking these unobserved trends into account puts the functional form in a regression discontinuity environment with a time running variable (Anderson, 2014). Unobserved trends that may affect deforestation are assumed to behave smoothly around the year of implementation since the only change in this specific date is the implementation of the SFM zone. Thus, a significant β_2 can be entirely attributed to the treatment and allows the identification of the changes in deforestation trends which are induced by the treatment captured by the coefficient β_4.

4.3 Sensitivities

In order to increase confidence in my estimates, I provide a sensitivity analysis for each result presented in this paper, concerning different potential threats to identification.
A first evident test is to include several definitions of the *dependent variable*. My main specification is the deforestation in a grid cell normed on the remaining forest cover in that grid cell. The advantage of this definition is that it accounts for the simple fact that where more forest is left, more deforestation is physically possible. Thus, the effect in grid cells with a lot of remaining forest would be overestimated. However, if one is only interested in the total area of avoided deforestation, due to a specific treatment, the dependent variable has to be measured in levels. For that matter, I use the deforestation in hectare per grid cell in a year. Moreover, I provide estimations on the probability that any deforestation may occur in the grid cell.
Table 2 presents estimations on deforestation trends measured in the several forms described above. While the dependent variable in a difference-in-differences estimation is allowed to differ in levels between treatment and control group, a pre-condition for a valid estimation is that the trends are parallel in both groups.

Table 2: Pre-test on Characteristics

	Private (FSC)				Public (RESEX)			
	Df %	Df ha	Df 1/0	Fr	Df %	Df ha	Df 1/0	Fr
L.Inside × Trend	0.074	0.022	0.514*	0.387	0.096	0.057	0.239	-0.017
	(0.083)	(0.048)	(0.260)	(0.249)	(0.080)	(0.055)	(0.220)	(0.279)
Observations	0.688m	0.688m	0.688m	0.688m	2.75m	2.75m	2.75m	2.75m

Note: Dependent variables are deforestation in percentage of remaining forest cover $Df\%$, deforestation in hectare *Df ha*, the probability of deforestation $Df1/0$ and the remaining forest cover Fr in a grid cell. Pre-trends before the policy implementation is measured by an interaction term $Inside \times Trend$. Not shown in the table but included in the regression are the subterms of the interaction term, namely $Inside$ and $Trend$ as well as year and municipality fixed effects. Standard errors are in parentheses and clustered at the municipality level.

The interaction term $Inside \times Trend$ combines a dummy that indicates if a grid cell is located within a zone and a trend variable that indicates the number of years before the policy treatment. This interaction term estimates if differences between treatment and control group are significant in respect to the development of the dependent variables over time before the treatment was implemented. As the coefficients of the interaction term are insignificant, the hypothesis of parallel trends could not be rejected. An exception is the coefficient on the probability of deforestation *Df 1/0* in the private zone's sample, which is significant on the 10% level. Thus, the following results in regard to this variable should be interpreted carefully.

Another concern is that results could be biased by a specific choice of the buffer size around the zone, which defines the *control group*. Therefore, I repeat each table with different definitions of the control group, by mainly increasing the baseline definition of 30 km to 60 km or to narrow it down to 10 km.

In my main specification I implement the RD Design by using a parametric model. It is stated by Gelman and Imbens (2017) that regression discontinuity designs of higher polynomial order are prone to noisy estimates and sensitive to the degree of the polynomial chosen in the regression. Moreover, it is claimed that designs above the second polynomial degree cover confidence intervals incompletely. However, as Lee and Lemieux (2010) suggest, checking *nonparametric* specifications of the model provide more flexible estimates of the regression function. One straight forward way to implement a nonparametric model is to simply include polynomials of the assignment variable as regressors. Therefore, I include robustness by adding the second polynomials of the time variable, in order to relax the assumption of linearity in my models.

A further concern which emerges when using RD Designs regressions, especially if it is run at a geographical border (Keele and Titiunik, 2015), is that variables may be *spatially correlated*. Similar values could either appear near to each other or dissimilar ones could be located closely to each other. Both cases would bias results. I control for this by clustering the standard errors at the municipality level in all regressions and run further robustness that cluster the standard errors at the municipality-year level and at the state-year level. Further robustness which are specific to the regression form of each result table are described within the following section 5.

5 Empirical Results

This section empirically analyses the relationship between deforestation and the public and private zoning policy, assessing whether the level and form of deforestation changed significantly after the area was officially established as a sustainable-use zone. As a baseline I start with a simple difference-in-differences model which estimates the average treatment effect for grid cells within sustainable use zones before and after the designation. In a second step, I further disentangle the effect in its spatial and temporal dimension, which provides insights in the deforestation dynamics within and outside the protected area.

Table 3 documents the main treatment effect for three measures of deforestation: Deforestation in relation to remaining forest cover in columns (1) and (2), the area of deforestation in hectare in columns (3) and (4), and the probability of deforestation in column (5) and (6). The upper panel considers only the internal treatment effect and the lower panel also includes the external treatment. Columns (1), (3) and (5) include zone and year fixed effects. This makes it possible to show the effect of implementation compared to the general effect that the location has on the grid cell. I find that deforestation rates before the treatment are in average about 1.8% lower than in the control group what corresponds to a 0.89 ha less deforestation. The probability of deforestation is 6.8% lower than in the control group. Columns (2), (4) and (6) include grid cell fixed effects and thus the *inside* term is omitted. The coefficient of the interaction term $Inside \times T$ shows how deforestation changed after the zone gets the certification. The coefficient is positive and significant on the 1% level for all deforestation measures and for all regression models in table 3. Coefficients between the two specifications are equal in significance and polarity, moreover, similar in size which indicates that the pre-differences between grid cells in the treatment or the control group are well captured by cell fixed effects. After the certification, deforestation rates increase by 0.69% [14], which is a considerable number

[14]Total effects in the *zone fixed effects* model are calculated by: $\beta^{Inside \times T} + \beta^{Inside} + \beta^{T}$. Total effects in the grid fixed effect model is: $\beta^{Inside \times T} + \beta^{T}$

Table 3: Baseline FSC

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	1.293***	1.361***	0.717***	0.715***	5.337***	4.870***
	(0.368)	(0.288)	(0.186)	(0.164)	(1.280)	(1.145)
Inside	-1.795***		-0.890***		-6.839***	
	(0.350)		(0.176)		(1.188)	
T	-0.659**	-0.673**	-0.385**	-0.385**	-1.600	-1.499
	(0.299)	(0.304)	(0.160)	(0.167)	(0.982)	(1.014)
Total Effect	-1.16	0.69	-0.56	0.33	-3.10	3.37
Control Group	30km	30km	30km	30km	30km	30km
Fixed Effects	Year& Zone	Year& Grid	Year& Zone	Year& Grid	Year& Zone	Year& Grid
Observations	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m
R-squ	0.04	0.17	0.04	0.15	0.07	0.27
Inside × T	1.325***	1.360***	0.730***	0.696***	5.536***	5.009***
	(0.380)	(0.289)	(0.191)	(0.159)	(1.330)	(1.201)
Outside × T	0.131	-0.002	0.054	-0.064	0.785	0.471
	(0.164)	(0.227)	(0.103)	(0.137)	(0.713)	(0.850)
Inside	-1.885***		-0.932***		-7.239***	
	(0.359)		(0.179)		(1.235)	
Outside	-0.325**		-0.152**		-1.455***	
	(0.123)		(0.061)		(0.488)	
T	-0.696**	-0.673**	-0.401**	-0.366**	-1.825*	-1.638
	(0.298)	(0.312)	(0.158)	(0.168)	(0.960)	(1.046)

Note: The dependent variables are the percent deforested in cell i; area deforested in grid cell i in hectare; and whether or not a grid had any deforestation. *Inside* is an indicator equal to one if a grid cell is located in the zone and T is equal 1 as soon as a zone is certificated or officially established, respectively. The internal treatment effect is measured by ($Inside \times T$). Variable D measures the distance to the border in km. *Outside* is a variable that is one if a grid cell is located within the first 10 km outside of the border. The external treatment effect is measured by ($Outside \times T$). Upper panel includes only internal treatment regressors and lower panel additionally includes external treatment regressors. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

in comparison with the an average deforestation of 1.55% in the sample. Column (3) shows that this corresponds to 0.33 hectare per grid cell, which sums up to 8057 ha for the entire certified forest per year after the certification. Finally, column(6) exhibits that the probability for deforestation raises about 3.4%. The lower panel additionally provides information on potential spillover effects of the treatment. Generally, deforestation rates are 0.33% lower in grid cells that are located close to the zones' border compared to grid cells located further away from the border. However, the treatment itself does not change the deforestation rates in the adjoining forests, since the interaction term *Outside* × *T* stays insignificant over all specifications.

Table 4: Baseline RESEX

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	0.229***	0.238***	0.083**	0.081***	0.893***	0.940***
	(0.064)	(0.054)	(0.038)	(0.030)	(0.245)	(0.217)
Inside	-0.347***		-0.143*		-1.344***	
	(0.116)		(0.076)		(0.433)	
T	0.136**	0.133**	0.051	0.052	0.336*	0.321*
	(0.053)	(0.053)	(0.032)	(0.034)	(0.174)	(0.166)
Total Effect	0.02	0.37	-0.01	0.13	-0.12	1.26
Control Group	30km	30km	30km	30km	30km	30km
Fixed Effects	Year& Zone	Year& Grid	Year& Zone	Year& Grid	Year& Zone	Year& Grid
Observations	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m
R-sq	0.02	0.13	0.01	0.11	0.03	0.21
Inside × T	0.288***	0.302***	0.109**	0.110***	1.106***	1.178***
	(0.082)	(0.069)	(0.047)	(0.037)	(0.300)	(0.261)
Outside × T	0.168***	0.184***	0.074***	0.083***	0.602***	0.681***
	(0.056)	(0.056)	(0.028)	(0.030)	(0.185)	(0.178)
Inside	-0.412***		-0.169**		-1.595***	
	(0.128)		(0.080)		(0.474)	
Outside	-0.180***		-0.072***		-0.691***	
	(0.056)		(0.024)		(0.202)	
T	0.078	0.070	0.025	0.023	0.128	0.086
	(0.060)	(0.059)	(0.034)	(0.035)	(0.206)	(0.192)

Note: The dependent variables are the percent deforested in cell i; area deforested in grid cell i in hectare; and whether or not a grid had any deforestation. *Inside* is an indicator equal to one if a grid cell is located in the zone and T is equal 1 as soon as a zone is certificated or officially established, respectively. The internal treatment effect is measured by $(Inside \times T)$. Variable D measures the distance to the border in km. *Outside* is a variable that is one if a grid cell is located within the first 10 km outside of the border. The external treatment effect is measured by $(Outside \times T)$. Upper panel includes only internal treatment regressors and lower panel additionally includes external treatment regressors. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table 4 is analogous to table 3 but it considers the RESEX sample. Variable T is a dummy indicating the date of establishment of a zone and all years after. This is different to the FSC sample where T can become 0 again if a certificate is suspended by the FSC or if firms do not extended their certificate. In contrast to table 3, the coefficient for T is positive in all specifications and significant in three of them. As in the FSC sample the inside dummy is negative and significant, showing that deforestation is generally lower inside of a RESEX zone than outside of it. However, the official acknowledgement as a protected zone increases deforestation, which results in a total effect that is close to zero for deforestation measured in percent of remaining forest in columns (1) and(2) and for deforestation measured in hectares in columns (3) and (4). Including fixed effects in columns (2) and (4) shows that the treatment increases deforestation about 0.37% within the zone which corresponds to an increase of 0.13 hectares. In columns (5) and (6) the probability for any deforestation is the dependent variable and exhibit that the probability of deforestation increase 1.26% after implementation. In contrast to the FSC case, the lower panel reports significant significant spillover effects to the neighbouring forests where deforestation also increases after the implementation of the zone.

Comparing the magnitude of the effect of both types of forest zones reveals that the certification date increases deforestation rates more than twice as much as the implementation of the governmental conservation zone. Moreover, the area of deforested and the probability of deforestation is almost three times higher in the case of private zones.However, considering the total effects also reveals that the probability of being affected by deforestation grows by 3.4 % for grid cells located in a certified area after passing the first assessment audit.

Deforestation rates are still 3.1% lower for grid cells within the certified zones than in grid cells which surrounds them. For public zones the probability of deforestation increases only by 1.26 % after designation. Nevertheless, the total effect of for a grid cell to be located within a public zone decreases the probability of deforestation only by 0.12% compared to the control group. Thus, considering the total effect a grid cell within a private zone is better protected than a grid cell within a public zone. However, in private zone they also lose more of their effectiveness after implementation.

Tables A.4 and A.5 repeat column (1) of tables 3 and 4, which include zone fixed effects, geographical controls and remaining forest cover as control variables. Results stay robust to the inclusion of these additional controls. Decreasing the control group and the treatment group to grid cells located not further than 10 km from the border, located inside and outside the zone, table A.6 and A.7 show that results are robust but coefficients decrease in size. Extending the control group by including a 60 km buffer, table A.8 and A.9 present evidence that treatment effect stays robust and increases in size. Finally, table A.10 and A.11 control for spatial autocorrelation. Results remain equal in size and significance in the case of private zones, shown in table A.10. For public zones, however, the specification in column (3) and (4) in table A.11, where deforestation in hectares is the dependent variable, loses significance.

5.1 Spatial DD

Figure 1 plots the βs of the treatment at a zone's border. The graph focuses on the first 30 and 50 kilometers around the border. Negative values indicate distances to the border within the zone and positive values describe distances to the border from outside the zone. These graphs make it possible to observe the increased pressure from outside the zone before the implementation as well as spillovers to the forest plots outside the zone after the treatment.

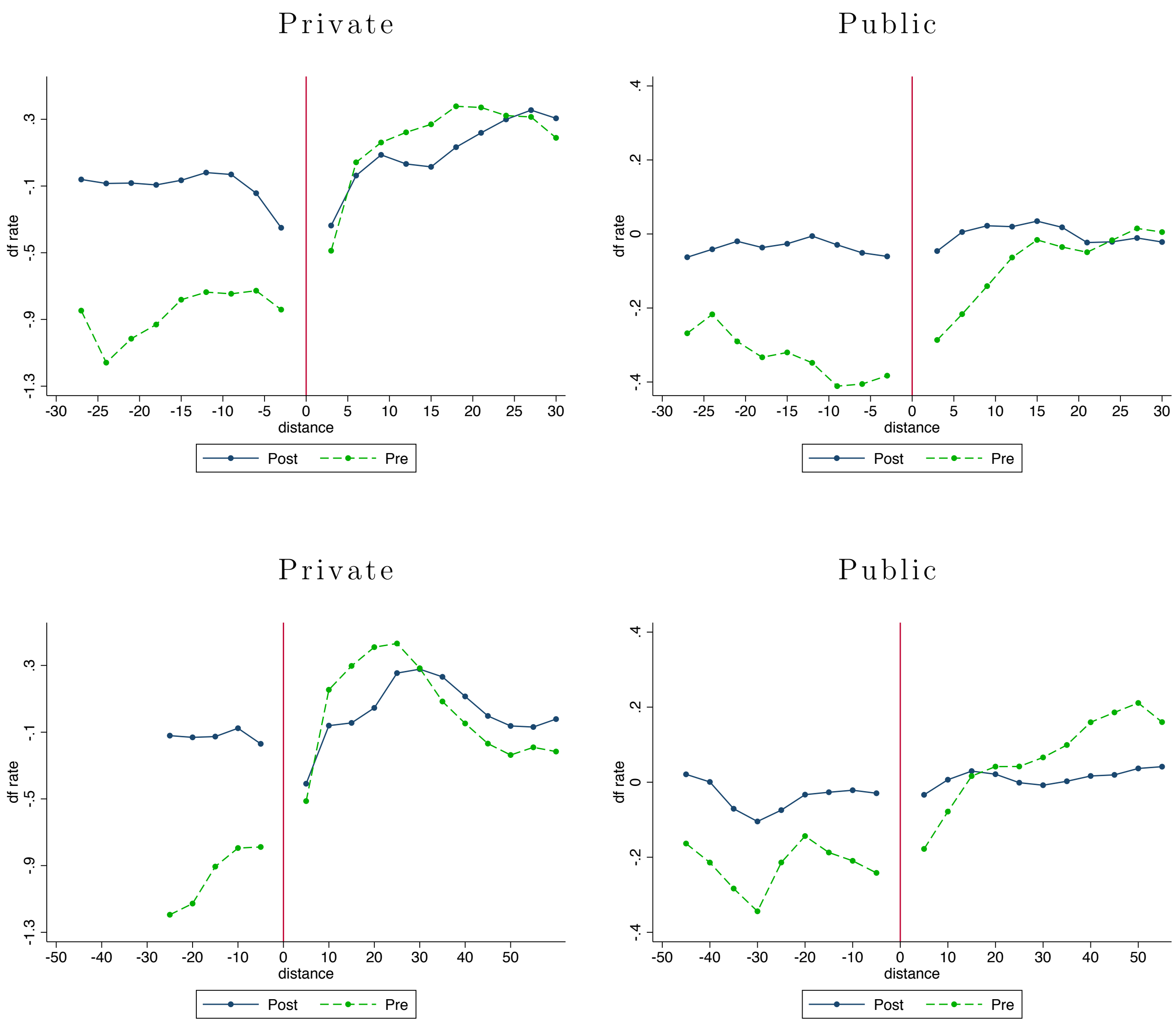

Figure 1: Diff-in-diff at the border

Note: The figure plots the β coefficients of the treatment on deforestation against the distance to the zone border of FSC zones (left panel) and RESEX zones (right panel) for each kilometer within a buffer of 30 km (upper panel) and 50 km (lower panel).The regression, which is subject to this graph, is identical to equation 5 but replaces the $D \times T$ variables with full sets of distance-to-the-border effects and includes a dummy variable for each bin shown in the figure. The bins have a size of 3 km (in the 30km panel) and of 5 km (in the 50 km panel). Negative distances indicate that the grid cell is located inside a zone and positive distances are for grid cells outside. The dashed green line plots the predicted relation between the two variables *before* the zone was established and the solid blue line the values *after* the implementation.

The green dashed line shows deforestation rates before certification and the solid blue line illustrates their course after the zone's implementation. "The left and the right panel consider the situation around FSC certified zones and around RESEX zones, respectively. The upper figures include the first 30 km around the border and the lower figures zoom out to 50 km around the border. Note that for the FSC panel the maximum distance from a center to the closest border is 40 km. Hence, the inside distance to the FSC zones is limited to 30 km here in order to keep results comparable. Figure A.10 in the appendix provides a closer look to within a 10 km buffer around the border.

In the FSC panel the increase in deforestation after certification is clearly visible by the gap between the blue line and the green dashed line. For the control group, grid cells outside the zone, post-treatment deforestation is lower between kilometre 6 and kilometer 27 and slightly higher close to the border and with larger distances. Thus, a clear spillover effect is not visible.

The upper graph on the right side reveals that inside of public SFM zones, deforestation rates after the designation (solid blue line) also jumped above the pre-treatment level (dashed green line) on both sides of the border. Both post-designation curves remain on an equal level and appear to be quite stable around the zero-line. Interestingly, the pre-treatment curve shows lower level close to the border and increases steadily with higher distances to the border while exceeding the post-line around kilometre 25. This indicates increasing pressure from the neighbourhood on the forest area, which is treated. This becomes even more visible in the lower 50 km graph, where the pre-treatment begin to increase sharply, right outside of the border.

In summery, the graph revealed that, in case of private zones, deforestation rates between inside and outside grid cells rather approximate after the certification and the discontinuity at the border, which could be seen before, almost vanishes. Similarly, a discontinuity in case of public zones is not found after implementation of the policy and differences between the inside and outside level of deforestation rates, which could be observed before the treatment, are offset afterwards.

Table 5 presents the results from an estimation of the spatial DD equation 5. The first part of the table, columns (1)-(3) show the results of the FSC sample and columns (4)-(6) show the estimations of the RESEX sample. Each column includes cell and year fixed effects, to take unobserved time-invariant and location-invariant variables into account. Columns (1) and (4) use the full sample, including all grid cells which are located within 60 km around the border. The rest of the columns include only cells within 30 km distance from the border, where location characteristics are assumed to be more similar. In columns (1), (2), (4) and (5) the treatment group are all grid cells that fall within a zone. In columns (3) and (6) I further control an external treatment effect by including the first 10 km outside of the zone. The remaining outside cells form the control group.

In the three columns of the FSC panel, the coefficient of the interaction term $Inside \times T$, which accounts for the treatment effect close to the border, is positive and significant. The triple interaction term $Inside \times T \times D$ includes the continuous variable D which

Table 5: Spatial DD

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	1.285***	1.304***	1.757***	0.086	0.059	0.153
	(0.358)	(0.396)	(0.513)	(0.068)	(0.059)	(0.122)
Inside × D × T	1.673	2.233	0.181	1.067***	1.225**	0.789
	(1.095)	(1.764)	(2.185)	(0.408)	(0.508)	(0.671)
D × T	1.135	1.001	3.052	-0.932***	-1.156***	-0.719*
	(0.780)	(1.498)	(1.978)	(0.237)	(0.328)	(0.435)
T	-0.682*	-0.833**	-1.286**	0.416***	0.307***	0.213**
	(0.392)	(0.395)	(0.513)	(0.091)	(0.071)	(0.104)
Outside × T			0.599			0.158
			(0.429)			(0.144)
Outside × D × T			-2.833			-1.368
			(4.227)			(1.282)
Total Effect	0.60	0.47	0.47	0.50	0.37	0.37
TE Distance	1.43	1.42	1.42	0.53	0.38	0.38
Control group	60km	30 km	30(-10)km	60km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	3.026m	1.42m	1.42m	17.3m	11.9m	11.9m
R-sq	0.17	0.17	0.17	0.13	0.13	0.13

Note: The dependent variable is the deforestation rate in a grid cell. *Inside* is an indicator equal to one if a grid cell is located in the zone and T is equal 1 as soon as a zone is certificated or officially established, respectively. The dependent variable is the percent deforested in a grid cell. The internal treatment effect is measured by ($Inside \times T$). Variable D measures the distance to the border in km. *Outside* is a variable that is one if a grid cell is located within the first 10 km outside of the border. The external treatment effect is measured by ($Outside \times T$). All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

measures the distance of a grid cell to the border. The coefficients are positive but not significant suggesting that the deforestation rates further increase closer to a zone's centre.

Columns (3) include interactions with the *outside* dummy that indicates grid cells located within the first 10 km outside of a zone's border. The intention here is to capture the external effect of the treatment and to control for possible spillover effects to the neighbouring grid cells. The coefficient of $Outside \times T$ is positive but not significant, while the coefficient of $Inside \times T$ is robust to the inclusion of the additional interaction terms and slightly higher than in columns (1) and (2). The coefficient of the triple interaction term *Outside* $\times T \times D$ is negative which corresponds to the lower levels which could be seen in figure 5. However, due to the high variance the result cannot be statistically verified. For the RESEX panel, the coefficients of the treatment interaction term become insignificant compared to results in the baseline table 4. The triple interaction term has a positive and significant coefficient which indicates that timber production is taking place closer to a zone's centre than to the border. The interaction term $D \times T$ is negative and significant, describing a decrease in deforestation within a certain distance to the border. However, considering the total effect *TE Distance* of the treatment with higher distance to the border and the total treatment effect *TE* at the border, it is visible that they are almost equal in size, although the later is not significant.

The results of the spatial examination of the sustainable forest management policy showed, on the one hand, that for the public zone's the deforestation levels outside and inside the zone approximated after the establishment of the zone. Thus, for the public zones, the establishment of the zone seems to have a rather general effect on the whole region by stabilizing deforestation rates, which might be due to more monitoring efforts or better organized logging.

However, outside of private zones, deforestation rates close to the border remained stable over the certification process and afterwards. They exhibit a tendency to increase. The inside deforestation rates jumped to the level of the outside deforestation close to the border after certification. The results here suggest that the effect of the certification could be rather detected within the treated zone and does not influence deforestation on the outside.

Taking deforestation in hectare as a dependent variable, table A.12 exhibits that in the private zones deforestation close to the border increases just by 0.27 ha, while with higher distance to the border deforestation increases by even 0.82 ha. However, this is only significant for the large sample, which includes all grid cells within 60 km around the border. The treatment effect of the public zones becomes completely insignificant. Furthermore, results are robust to a nonparametric specification shown in table A.13 and to different buffer sizes around the border, which is shown in table A.14.

5.2 Time trends

Besides the investigation of discontinuities at the border of a zone, a discontinuity at the temporal threshold, the year of implementation, underpins the existence of a treatment effect. Moreover, trends in deforestation rates before and after the treatment occurs, allows one to distinguish long-term from short term effects of the policy.

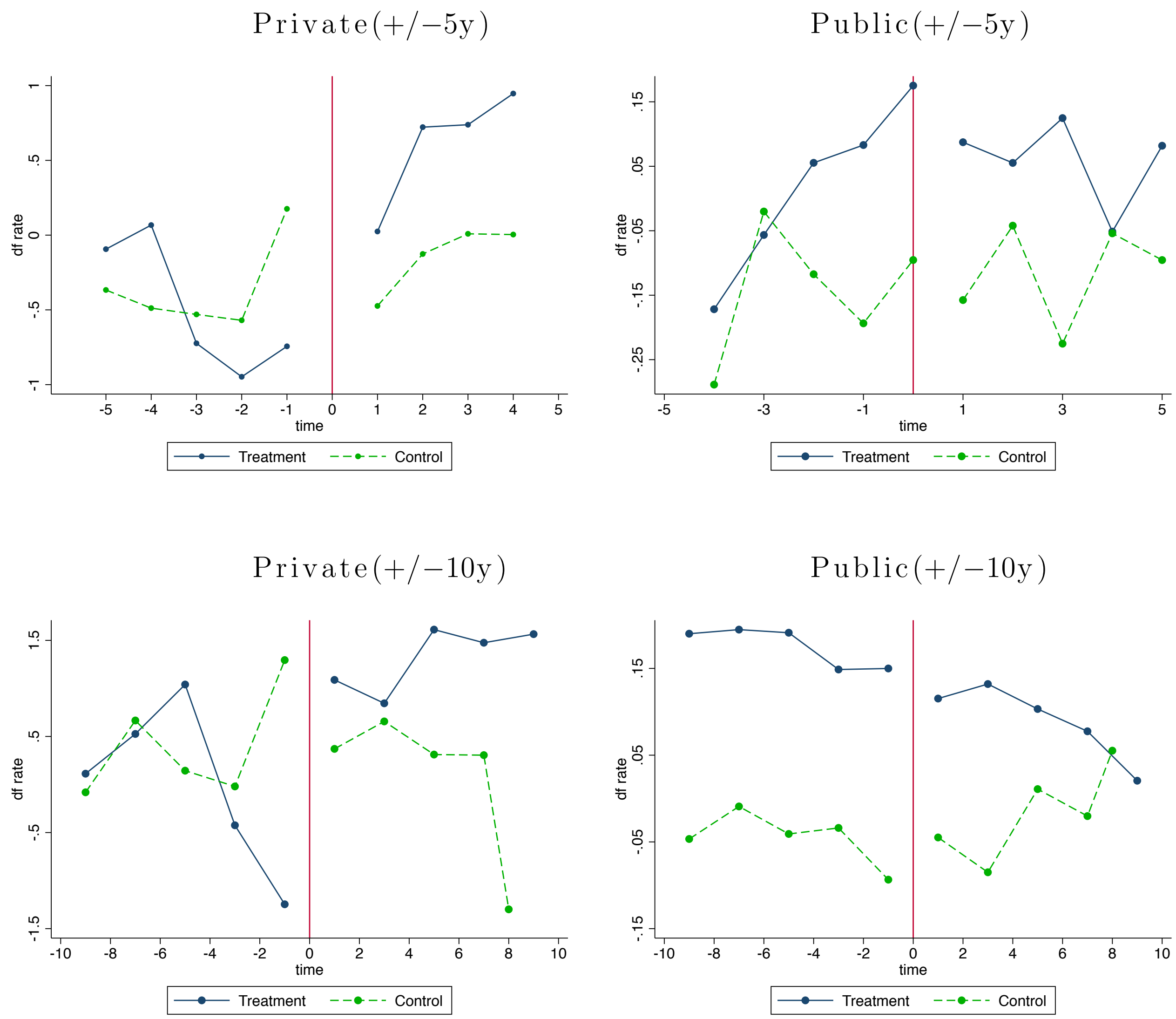

Figure 2: Diff-in-diff trends

The figure plots the β coefficients of the treatment on deforestation against the years before and after the date of implementation of FSC (left panel) and RESEX (right panel) zones for each year before and after the date of the treatment. The regression, which is subject to this graph, is identical with equation 6 but replaces the $YT \times T$ variables with full sets of years-since-destination effects as well as includes a dummy variable for each bin shown in the figure. Bins sizes are one year for the upper panels and two years for lower panel. Negative years indicate that years before the implementation date and positive values years afterwards The dashed green line plots the predicted relation between the two variables for *non-treated* grid cells and the solid blue line the values of ever *treated* grid cells. The upper panel plots rates deforestation against time in a ten year period; 5 years before and 5 years after the treatment. The lower panel estimates deforestation rates in a two-year rhythm for a 20-year period; 10 years before and 10 years after. The regressions follow specification given in equation 6, including dummies for each possible year before and after the treatment.

Figure 2 plots deforestation against time. Negative values indicate years before the implementation and positive values years after the implementation of the zone. The blue solid line shows estimated deforestation rates for the treated grid cells and the green dashed line for grid cells in the control group. The graphs on the left are estimations of the FSC certified zones and illustrates that around years before the the first audit, deforestation rates already begin to decrease and fall below the outside level 3 years before. This suggests that certificate holders reduce deforestation on their land before the audit, probably in order to increase the chances to of acquiring the certificate. The data are limited in terms of information about the ownership and change of the ownership of the area. Thus, the cut-off point here is when the firm and its forest has successfully passed the third-party audit. It appears, that this leads to a clear jump of the blue solid line at the border, indicating a rapid increase of deforestation rates after the firm received the certificate.

The right panel of figure 1 plots the estimation results for the public zones. In contrast to the private zones, the deforestation rates after the designation of the zone are lower and show a tendency to decrease further the longer the time they are designated as a conservation zone. Outside curves appear to stay quite stable with a slight trend to decrease over time.

Table 6: Time DD

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	1.349***	2.521***	1.416***	-0.297***	-0.084	-0.298***
	(0.358)	(0.742)	(0.399)	(0.076)	(0.069)	(0.092)
Inside × YT	-0.094**	-0.607***	-0.110**	0.188***	0.118***	0.213***
	(0.044)	(0.210)	(0.050)	(0.041)	(0.038)	(0.049)
Inside × YT × T	0.216**	0.683***	0.229***	-0.180***	-0.129***	-0.205***
	(0.084)	(0.223)	(0.084)	(0.047)	(0.049)	(0.055)
YT × T	-0.085	0.092	-0.097	0.123**	-0.027	0.147***
	(0.073)	(0.203)	(0.077)	(0.049)	(0.061)	(0.055)
T	-0.663**	-1.354***	-0.731**	0.356***	0.061	0.357***
	(0.321)	(0.455)	(0.354)	(0.100)	(0.092)	(0.112)
Outside × T			0.249			-0.011
			(0.275)			(0.084)
Outside × YT			-0.061			0.073**
			(0.043)			(0.037)
Outside × YT × T			0.047			-0.074*
			(0.083)			(0.038)
Total Effect	0.69	1.17	0.69	0.06	-0.02	0.06
TE Over Time	0.72	1.33	0.71	0.19	-0.06	0.21
Sample	10 years	5 years	10 years	10 years	5 years	10 years
Control group	30km	30 km	30(-10)km	30km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	1.497m	0.859m	1.497m	11.9m	7.216m	11.9m
R-sq	0.17	0.25	0.17	0.13	0.22	0.13

Note: The dependent variable is the deforestation rate in a grid cell. *Inside* is an indicator equal to one if a grid cell is located in the zone and T is equal to one as soon as a zone is certificated or officially established, respectively. The dependent variable is the deforestation rate in a grid cell. The internal treatment effect is measured by ($Inside \times T$). Variable YT measures the number of years before (-) or after (+) the treatment date. *Outside* is a variable that is one if a grid cell is located with in the first 10 km outside of the border. The external treatment effect is measured by ($Outside \times T$). All columns include grid and year fixed effects. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on municipality fixed effects. ***, **, *=significant at 1, 5 and 10 % level.

Table 6 estimates equation 6 for both type of zones with including 5 years around the treatment date in columns (2) and (4), and 10 years in the other columns. Columns (3) and (6) include spillover effects on grid cells located within 10 km around the zones. Table 6 confirms first graphical impressions since the internal diff-in-diff parameter $Inside \times T$, which measures the direct effect of the treatment around the certification date, is significant and positive in all three specifications estimated in the FSC panel. The coefficient is larger in size and significant at a higher level in the case of the shorter 10 years range around the treatment date compared to the longer 20 years period. The interaction $Inside \times YT$ describes the time trend of deforestation within the zone before the certification. In line with the results presented in table 2, the coefficient is negative and relatively large in the 5 years before the audit. The triple interaction of $Inside \times YT \times T$

estimates the development of the effect in the years after the treatment. This coefficient is positive and significant for all specifications, but about 3 times higher in the shorter time period in column (2). These results combined with the graphical illustration in figure 2 yield to the conclusion that until one year before the first audit, which is the most extensive and detailed audit, forest owners keep deforestation particularly low [15] and relax this strict behavior after a successful certification process, what explains the increase in deforestation afterwards.
For the public zones, the coefficient of interest of the interaction term $Inside \times T$ turns negative and is significant in the sample of the large period. Interestingly, the situation in the public zones is quite the opposite to what we see for the private zones; an increase in deforestation before the designation of the zone, a drop in deforestation rates afterwards and a continuously decreasing trend over time, while deforestation in the control group show some evidence to increase. While the total effect of the policy is very similar or identical to the baseline specification for the private zones, it is close to zero for the public zones. Thus, for public zones pressure on the forests seem to have been increasing before the designation and appear to be controlled afterwards.
Table A.15 again takes deforestation in level as the dependent variable and provides quite similar results. The total effect remains equal over time for the certificated zones and is close to zero for the public zones. Including a the second polynomial in table A.16 does not change the results of the treatment effect. Changing the number of observations by increasing the buffer zone around the border to 60 km in table A.17 and limiting it to 10 km in table A.18 does not change the significance and sign of the coefficients but slightly increases and decreases the effect in size, respectively.

Up to here, the results have shown that private forests which are certified for SFM practices increase their deforestation rates once they have passed the audit. Results for public zones suggest that forests there experienced increasing pressure before the designation of the zone and significantly lower deforestation rates when controlling for time trends. The next chapters further examines the effectiveness of the sustainable-use zones by splitting up the heterogeneity of their microeconomic location and macroeconomic drivers. To capture this, first the focus lies on the geographical location of the zone and its environment, which differs between the zones but is fixed over time. Second, it is estimated how changes in commodity prices, which may lower or increase the opportunity costs of deforestation, change the outcome of the SFM polices. Prices are considered as exogenous shocks which change over time.

[15] This could happen via better monitoring to combat illegal deforestation or via lower harvesting rates.

5.3 Local Heterogeneity

With an area larger than 5 million km^2, the Brazilian Amazon demonstrates quite heterogeneous patterns in terms of infrastructure fertility and accessibility to markets or to the processing industry. Consequently, the pressure on the forest also differs substantially over the whole region. As suggested in model by Pfaff et al. (2014), the probability of the forest being cleared depends on the rent that the land provides. If a conservation zone is implemented at a place where the land rent is zero or below zero (due to clearing costs), the policy will not be effective since land conversion is unlikely even in the absence of protection. The importance of the positioning of conservation zones towards places with human activity to actually prevent deforestation is highly debated in the literature. For instance, in a study across 147 nations PA networks Joppa and Pfaff (2009) find that the majority of protected areas over all countries are located with high distance to roads and cities, which reduces their effectiveness remarkably. In this subsection, I study the effects of four local characteristics on the effectiveness of private and public sustainable-use zones in reducing deforestation rates, following an approach by Dell (2015).

The location of sustainable-use zones plays a twofold role for the effectiveness of the zone since it could influence both the pressure on the forest and the prospects of the SFM project. First, the distance to the closest city is important as a potential sales market or a hub for further transport to export markets. Apart from that, land rents close to cities are usually higher than in rural areas, which makes clearing there more probable. Second, low distance to roads are important for a direct transport of harvested timber but also provides easier access to the forests for illegal operators. Third, I take distance to the closest sawmill as a proxy for access to the proceeding industry which again could save transaction costs for SFM producers but also gives incentives for higher deforestation in the surrounding of the mill. Finally, I use the distance to the closest navigable river as an alternative form of transportation for extracted forest products and timber. In the legal Amazon, rivers are a common way of shipping timber from one place to another. It is the most cost saving form for long distance transports (Barros and Uhl, 1995). Especially for traditional populations and forest communities, the access to a river can be essential to reach markets in remote cities or harbours, since they often lack motorized vehicles.

Table 7: Local characteristics: Private zones (FSC)

	(1) City	(2) City	(3) Roads	(4) Roads	(5) Sawmill	(6) Sawmill	(7) River	(8) River
Inside	-1.136**	-1.242***	-0.536*	-0.629**	-0.446*	-0.546**	-0.773**	-0.867***
	(0.429)	(0.414)	(0.281)	(0.310)	(0.239)	(0.262)	(0.307)	(0.324)
Inside × Dist. Site	-1.343***	-1.381***	-2.027***	-2.084***	-2.115***	-2.153***	-1.678***	-1.756***
	(0.390)	(0.357)	(0.586)	(0.623)	(0.525)	(0.549)	(0.542)	(0.550)
Inside × T × Dist. Site	0.035	0.137	0.621	0.612	0.606	0.440	0.534	0.678
	(0.527)	(0.596)	(0.684)	(0.736)	(0.545)	(0.574)	(0.620)	(0.686)
Inside × T	1.031**	0.940*	0.449	0.429	0.499*	0.566*	0.548	0.466
	(0.455)	(0.515)	(0.318)	(0.350)	(0.298)	(0.323)	(0.483)	(0.523)
T	-0.202	-0.133	0.249	0.256	0.269	0.198	-0.205	-0.145
	(0.288)	(0.316)	(0.295)	(0.287)	(0.275)	(0.267)	(0.269)	(0.278)
T × Dist. Site	-0.359	-0.429	-1.135**	-1.109**	-1.096***	-0.934***	-0.368	-0.464
	(0.270)	(0.321)	(0.434)	(0.451)	(0.274)	(0.269)	(0.333)	(0.357)
Outside		-0.262		-0.219		-0.306		-0.164
		(0.195)		(0.227)		(0.191)		(0.219)
Outside × T × Dist. Site		-0.033		-0.112		0.019		-0.259
		(0.446)		(0.345)		(0.264)		(0.303)
Outside × Dist. Site		0.217		-0.039		-0.578		0.449
		(0.568)		(0.477)		(0.367)		(0.462)
Outside × T		-0.195		-0.025		0.290		-0.227
		(0.293)		(0.282)		(0.219)		(0.284)
Post Dist< 0.5	-1.97	-2.11	-2.38	-2.52	-2.28	-2.43	-1.94	-2.09
Post Dist > 0.5	-0.11	-0.30	-0.09	-0.20	0.05	0.02	-0.22	-0.40
Pre Dist < 0.5	-2.48	-2.62	-2.56	-2.71	-2.56	-2.70	-2.45	-2.62
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Observations	1.4m	1.4m	1.4m	1.4m	1.4m	1.4m	1.4m	1.4m
R-sq	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Note: The dependent variable is the deforestation rate in a grid cell. *Inside* is an indicator equal to one if a grid cell is located in the zone and T is equal 1 as soon as a zone is certificated or officially established, respectively. The dependent variable is the deforestation rate in a grid cell. The internal treatment effect is measured by ($Inside \times T$). The external treatment effect is measured by ($Outside \times T$). *DistSite* is a dummy variable that is one if the grid cell belongs to the 50% of grid cells (based on the entire sample) with the shortest distance to the geographical characteristic considered. These geographic characteristics are: Distance to the next urban space (city), distance to the closest road, distance to the closest sawmill and distance to the closest navigable river. Post Dist. > 0.5 and Post Dist < 0.5 give the computed total treatment effects for grid cells belonging to the 50% further away from the site and the total effect for those grid cells which are located closer to the site, respectively. Pre Dist < 0.5 reports the total effect before the treatment for gird cells located closer to the local characteristics reported in the table. All columns include zone and year fixed effects. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Tables 7 and 8 examine whether patterns of heterogeneity in the data are consistent with the hypothesis that the placement of zones determines their effectiveness. Columns (1),(3),(5) and (7) focus merely on the treatment effect and columns (2),(4), (6) and (8) take spillovers into account. The basis for the specifications here is column (1) of the baseline model in table 3. Additionally, a triple interaction term including the distance to each local characteristic is included to account for heterogeneity in the effect. I chose the model with *zone fixed effects* instead of *grid fixed effects* here to be able to include the interaction $Inside \times Dist.Site$ and the variable $Inside$, which makes it possible to calculate the pre treatment effect of a zone being located close to one of the geographical characteristics studies in this chapter.

The $Dist.Site$ is an indicator that equals one if the median distance from a zone to the closest city, road, sawmill or navigable river is lower than the median distance of all zones. Table 7 exhibits the results for the private, FSC certified zones.
Over all geographical characteristics the table show that being inside a forest that will be certified in the future reduces deforestation rates independently if the forest is relatively close to a place with human activity or not, this is shown by the negative sign of the coefficient of $Inside$ and $Inside \times Dist.Site$. However, the reductive effect is larger in size and significance if the forest is located closer to a city, road, sawmill or river. The treatment variable that shows the effect of the certification on deforestation in a grid cell is not significant for zones closer spots with economic activity or infrastructure. The treatment effect for zones far away from cities and sawmills is positive and significant. This suggests that FSC zones are increasing deforestation especially in remote places where commercial forestry and deforestation in general was very low before the FSC zone appeared. Moreover, it implies that they are more effective if access to markets and the processing industry is given. Another explanation could be that those zones, which are located closer to the markets, are economically more successful and can therefore afford better monitoring systems, which reduce illegal deforestation within their borders.
Total effects at the bottom of the table show that average deforestation rates for a grid cell being within the zone is about 2.5% lower if the zone is located closer to spots with higher forest pressure. By just comparing the reduction of the negative effect of a zone after certification, it is revealed that a zone close to a city loses about 21% of its effectiveness while zones far away from cities lose about 90% of their effectiveness.[16] This pattern is solid for all characteristics and shows that the augmenting effect certification has on deforestation is driven by those zones located further away from places with economic activity. The external treatment effect is insignificant for all geographical characteristics.

[16] This numbers are calculated as follows. For zones with high distance to cities the pre-effect before the certification was 1.136 and post-effect -0.11: $\frac{-1.136-(-0.11)}{-1.136} = 0.903$. Analogue for zones close to cities: $\frac{-2.48-(-1.97)}{-2.48} = 0.205$.

Table 8: Local characteristics: Public zones (RESEX)

	(1) City	(2) City	(3) Roads	(4) Roads	(5) Sawmill	(6) Sawmill	(7) River	(8) River
Inside	-0.154	-0.249*	-0.338***	-0.430***	-0.345***	-0.403***	-0.236	-0.274
	(0.145)	(0.150)	(0.062)	(0.080)	(0.081)	(0.097)	(0.165)	(0.172)
Inside × Dist. Site	-0.315*	-0.263	0.069	0.123	0.110	0.101	-0.143	-0.191
	(0.164)	(0.165)	(0.191)	(0.192)	(0.145)	(0.139)	(0.171)	(0.178)
Inside × T × Dist. Site	-0.031	-0.055	-0.056	-0.068	0.124	0.136	0.192	0.242*
	(0.109)	(0.123)	(0.113)	(0.124)	(0.092)	(0.097)	(0.118)	(0.128)
Inside × T	0.232***	0.304***	0.261***	0.325***	0.165***	0.209***	0.129	0.156
	(0.068)	(0.088)	(0.063)	(0.076)	(0.057)	(0.073)	(0.082)	(0.103)
T	0.234**	0.166	0.231**	0.162	0.324***	0.282***	0.282***	0.247***
	(0.101)	(0.109)	(0.098)	(0.098)	(0.098)	(0.106)	(0.070)	(0.079)
T × Dist. Site	-0.131	-0.106	-0.152	-0.139	-0.351***	-0.365***	-0.247***	-0.294***
	(0.119)	(0.131)	(0.109)	(0.110)	(0.129)	(0.132)	(0.079)	(0.083)
Outside		-0.362***		-0.407***		-0.121*		0.009
		(0.071)		(0.084)		(0.070)		(0.080)
Outside × Dist. Site		0.346***		0.487***		-0.104		-0.354***
		(0.093)		(0.119)		(0.138)		(0.126)
Outside × T × Dist. Site		-0.268**		-0.356***		0.113		0.363***
		(0.112)		(0.116)		(0.103)		(0.117)
Outside × T		0.309***		0.333***		0.094		-0.030
		(0.076)		(0.073)		(0.071)		(0.092)
Post Dist< 0.5	-0.17	-0.20	0.01	-0.03	0.03	-0.04	-0.02	-0.11
Post Dist> 0.5	0.08	0.06	-0.08	-0.10	-0.18	-0.19	-0.11	-0.12
Pre Dist< 0.5	-0.47	-0.51	-0.27	-0.31	-0.24	-0.30	-0.38	-0.46
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Observations	11.9m	11.9	11.9m	11.9m	11.9	11.9m	11.9m	11.9
R-sq	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Inside is an indicator equal to one if a grid cell is located in the zone and T is equal 1 as soon as a zone is certificated or officially established, respectively. The dependent variable is the deforestation rate in a grid cell. The internal treatment effect is measured by $(Inside \times T)$. The external treatment effect is measured by $(Outside \times T)$. $DistSite$ is a dummy variable that is one if the grid cell belongs to the 50% of grid cells (based on the entire sample) with the shortest distance to the geographical characteristic considered. These geographic characteristics are: Distance to the next urban space (city), distance to the closest road, distance to the closest sawmill and distance to the closest navigable river. Post Dist. > 0.5 and Post Dist < 0.5 give the computed total treatment effects for grid cells belonging to the 50% further away from the site and the total effect for those grid cells which are located closer to the site, respectively. Pre Dist < 0.5 reports the total effect before the treatment for gird cells located closer to the local characteristics reported in the table. All columns include grid and year fixed effects. All columns include zone and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table 8 shows the results for the public zone sample and reveals that a general lower deforestation rate before the implementation of the zone is only significant for zones in remote areas, since the coefficient of *Inside* is always negative. The only exception are zones close to cities, however, only if the external effect is not taken into account. The treatment effect is negative if the zone is located far away from cities, roads and sawmills and positive but not significant for zones with larger distances to rivers. For public zones the location effect appears to be even larger than for private zones. For instance, considering zones, which are located with high distance to roads, the area loses about 97% of the effectiveness it had before its designation as an extractive reserve.

For zones close to rivers a positive effect could be detected in column (8). In general, table 8 confirms that the establishment public zones has a higher effect on the surrounding area than private zones.

The external effects in column (2) and (4) show that after the designation of zones next to cities and roads, the deforestation decline significantly 10 km around the zones. However, deforestation rates increase in neighbouring forests of zones in more remote areas. These results are in line with the hypothesis that sustainable-use zones are effective when they are sited where the pressure on the forest is already large, however, if they are placed into the interior of a tropical forest, starting any timber production there will increase deforestation.

The external effects are not significant in the case of sawmills but positive if a zone is located close to a river. As mentioned above, for those public zones which are not connected to cities and harbours via roads, rivers become the only possibility to transport goods and people. Thus, in grid cells close to rivers (within and outside of the zones), deforestation increases after the designation of the zone, since access to the river-transportation network is created in order to let the inhabitants of the reserve participate in the trade with sustainable products. Results are robust to the larger control group of 60km, which is shown in tables A.19 and A.20. The total negative effects are slightly smaller than in the main specification. Moreover, tables A.21 and A.22 include grid fixed effects and reveal that the discrepancy between zones in high- and low-pressure locations is larger for private forest plots than for public reserves.

Summarizing the above, it could be seen that the effectiveness of private zones located close to economic centres, to the proceeding industry and to transport systems is higher than the effectiveness of public zones, while the spillovers on the surrounding area are negligible. The public zones could have an attenuating influence on deforestation in their neighbourhood if located at a spot close human activities, however, within their borders deforestation appears to significantly increase after designation as further the zone is located from infrastructure and cities.

5.4 Exogenous Price Shocks

In this section, an additional aspect contributing to the effectiveness of sustainable-use conservation zones, the changes in international commodity prices, is studied.

The intuition behind this link is that the opportunity costs of deforestation decreases when commodity prices are high due to the fact that expansion of crop fields and pasture becomes more profitable and deforestation itself becomes more feasible (Angelsen and Kaimowitz, 1999). From the empirical point of view, the advantage of including international prices into the estimation is that they are equal and exogenous for the entire Amazon and obviously also for the conservation zones. In contrast to strictly protected zones, sustainable-use zones do not only experience higher commodity prices as an increase of the land value and, therefore, as higher pressure on the forest, but also as a potential increase of their own income. This, however, depends on the production structure of the zone and of the commodity whose price increases. In this study, I use the prices of four commodities of which two are agricultural commodities, produced outside of the zones, and two are commodities, which are also produced inside the zones. First, I consider the production of the most land intensive good in the Brazilian Amazon, which is cattle. A strong correlation between cattle ranching and recent deforestation is suggested, since crops tend to be planted on previously used pastures and not directly on newly deforested area. For instance, Barona et al. (2010) and Morton et al. (2006) find that increasing soy production shift cattle ranching further north, where agriculture has not arrived yet. Carriquiry et al. (2016) confirm that especially states located at the agricultural frontier are likely to have increasing number of cattle ranching. For instance, in the state Rondônia, 30% of the total territory is covered by pasture at places where has been closed forest a few years before. Similarly, the expansion of crop fields, especially soybeans and corn, reached remarkable dimensions in the recent years.[17] Consequentially, the relationship between rising commodity prices and decreasing forest cover in the Amazon is subject of various studies, from which I want to emphasize three here:

In a panel data set including over 300 municipalities in Southern Amazon states, Assunção et al. (2015) find that deforestation is responsive to agricultural prices, such that deforestation declines when agricultural prices are low. However, anti-deforestation policies, such as the establishment of new conservation zones, implemented between 2004 and 2008 significantly reduced deforestation, even in times of commodity price booms. Their results are in line with those presented in a broader study by Hargrave and Kis-Katos (2013), covering the entire Amazon over a longer time period. The authors conclude that the remarkable decrease in deforestation in the 2000s could be partly attributed to the implementation of monitoring and control policies while higher agricultural prices and lower timber prices had an opposite effect. Finally, Harding et al. (2018) ,who disentangle the single policies, show that the conservation zone policy is related with leakage to unprotected land when commodity prices increase.

[17]According to numbers published by the IBGE (2017) soy fields increases by 69503 km^2 and corn fields by 31140 km^2 between 2002 and 2015.

Ideally, conservation zones could reduce the pressure of high commodity prices on the forest as they form a blockade which stops the agricultural frontier to move further into intact forest land.
Next, I take a look at timber, which is the main product of the FSC certified zones and is also important for the economy in the RESEX zones. Compared with the agricultural sector the timber sector nowadays plays a smaller role in the deforestation of the Brazilian Amazon.[18] Nevertheless, it indirectly supports agriculture expansion by opening up new paths into the forest, since for species traded with high enough prices, the construction of new roads can be economically beneficial (Chimeli et al., 2012).
Higher timber prices also increase the value of sustainably produced timber and sustainably managed forest land (Damette and Delacote, 2011). Thus, higher prices could have a twofold effect on the envriomental outcome of sustainable-use zones. On the one hand, they could make investment in the extension of the production area more attractive, if opportunity costs of illegal harvesting and the benefits from sustainable production are high enough. On the other hand, they could be an incentive for sustainable foresters to increase production and overharvest the forest in years when timber prices peak. Still, one of the main principles of sustainable forest management are fixed, pre-determined harvest rates which should not be exceeded to maintain the ecological system. Thus, the expected outcome for effective SFM zones are smooth deforestation rates over periods of timber price fluctuations.
The fourth price index I include is an index for non-timber forest products like rubber, fruits, and nuts. I take the three main NTFP products Açaí (*Euterpe oleracea*), Brazil nuts (*Bertholletia exclesa*), rubber (*Hevea brasiliensis*) [19] produced in the Brazilian Amazon and weight them according to their production value in 2002. The NTFP production is seen as a conservation strategy that supports traditional livelihoods and increases the value of forests. In the extractive reserves this production is used for both; own consumption and market sale. In the FSC zones, the production is quite limited. Only 3 of 35 FSC zones are documented to extract other forest products but timber, which might be due to their lower economic value. In a theoretical model on rubber collection, Jaramillo-Giraldo et al. (2017) estimate that in the Amazonian state of Acre, a potential average yield of 0.36 kg/ha/year is realistic, which is not sufficient to secure the livelihood of a rubber collector without governmental subsidies. Similarly, a study

[18]While it was the most important sector in the region in the region from the 1970s to the early 2000s, it lost significance in recent years due to a strict policy change and the high profits offered in large scale agricultural business.

[19]In the 19th and at the beginning of the 20th century, when natural rubber began to be an essential material for the production of tires, planes and military equipment, thousands of people migrated to the Amazonian region where the material has its natural origin. This boom ended suddenly when the British biologist Henry Wickham took 70,000 seeds of *Hevea brasiliensis* to plant them in Sri Lanka, Malaysia and Singapore in order to establish large plantations. Nowadays about 90% of the natural rubber production comes from Asia.

by Shone and Caviglia-Harris (2006) finds that the harvest value from the collection of NTFP is around US$35/ha/year, while at the same time the income from a crop yield is US$143/ha/year.[20] This small revenue is often due to a lack of local markets for these products and a limited access to the large and well-paying export markets.
In contrast to the three other commodities, the relationship between deforestation and an increase in the price of these forest products is expected to be negative, at least for those zones that actively produce them. Naturally, the more forest is lost, the less can be extracted.

The estimated model of table 9 is analogous to baseline model presented in column (2) of tables 3 and 4 but extended by each commodity's price index. I interact the price index with the treatment interaction term $Inside \times T$ and, consequentially, with all subterms of it.

[20]Other studies find a range of US$17- 6330 ha/year (Arets and Veeneklaas, 2014), while one has to be careful to in differentiate between potential, realistic and actual harvest quantity.

Table 9: Price Effects on Deforestation: FSC

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.932**	0.974**	1.091**	0.866**	1.006**	1.304**	1.211***	1.192***
	(0.346)	(0.382)	(0.404)	(0.392)	(0.443)	(0.481)	(0.329)	(0.350)
Inside × T × Price Index	6.094	5.825	1.196**	1.894***	0.482	-0.054	0.126	0.363
	(4.703)	(5.421)	(0.496)	(0.554)	(0.860)	(0.881)	(2.260)	(2.212)
Inside × Price Index	5.501	4.497	-1.823***	-2.360***	1.232	1.365	-0.654	-0.980
	(19.155)	(20.325)	(0.501)	(0.701)	(1.535)	(1.788)	(3.481)	(3.492)
T × Price Index	-8.533**	-8.251*	-1.519***	-2.205***	0.070	0.593	0.493	0.258
	(3.550)	(4.118)	(0.539)	(0.595)	(0.722)	(0.781)	(2.218)	(2.165)
Price Index	8.361	9.289	1.479**	2.017***	-0.889	-0.996	2.216	2.538
	(9.384)	(11.940)	(0.544)	(0.678)	(1.382)	(1.655)	(2.429)	(2.418)
T	-0.195	-0.239	-0.043	0.181	-0.676	-0.966*	-0.724*	-0.706
	(0.399)	(0.419)	(0.523)	(0.533)	(0.482)	(0.508)	(0.419)	(0.443)
Outside × T		0.162		-0.665**		0.925***		-0.067
		(0.198)		(0.325)		(0.223)		(0.270)
Outside × Price Index		-4.449		-1.779***		0.417		-1.202
		(11.701)		(0.643)		(1.412)		(0.961)
Outside × T × Price Index		-1.060		2.102***		-1.772***		0.827
		(3.563)		(0.593)		(0.544)		(0.982)
In. PI Effect Post	0.87	0.82	0.26	0.06	1.24	1.31	0.48	0.44
In. PI Effect Pre	0.60	0.60	-0.13	-0.13	0.18	0.19	0.20	0.20
Ex. PI Effect Post		-0.68		-1.18		-0.43		-0.79
Ex. PI Effect Pre		0.21		0.09		-0.30		0.17
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Observations	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.4m
R-sq	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Note: The dependent variable is the deforestation rate in a grid cell. *Inside* is a dummy indicating all grid cells within a zone and *Outside* is a dummy indicating all grid cells within the first 10 km outside the zone. T is a dummy which is one for all years the area receives the treatment. Column(1)-(2) includes the price index for cattle, (3)-(4) includes the price index for corn, (5)-(6) include the price index for Non timber forest products. The price index is based on the year 2002 and weighted by a municipality-specific commodity intensity. Column (2), (4), (6) and (8) additionally include controls for the external treatment effect. Total Effects of the price on the deforestation rates before and after the treatment are given at the bottom of the table. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table 9 shows that the positive treatment effect $Inside \times T$ is robust to the inclusion of any price index. The triple diff-in-diff interaction term $Inside \times T \times PI$ describes the the treatment effect at the time of high commodity prices. A positive value would indicate that higher prices increase deforestation even more within a certificated zone. A negative sign of its coefficient would indicate that deforestation rates are lower within the treated zone when prices are high, compared to the contrafactual. The only commodity

for which the coefficient of the triple interaction term is significant is corn in column (3) and (4). The positive coefficient indicates higher deforestation after certification in the presence of high corn prices, which is not the expected outcome for a well-working SFM zone, such as described above. Taking a look at the coefficient of $Inside \times PI$, which provides information about deforestation rates before the certification shows a negative sign and therefore indicate lower deforestation rates before. Computing the total effects results in an increase of 0.39% [21] what corresponds to additional 0.17 ha per grid cell.
Regarding the external treatment effects in column (4) of table 9 shows that there are no spillover effects of the sustainable forestry zone which would prevent to forests in the neighbourhood from higher deforestation, motivated by high cattle prices. The opposite is true for timber prices. Here the treatment effect is positive but turns negative when timber prices are high. This indicates that the presence of FSC certificated forestry projects in a region decrease conventional or illegal logging in the direct neighbourhood. In times of high timber prices, managers of certified zones might be more willing to invest, prepare and protect the surrounding areas for being included in the certified zone in the future.
In general, the total effects in the bottom line show that after certification, high prices of any commodity included in this study increase deforestation within the zone, however only significantly in the case of corn. Deforestation in the neighbouring forests is lower in the presence of the private zone and with high prices, which could be interpreted as a sign of higher protection efforts to forests near by, especially when pressure on these forests increases.

For extractive reserves, table 10 presents results of the analogues model used in table 9. The triple interaction term $Inside \times T \times PriceIndex$ is positive for high agricultural prices and negative and significant for high prices of commodities produced within the reserve. The treatment interaction term $Inside \times T$ accounts for the effect of the SFM zone after its implementation in the times of low timber prices. In columns (1) and (2) the table exhibits an increase in deforestation rates after the designation of the zone independently of the prices. However, in presence of high agricultural prices the coeffcients are only significant at the 10% level and not significant in columns (3) and (4). The external effect shown in column (2) suggests that high prices for cattle products increase deforestation rates in the forests that surround the extractive reserves. .
Columns (5) and (6) show the expected negative values of high timber prices on the zone after designation. Also within the first 10 km outside the zone a significant reduction is found. This points in the direction of higher resistance against the pressure from the

[21] Note that total effects in tables 9 and 10 are calculated by: $\beta^{Inside \times T} + \beta^{PI} \cdot \overline{PI} + \beta^{Inside \times T \times PI} \cdot \overline{PI} + \beta^{Inside \times PI} \cdot \overline{PI}\ \beta^{T \times PI} \cdot \overline{PI} + T =$ *In. PI Effect Post* and $\beta^{PI} \cdot \overline{PI} + \beta^{Inside \times PI} \cdot \overline{PI} =$ *In. PI Effect Pre*

Table 10: Price Effects on Deforestation: RESEX

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.245***	0.299***	0.216***	0.272***	0.045	0.077	0.190***	0.262***
	(0.070)	(0.088)	(0.075)	(0.092)	(0.056)	(0.076)	(0.063)	(0.087)
Inside × T × Price Index	0.277*	0.338*	0.029	0.035	-0.070***	-0.084***	-0.061***	-0.059**
	(0.160)	(0.183)	(0.033)	(0.040)	(0.021)	(0.025)	(0.021)	(0.027)
Inside × Price Index	-0.304	-0.374	0.005	0.005	0.149***	0.172***	0.094**	0.081*
	(0.243)	(0.288)	(0.044)	(0.051)	(0.036)	(0.045)	(0.038)	(0.043)
T × Price Index	-0.434**	-0.496***	-0.029	-0.035	0.014	0.028	0.069**	0.068*
	(0.165)	(0.187)	(0.030)	(0.037)	(0.016)	(0.020)	(0.028)	(0.035)
Price Index	0.065	0.135	-0.006	-0.007	-0.032	-0.054	-0.077*	-0.064
	(0.301)	(0.346)	(0.034)	(0.041)	(0.040)	(0.044)	(0.044)	(0.051)
T	0.123	0.071	0.123	0.068	0.193**	0.161*	0.139*	0.069
	(0.085)	(0.092)	(0.084)	(0.093)	(0.076)	(0.087)	(0.075)	(0.080)
Outside × T		0.165**		0.169**		0.090		0.203**
		(0.074)		(0.072)		(0.069)		(0.079)
Outside × Price Index		-0.234		-0.005		0.069		-0.033
		(0.195)		(0.037)		(0.043)		(0.043)
Outside × T × Price Index		0.222**		0.027		-0.044**		0.000
		(0.110)		(0.030)		(0.018)		(0.027)
Inside High PI	-0.03	-0.03	0.34	0.34	0.30	0.30	0.35	0.36
Inside Low PI	0.37	0.37	0.34	0.34	0.24	0.24	0.33	0.33
Outside High PI		-0.14		0.22		0.25		0.24
Outside Low PI		0.24		0.24		0.25		0.27
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Observations	11.9m	11.9	11.9m	11.9m	11.9	11.9m	11.9m	11.9
R-sq	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Note: The dependent variable is the deforestation rate in a grid cell. *Inside* is a dummy indicating all grid cells within a zone and *Outside* is a dummy indicating all grid cells within the first 10 km outside the zone. T is a dummy which is one for all years the area receives the treatment. Column(1)-(2) includes the price index for cattle, (3)-(4) includes the price index for corn, (5)-(6) include the price index for Non timber forest products. The price index is based on the year 2002 and weighted by a municipality-specific commodity intensity. Column (2), (4), (6) and (8) additionally include controls for the external treatment effect. otal Effects of the price on the deforestation rates before and after the treatment are n at the bottom of the table. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

forest industry of the public zones after the official establishment, while similarly timber production inside the zone remains stable.

Columns (7) and (8) focus on non-timber forest products and reveal a negative coefficient of the triple interaction term for the inside effect. This is the expected result, since forest density is positively correlated with the outcome of these products (Thomas et al., 2017). Table A.28 dismantles the NTFP index and estimates the effect for each of the three products. It can be shown that while the treatment effect is always negative for high prices, it is only significant in the case of brazil nuts. A possible explanation for this is that the global popularity of these nuts increases more and more and, simultaneously, that their harvest requires a intact ecosystem of the forest (Wadt et al., 2008). Regarding the magnitude in the bottom lines of table 10, one sees that for both timber and NTFP the total treatment effect is slightly higher in the presence of high prices but still very similar to the outcome with low prices.

These main estimates are quite robust to different sizes of the control group, shown in the appendix table A.25 and A.26. To check of spatial autocorrelation in tables A.31 and A.32 cluster the error terms at the municipality-year level and finds almost identical results. One exception is the corn price effect that loses significance when controlling for spatial clustering in column (3). Additionally, I include the second price lag to control for time autocorrelation as suggested by Bazzi and Blattman (2014). Tables A.29 and A.30 show that results are also robust to this test.

6 Discussion and Conclusion

This paper started with the rather broad question of whether forests which are managed sustainably decrease deforestation compared to the contrafactual. To answer this question, I empirically assessed various parameters that could influence the effectiveness of public and private sustainable-use zones in the Brazilian Amazon.

The results imply that deforestation rates increased significantly in FSC certified zones after certification between 0.5 and 1.2%, while results for extractive reserves are not robust. In a related study, Blackman et al. (2018) assess FSC certified FMUs in Mexico and finds positive effects of certification on deforestation, however, results are not statistically significant. The results examining deforestation dynamics over time illustrate that while deforestation rates within FSC certified zones are reduced in the years before the first audit occurs, deforestation rates jump immediately to a higher level after a successful certification. Since the certified area has to be examined each year, a reason for the consequent increase in deforestation could be that auditing agencies are less strict in their shorter annual reports than in the first principle assessment or less willing to suspend a certified zone, which they have approved once. I also cannot rule out that the higher deforestation rates after the certification are still within the harvest limits given by the FSC . However, I could show that the forests studied in this paper would have experienced less deforestation without certification.

For the public extractive reserves, the small positive impact of designation on deforestation vanishes, when I control for spatial or time specific trends. Literature on deforestation patterns in extractive reserves show that while deforestation is found to be less often and smaller than in the neighbouring land, an increase in deforestation within the zone is found close to riverbanks and roads (Ruiz-Perez et al., 2005). Reasons for these higher deforestation rates are associated with a fall in rubber prices and with the entry of intensive agriculture into the area of the reserve (Funi and Paese, 2012). Moreover, it is argued that the co-management between state and local population appears to be the key to the effectiveness of a zone. The reserve population requires governmental help for monitoring the entire reserve and a strong executive power which consequentially follows up illegal deforestation within the reserve's border (Da Silva, 2004).

Additionally, the results show how important it is to take geographical heterogeneity of sustainable-use zones into account. For both types of zones, I find that the increase in deforestation is higher and only significant in zones implemented at forest plots, which are located remote from markets and transport possibilities. Particularly, I find that private zones with higher distance to cities lose about 90% of there reductive effect on deforestation after certification and public zones remote from roads even lose 97% of their effect after designation. These results are in line with other studies which find that the mitigating effect on deforestation is estimated to be about 2-5 times higher for zones located close to cities and roads (Pfaff et al., 2015) and up to ten times higher if they are located in a region with high agriculture activity (Anderson et al., 2016).

Moreover, in case of public zones, I show that spillover effects on the adjoining forests are significant and equivalent to the internal effects: Closer to human settlements, zones have a reductive effect on deforestation in their direct neighbourhood but for zones located further away spillovers lead to higher deforestation rates in the direct neighbourhood.

This supports, on the one hand, the hypothesis that sustainable-use projects bring more forest loss and degradation into intact forest lands, since they provide access for non-sustainable harvesting and agriculture projects (see Brandt et al. (2016); Kleinschroth et al. (2017)). On the other hand, it also emphasizes the potential of mitigating deforestation within and even beyond a zone's border if located in environments where pressure on the forest is high.

Deriving policy implications from these results is not that straight forward as one would expect. Simply putting zones where they are most needed is a valid request. They could have a high impact on overall deforestation if located at the right spots. However, one has to keep in mind that the primary objective for the implementation of these SFM zones is not to avoid as most deforestation as possible. The communities, firms or private agents, who seek for a FSC certification, are aiming to increase the profits of their timber production by acting in a sustainable manner which guarantees a long-term harvest and the appreciation of important export markets. For them, the ideal placement of their forest would be a location where, on the one hand, markets and sawmills are still easily accessible, to keep transport costs low, and where, on the other hand, monitoring costs are not too high. Monitoring costs, of course, increase where large scale agriculture is expanding rapidly and illegal deforestation is frequently observed.

The federal government implements extractive reserves in order to clear land tenures and to provide a habitat for traditional populations that received international attention in the past. For the state, it is similarly important to keep monitoring costs low and provide places, which are not permanently threaten by growing human settlements and agricultural projects. Nevertheless, bringing timber production into closed forest - even if it is sustainable - and leave the most threatened parts of the forest for agricultural extension, could not be the desired solution. A carefully edited plan is necessary that decides about which forest plots are adequate for sustainable-use by private actors and how monitoring in and protection of public reserves could be improved to give them a realistic chance to also work in high-pressure areas.

Finally, findings from exogenous price shocks on the zones have useful lessons in terms of their effectiveness to reduce deforestation. Forest in extractive reserves are shown to benefit from high prices of brazil nuts, which implies that their extraction should be further supported and potentially promoted as particularly forest-saving. As mentioned by Hutton and Leader-Williams (2003), the major part of the revenues of extractive products does not reach the local inhabitants of such reserves but is distributed between retailers along the supply chain. Thus, significant improvements in the collection of these products could be made by if companies shorten their supply chain or begin to directly source from the collecting communities.

The results of this study underpin conclusions from former studies, which emphasize the limited effectiveness of forest certification as a market-based instrument in the combat against forest clearing. This has several reasons, starting from the small diffusion of timber certification in tropical countries and a self selection bias into the program to failures in the monitor and control system. Future studies have to reflect the conceptual short-comings of the policy and potentially wrong incentives which, as this study shows, could be implemented unintentionally.

This study also joins the broad opinion of the academic literature, which identifies the location of a public sustainable-use as the essential determinant for its effectiveness in reducing deforestation. It goes beyond former studies by illustrating the importance of considering deforestation dynamics over time, which appear to be quite important for the evaluation of the zones as one is able to distinguish long-term and short-term effects of the implementation and identify when a lack of compliance is most probable. Moreover, I could identify different cases of positive spillover effects, which were especially strong for public zones in environments with growing pressure on the forest. Finally, the relationship between high commodity prices and the effectiveness of sustainable forest management has been emphasized as a fact which is often neglected in the discussion on sustainable-use zones as an instrument of environmental protection.

A limitation of this study could be seen in some missing important information. Data on the ownership, the pre-production volume of timber or other purpose of the certificated areas before certification could be important to better understand the selection into the program and the decrease-increase dynamics of deforestation. Another weakness of the study is to not detect leakage which is indirectly linked to the implementation of a SFM zone. For instance, lumber companies could also use certification as a way of "green washing" their image by officially presenting the certified forests and hiding the unsustainable production somewhere else (Rico et al., 2018) or buying timber from other operators in order to maintain the supply of timber in the region (Aukland et al., 2003). Therefore, to compute the net effect of the policies these leakages have to be further investigated and quantified.

These shortcomings prevent me from drawing stronger conclusions on the effectiveness of public and private SFM zones in the Brazilian Amazon. However, the shortcomings do not jeopardize the main conclusion of this paper that - independently of its governance form - sustainable forest management cannot be seen as an encompassing solution for high deforestation rates in economically weak environments but could be an ingredient in a well-elaborated policy mix, which might need international support and continuous evaluation.

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Appendices

A Online Appendix

Contents

A.1 Data

A.1.1 Creation of the FSC Data

To receive spatial referenced data was possible by using public reports on the certified areas available on the FSC website (FSC, 2017). These reports, written by the third party audit agencies, reveal information about size, company, types of tree harvested, fertilizers and socio economic background of the municipality as well as working conditions. As shown in figure A.3 in most cases they also give at least one coordinate point per SFM unit. Further information, like maps of the units or even shape files, are available on company websites. However the exact localization is only possible with the help of the Rural Environmental Registry (CAR, 2017). This is a national coverage electronic registry that has been mandatory for all rural properties since 28 May 2012, when the Law of the Protection of the Native Forests (Law 12.651/2012) has entered into force in Brazil. National implementation of a rural registry is based on past experiences of other states, such as Mato Grosso and Par, that required a registration since 2008 as a condition for obtaining rural credit in the priority municipalities. Information on the owner of rural property is not publicly available. The CAR data provide geo referenced data as well as information on the size on all registered properties in Brazil. By careful comparison between the form and location on company maps (see figure A.4), coordination points, and size of the certificated units, it was possible to identify 49 FSC certificated areas in the Brazilian Amazon.

E. Classificação da área florestal			
Área Total Certificada			50.044,703 ha
1. Área total florestal			49884,13 ha
a. Área total de florestas de produção		41874,28 ha	
b. Área total de florestas sem produção (sem colheita)		8009,85 ha	
- Área de florestas protegidas (reserva absoluta)	3860,45 ha		
- Área sem colheita de madeira e gerenciado apenas para a produção de produtos florestais não-madeireiros e serviços	3183,33 ha		
- Remanescentes florestais não produtivos	966,07 ha		
2. Total de áreas não florestais (ex. Corpos d água, áreas úmidas, campos, afloramentos rochosos, estradas, etc.)			160,57 ha
F. Propriedade/Classificação do Manejo			
Propriedade da terra			State/Public own
Gestão da posse *(listar Posse Primária para certificados de Grupo)*			private managem
A área certificada é: Manejo privado	50.044,703 ha		
Manejo público/do Estado	- ha		

C. Data da Certificação

A empresa foi certificada em 30/12/2005

D. Latitude e longitude da operação

Localização geográfica do portão de entrada da Unidade de Manejo Florestal:
W 62,6316
S 08,9973

Figure A.3: Certification report

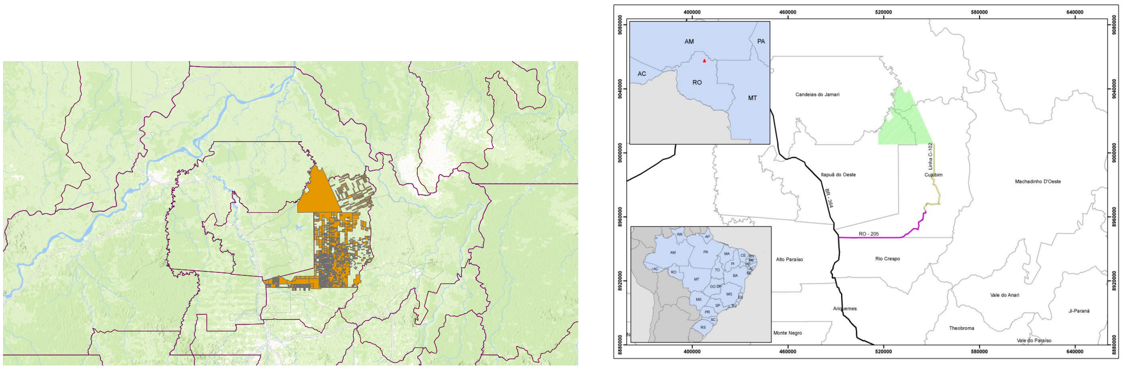


Figure A.4: CAR Data and Map provided by company

Moreover, to account for possible changes in the area which is under the scope of certification, I went through each report given for the identified areas in order to document changes in the scope of certification. For instance figure A.5 gives an example of the change in size of the PAE Equador.

Figure A.5: Change in the scope of certification

1.2. Exclusão de áreas do escopo do Certificado

O manejo florestal madeireiro do EMF ocorrerá apenas nas 23 áreas informadas acima que integram o Grupo de Produtores Florestais Certificados.

Em 2010, dois membros do Grupo, embora continuem associados e vivendo no PAE-Equador, decidiram se afastar temporariamente, sendo eles;

Nome do membro	Nome da área/colocação	Área total da UMF (ha)	Área de manejo (ha)	APP (ha)	Ano de entrada no Grupo
Francisco Pereira da Silva	Santa Bárbara	88,9	44,91	0,84	2005
Laurindo Maia de Alencar	RI	269,00	100,00	2,61	2010

A re-entrada destes produtores no Grupo de Produtores Certificados deve ser informada previamente ao organismo de certificação para que eles voltem a constar da lista e entrem na somatória de área certificada.

As demais 10 famílias de assentados extrativistas que também são associados à ASPPAE-SE e vivem no Projeto de Assentamento ainda não desenvolvem manejo florestal madeireiro, portanto não fazem parte do Grupo controlado pelo EMF e sua inclusão futura depende de informação pelo gerente do Grupo ao organismo de certificação.

A.2 Descriptives

Table A.1: Descriptive Statistics

Variable	Unit	Obs.	Mean	Min.	Max.	Source
Deforestation rate	%	23,642,122	0.66	0	100	own cal.
Deforestation	ha	23,642,122	0.33	0	100	INPE (2017)
Forest cover	ha	23,642,122	71.96	0	100	INPE (2017)
Inside FSC	km^2	1,688,723	0.02	0	1	FSC (2017)
Inside RESEX	km^2	1,688,723	0.23	0	1	MMA (2017)
Non-Forest Area	km^2	1,688,723	0.03	0	1	INPE (2017)
Soil quality	1-5	1,688,723	1.7	1	7	FAO (2017)
Distance city	km	1,688,723	64.57	0	364	MMA (2017)
Distance roads	km	1,688,723	42.49	0	251	INPE (2017)
Distance sawmill	km	1,688,723	201.17	0	694	MMA (2017)
Distance river	km	1,688,723	19.73	0	172	MMA (2017)
MUNICIPALITY LEVEL						
Deforestation	km^2	10,794	19.73	0	1,895	INPE (2017)
Forest cover	km^2	10,794	3,725	0	13,7627	INPE (2017)
GDP	Mio R$	10,794	327	2.74	67,572	IBGE (2017)
Exports	Mio R$	2,702	80.28	0	12,015	SECEX (2017)
Extraction Logs	Tsd m^3	10,794	17.56	0	1,521	IBGE (2017)
Extraction Fuelwood	Tsd m^3	10,794	14.89	0	1,000	IBGE (2017)
Extraction Acai	tons	10,794	192.8	0	34,421	IBGE (2017)
Extraction Brazil Nuts	tons	10,794	44.06	0	7,085	IBGE (2017)
Extraction Rubber	tons	10,794	4.22	0	550	IBGE (2017)
Employees	pers.	10,794	4,542	2	587,866	IBGE (2017)
Population(2000)	pers.	771	26,624	958	1,405,835	IBGE (2017)
Cattle	stock	771	83,293	100	1,264,991	IBGE (2017)
Soil quality	1-5	771	2.55	1	5	FAO (2017)
Accessibility	1-5	771	2.16	1	5	FAO (2017)

Table A.2: FSC zones

Company	First year certified	Last year certified	Reason for ending	Tenure	Area (km^2)
Agrocortex Madeiras do Acre Agroflorestal Ltda.	2015	2020	valid	F	1910
AMARCA	2004	2018	expired	C	417
Amata S/A. - Unidade Florestal Jamari	2012	2018	valid	F	521
APPAE Seringal Equador	2005	2015	expired	C	74
COMARU RDS Rio Iratapuru	2004	2013	suspended	C	8777
COOMFLONA	2013	2018	valid	C	259
FLONA Tapajós	2013	2018	valid	C	5330
Florestal Estadual do Antimary	2005	2014	expired	C	352
Florestal Santa Maria SA	2002	2016	expired	F	807
Indústria de Madeiras Manoa Ltda.	2005	2020	valid	F	744
Jari Florestal	2004	2017	suspended	F	3443
Juruá Fazenda Arataú	2002	2012	expired	F	439
Juruá Fazenda Picapau	2009	2017	expired	F	24.5
Juruá Fazenda Sucupira	2009	2017	expired	F	28.3
Juruá Florestal Ltda.	2002	2017	expired	F	59
Laminados Triunfo Ltda.	2005	2013	expired	F	76.7
LN Guerra Uberlandia	2015	2020	valid	F	1544
LN Guerra Industria e Comércio de Madeiras Ltda.	2012	2017	expired	F	470
Madeireira Segredo	2007	2016	expired	F	1057
Madeireira Vale Verde Ltda. (caracai)	2008	2013	expired	F	176
Mil Madeiras Preciosas Ltda.: Faz. Saracá	2007	2022	valid	F	359
Mil Madeiras Preciosas Ltda.: Faz. Dois Mil	1997	2022	valid	F	777
Mil Madeiras Preciosas Ltda.: Faz. Monte Verde I-V	2010	2022	valid	F	105
Mil Madeiras Preciosas Ltda.: Faz. Carribe II and II	2010	2022	valid	F	855
Ouro Verde Fazenda Canari	2006	2011	expired	F	87
Ouro Verde Fazenda Sao Jorge	2006	2011	expired	F	11.9
Ouro Verde Fazenda Bellas Aguas	2006	2011	expired	F	23.7
Ouro Verde Fazenda Ipanema	2006	2011	expired	F	23
Ouro Verde Fazenda Nova Uberaba	2006	2011	expired	F	21.15
Porto Dias	2002	2018	expired	C	221
Rohden Industria Lignea Ltda.	2003	2013	expired	F	255
Rondobel Indústria e Comércio de Madeiras Ltda.	2012	2013	expired	F	205
RRX Mineração e Serviços Ltda. - EPP	2015	2020	valid	F	873

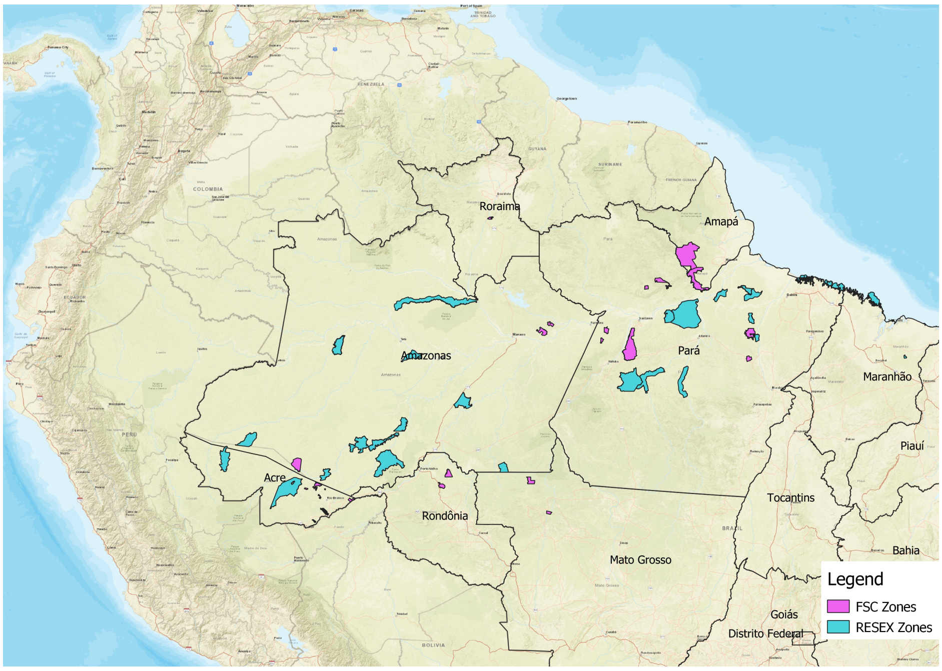
Note: Column (1) gives the name of the company or organization that applied for the FSC certificate. *First year certified* reports the year when the organization obtained the certification and *Last year of certification* reports the year when the certificate expired or was suspended. Column (4) gives information about the status of the certificate and column (5) categorizes the certificated organization in "F" for firm or "C" for community. The last column reports the size of the certificated area. For the FSC zones COOMFLONA, COMARU, FLONA Tapajós and Porto Dias, there the area corresponds to the area of the total PAE or FLONA respectively. The coordinates of the UMFs are not exactly available but are located within the parks.

Table A.3: RESEX zones

RESEX Name	First Year	Municipalities	State	Admin.	Area(km^2)
Arapixi	2006	Boca do Acre	AM	federal	1336.4
Arióca Pruanã	2005	Oeiras do Pará	PA	federal	834.5
Canutama	2009	Canutama	AM	estadual	1979.9
Catuá-Ipixuna	2003	Coari (66.15 %), Tefé (33.85 %)	AM	estadual	2174.9
Cazumbá-Iracema	2002	Sena Madureira (98%) Manoel Urbano (2%)	AC	federal	7508
Chocoaré - Mato Grosso	2002	Santarém Novo	PA	federal	27.9
Cururupu	2004	Bacuri (4%) Cururupu (94%) Serrano do Maranhao (6%)	MA	federal	1850.5
Guariba	2005	Apuí (71.69 %), Novo Aripuanã (28.31 %)	AM	estadual	1504.7
Lago do Capanã Grande	2004	Manicoré	AM	federal	3041.5
Médio Purus	2008	Lábrea (91.41 %), Pauini (8.26 %), Tapauá (0.33 %)	AM	federal	6042.1
Rio Gregório	2007	Ipixuna (58.76 %), Eirunepé (41.22 %)	AM	estadual	4270
Rio Jutaí	2002	Jutaí	AM	federal	2755.3
Rio Unini	2006	Barcelos	AM	federal	8333.5
Gurupá-Melgaço	2006	Gurupá (51.78 %), Melgaço (48,22 %)	PA	federal	1453
Ipaú-Anilzinho	2005	Baião	PA	federal	558.2
Ituxi	2008	Lábrea	AM	federal	7769.4
Lago do Cedro	2006	Aruanã	MT	federal	173.4
Mãe Grande de Curuçá	2002	Curuçá	PA	federal	370.6
Mapuá	2005	Breves	PA	federal	944.6
Marinha Cuinarana	2014	Magalhães Barata	PA	federal	110.4
Marinha de Araí-Peroba	2005	Augusto Corra	PA	federal	442.6
Marinha de Caeté-Taperaçu	2005	Bragança	PA	federal	418.1
Marinha de Gurupi-Piriá	2005	Viseu	PA	federal	740.8
Marinha de Tracuateua	2005	Tracuateua (65,71 %), Bragança (0,71 %)	PA	federal	185.9
Marinha do Maracanã	2002	Maracanã	PA	federal	300.2
Marinha Mestre Lucindo	2014	Marapanim	PA	federal	192.5
Marinha Mocapajuba	2014	So Caetano de Odivelas	PA	federal	210.3
Renascer	2009	Prainha	PA	federal	2117.4
Rio Iriri	2006	Altamira	PA	federal	3989.4
Rio Xingu	2008	Altamira	PA	federal	3038.4
Riozinho da Liberdade	2005	Cruzeiro do Sul (2,79%) Tarauacá (95,59%)	AC	federal	3256
Riozinho do Anfrísio	2004	Altamira	PA	federal	7363.4
São João da Ponta	2002	São João da Ponta	PA	federal	32
Terra Grande-Pracuúba	2006	Curralinho (64.58 %), São Sebastião da Boa Vista (35.42 %)	PA	federal	1947
Verde para Sempre	2004	Porto de Moz	PA	federal	12887.2

Note: Column (1) reports the name of the RESEX zone. Column (2) gives the first year officially recognized as a sustainable use zone under legal protection. Column (3) shows to which % the zone is located in which municipalities and the corresponding state (column(4)). The Administrative level is given in column (2), which is here either national or federal. The size of the zone is visible in the last column. For marine reserves ("Marinha"), only the onshore area is included.

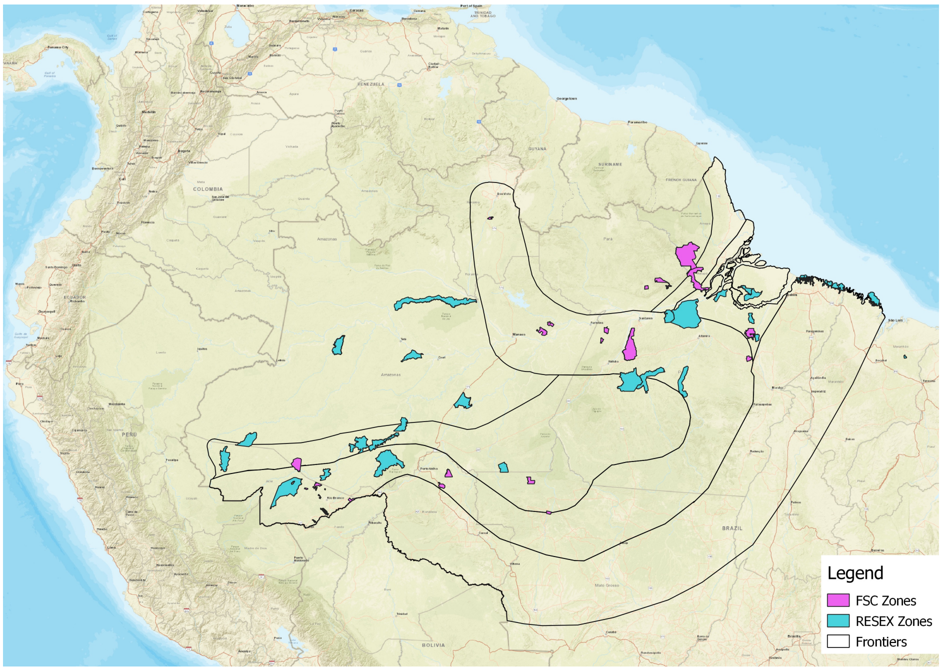
Figure A.6: Zones in States



Layer Source:ESRI Standard

Map displays FSC and RESEX zones distributed over the Brazilian Amazon. The black lines mark the state frontiers.

Figure A.7: Agricultural Frontier

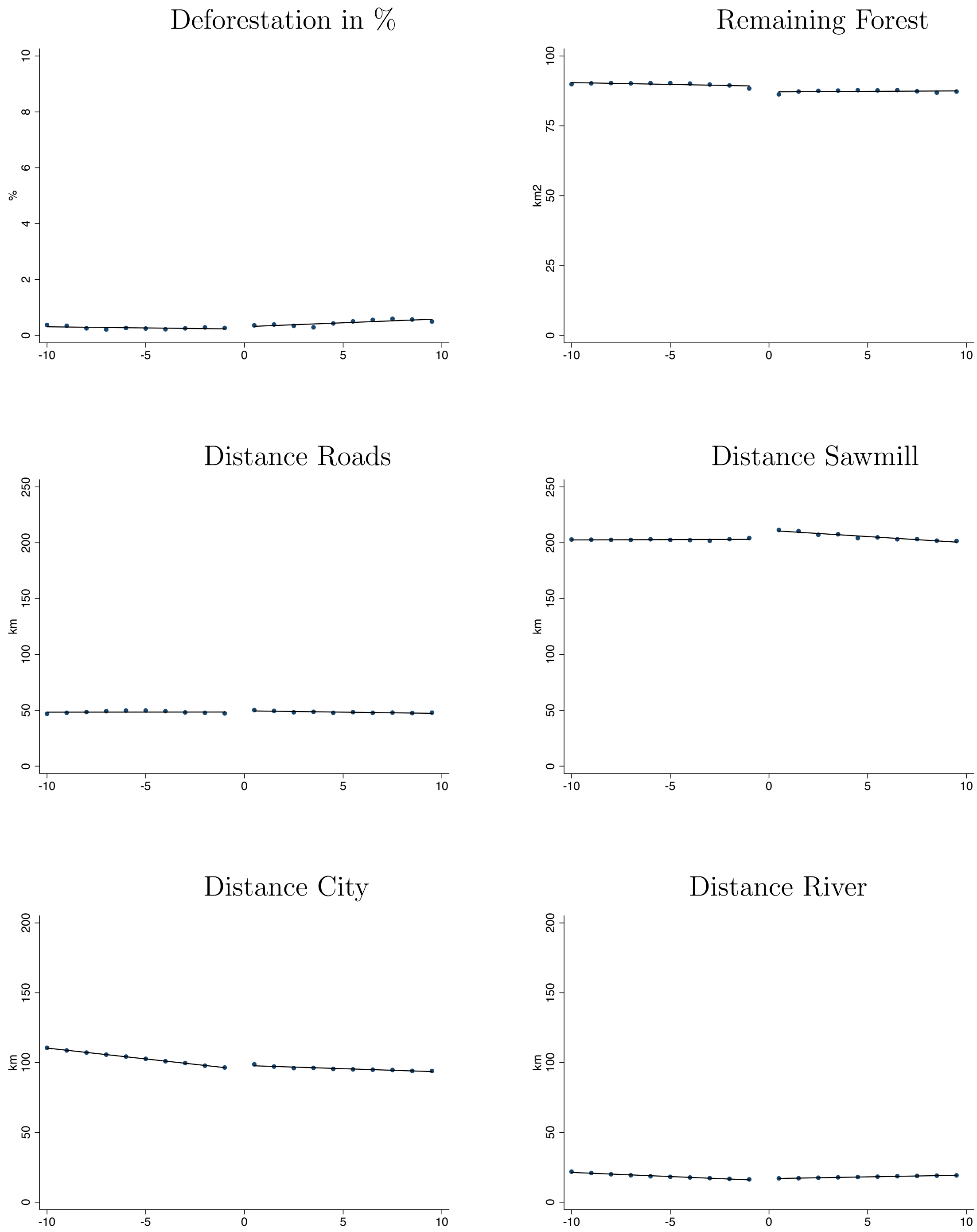


Layer Source:ESRI Standard

Map displays FSC and RESEX zones distributed over the Brazilian Amazon. The black lines mark the agricultural frontier or arc of deforestation where most of deforestation takes place.

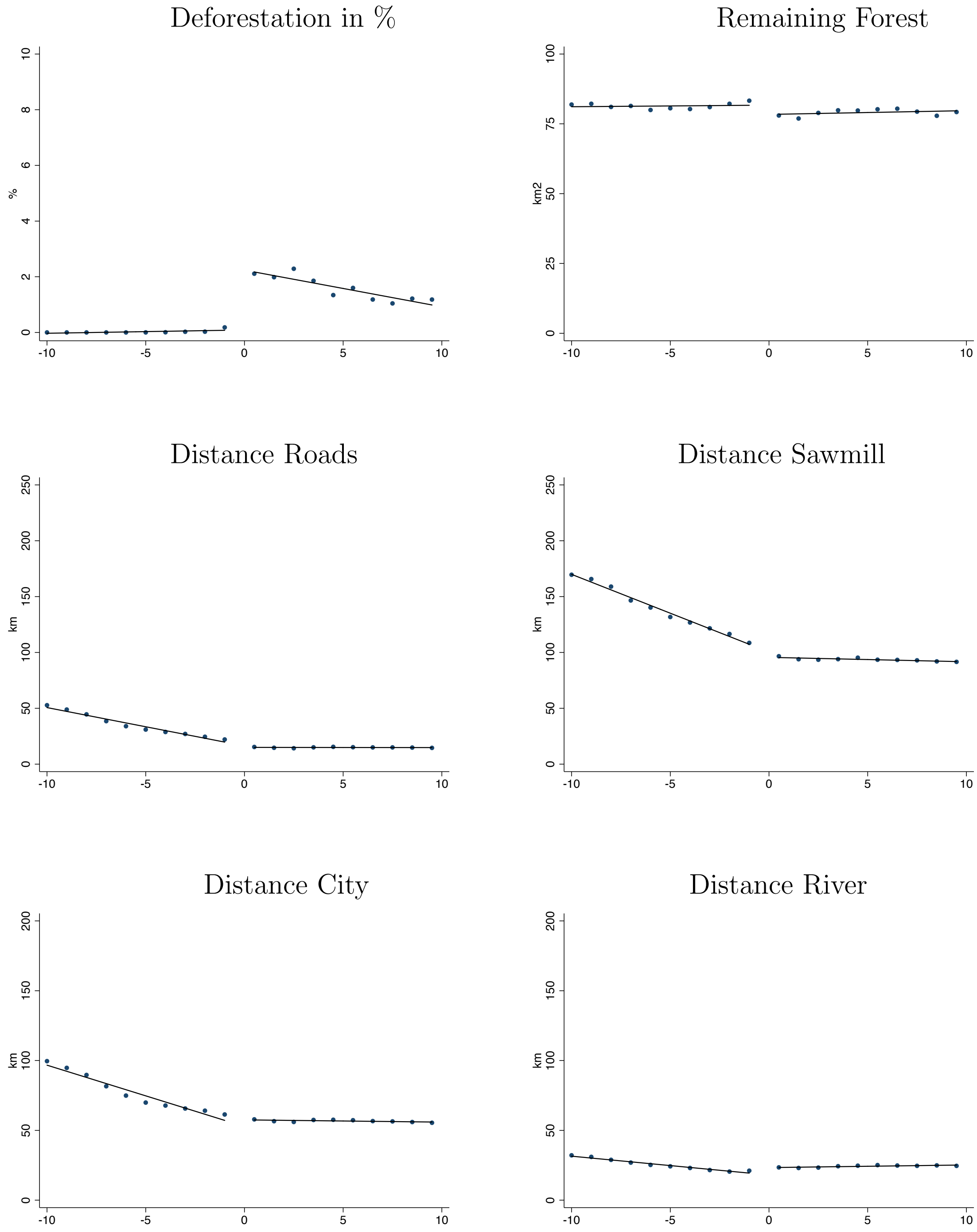
A.3 Descriptive Graphs

Figure A.8: Covariates at the RESEX border



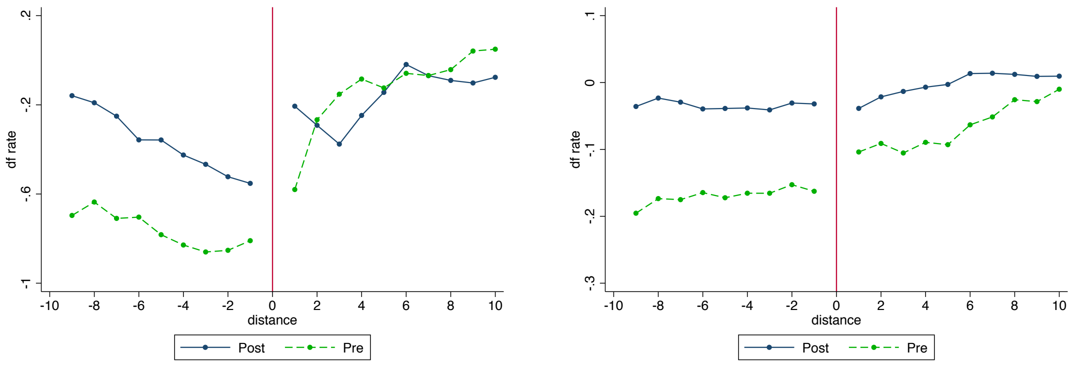
Note: Graphs plot the average value of each variable against distance to a zone's border at 500 m bins around. Negative values indicate grid cells inside a zone and positive values indicate grid cells outside the zone. Distances variables are time invariant. Values of the year 2002 before any zone was implemented are used to plot remaining forest and deforestation

Figure A.9: Covariates at the FSC border



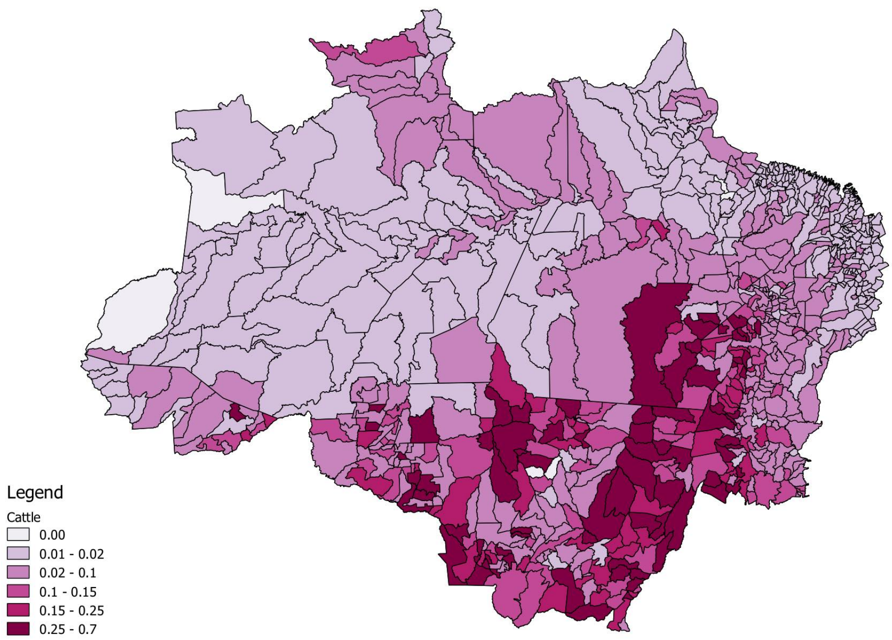
Note: Graphs plot the average value of each variable against distance to a zone's border at 500 m bins around. Negative values indicate grid cells inside a zone and positive values indicate grid cells outside the zone. Distances variables are time invariant. Values of the year 2002 before any zone was implemented are used to plot remaining forest and deforestation

Figure A.10: Spatial RDD: Private and Public Zones 10 km



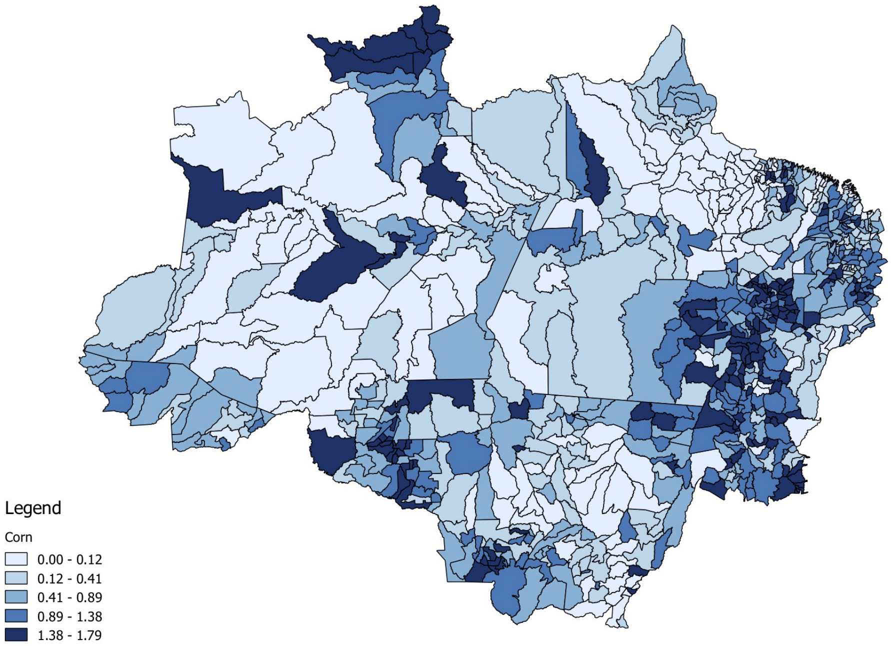
Note: The figure plots the β coefficients of the treatment on deforestation against the distance to the zone border for private zones (left panel) and public zones (right panel). The regression, which is subject to this graph, is identical with equation 5 but replaces the $D \times T$ variables with full sets of distance-to-the-border effects as well as includes a dummy variable for each bin shown in the figure. The bins have a size of 1 km. Negative distances indicate that the grid cell is located inside a zone and positive distances are for grid cells outside. The dashed green line plots the predicted relation between the two variables *before* the zone was established and the solid blue line the values *after* the implementation.

Figure A.11: Cattle intensity across municipalities



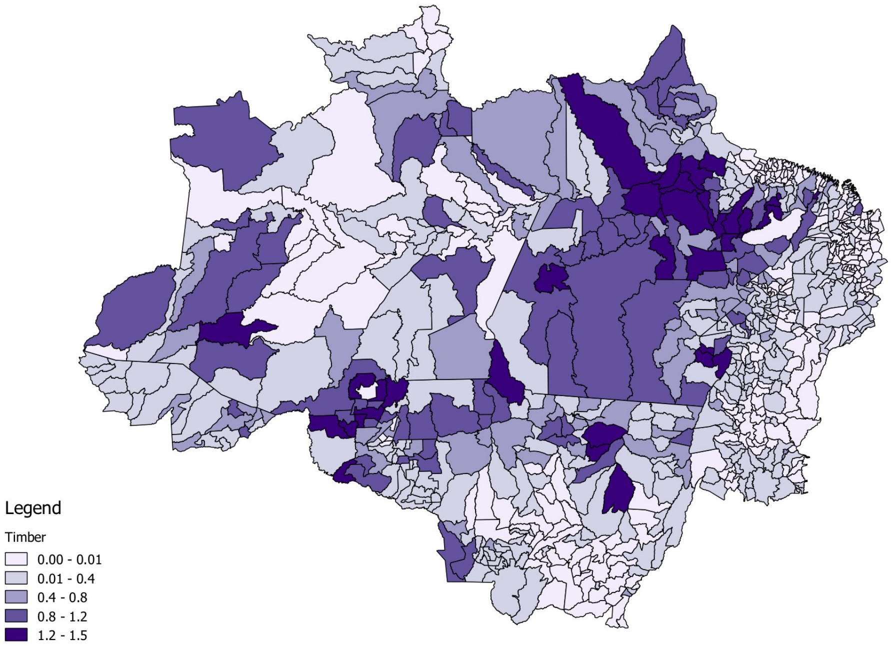
Note: Map illustrates the cattle weights calculated by equation 2 across the Amazonian municipalities.

Figure A.12: Corn intensity across municipalities



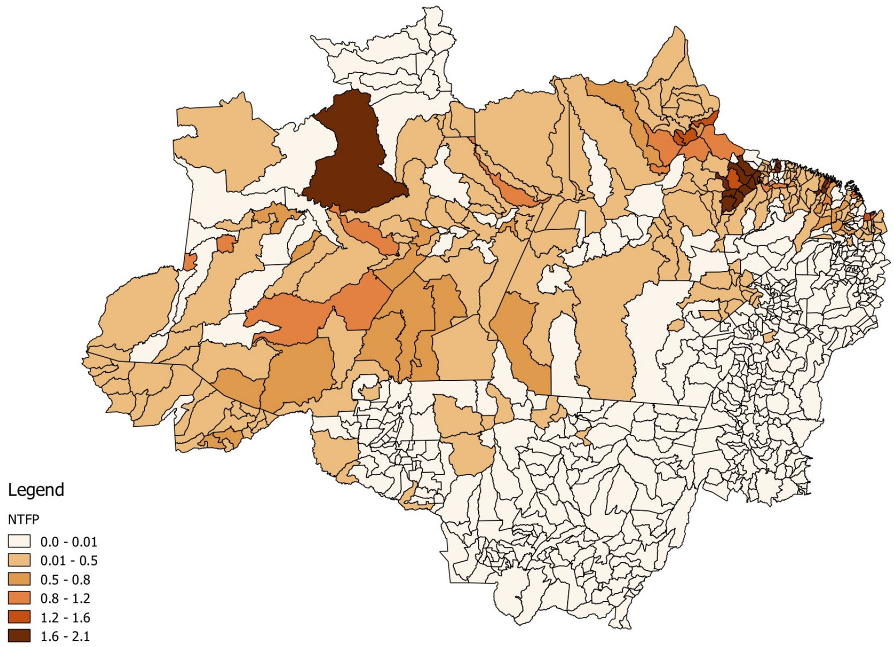
Note: Map illustrates the corn weights calculated by equation 2 across the Amazonian municipalities.

Figure A.13: Timber intensity across municipalities



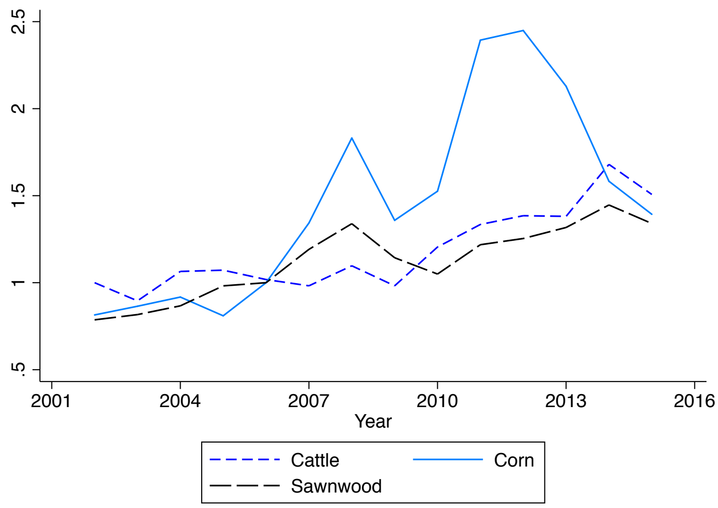
Note: Map illustrates the timber weights calculated by equation 2 across the Amazonian municipalities.

Figure A.14: NTFP intensity across municipalities



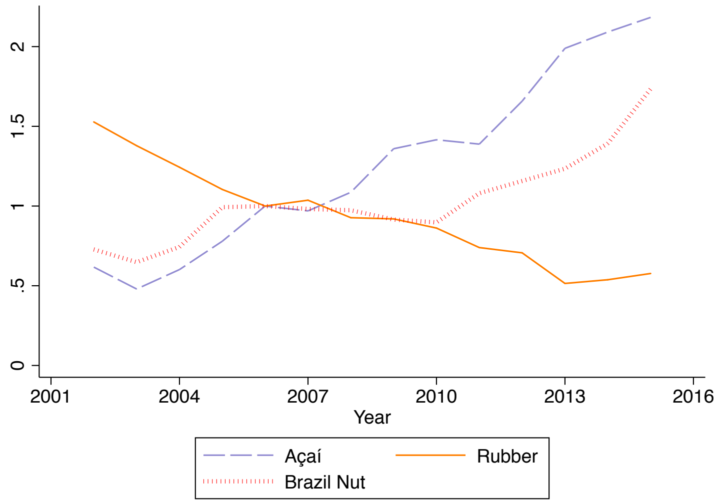
Note: Map illustrates the NTFP weights calculated by equation 2 across the Amazonian municipalities.

Figure A.15: Commodity Price development



Note: Graph plots the price indexes of cattle, corn and sawnwood over time, from 2002-2015.

Figure A.16: NTFP Price development



Note: Graph plots the price indexes of the three non timber forest products over time, from 2002-2015.

A.4 Robustness

A.4.1 Baseline

Table A.4: FSC Baseline: Zone FE with geographic Controls

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-1.320***	-1.391***	-0.877***	-0.922***	-5.977***	-6.387***
	(0.289)	(0.286)	(0.188)	(0.183)	(1.158)	(1.165)
T	-0.624**	-0.658**	-0.391**	-0.405**	-1.581	-1.800*
	(0.304)	(0.304)	(0.160)	(0.159)	(0.990)	(0.980)
Inside×T	1.169***	1.201***	0.736***	0.749***	5.280***	5.486***
	(0.358)	(0.370)	(0.192)	(0.198)	(1.265)	(1.317)
Outside		-0.218**		-0.135**		-1.256***
		(0.101)		(0.065)		(0.401)
Outside×T		0.118		0.049		0.755
		(0.168)		(0.105)		(0.711)
Remaining Forest	-0.026***	-0.026***	0.004**	0.004**	-0.025***	-0.025***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.007)	(0.007)
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Geographic Controls Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1.4m	1.4m	1.4m	1.4m	1.4m	1.4m
R-sq	0.05	0.05	0.04	0.04	0.08	0.08

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). All columns include zone and year fixed effects. Standard errors in parentheses are clustered on municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.5: RESEX Baseline: Zone FE with geographic Controls

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-0.317***	-0.383***	-0.135**	-0.161**	-1.237***	-1.490***
	(0.097)	(0.106)	(0.065)	(0.068)	(0.366)	(0.396)
T	0.139**	0.079	0.051	0.025	0.343**	0.129
	(0.054)	(0.060)	(0.032)	(0.034)	(0.173)	(0.201)
Inside×T	0.232***	0.293***	0.083**	0.110**	0.901***	1.120***
	(0.061)	(0.078)	(0.036)	(0.044)	(0.236)	(0.286)
Outside		-0.181***		-0.073***		-0.692***
		(0.048)		(0.021)		(0.175)
Outside×T		0.174***		0.074***		0.617***
		(0.055)		(0.027)		(0.180)
Remaining Forest	-0.014***	-0.014***	-0.000	-0.000	-0.031***	-0.031***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.005)	(0.005)
Control Group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Geographic Controls Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11.9m	11.9	11.9m	11.9m	11.9	11.9m
R-sq	0.03	0.03	0.02	0.02	0.04	0.04

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). All columns include zone and year fixed effects. Standard errors in parentheses are clustered on municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.6: FSC Baseline: 10 km

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-1.608***		-0.774***		-5.866***	
	(0.378)		(0.193)		(1.229)	
T	-0.661**	-0.746**	-0.394***	-0.433**	-2.075**	-2.035*
	(0.254)	(0.285)	(0.131)	(0.162)	(0.975)	(1.069)
Inside × T	1.000***	1.203***	0.567***	0.660***	4.167***	4.072***
	(0.367)	(0.347)	(0.198)	(0.213)	(1.225)	(1.092)
Total Effect	-1.27	0.46	-0.60	0.23	-3.77	2.04
Treatment Group	10km Zone	10km Zone	10km Zone	10km Zone	10km Zone	10km Zone
Control Group	10km Outside	10km Outside	10km Outside	10km Outside	10km Outside	10km Outside
Observations	557604	557604	557604	557604	557604	557604
R-sq	0.04	0.17	0.03	0.14	0.08	0.27

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.7: RESEX Baseline: 10 km

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-0.219**		-0.102*		-0.848***	
	(0.090)		(0.061)		(0.323)	
T	0.120**	0.123**	0.038	0.043	0.267*	0.266*
	(0.047)	(0.047)	(0.023)	(0.029)	(0.149)	(0.138)
Inside × T	0.121***	0.114**	0.041	0.031	0.509***	0.511***
	(0.046)	(0.047)	(0.026)	(0.025)	(0.147)	(0.140)
Total Effect	0.02	0.24	-0.02	0.07	-0.07	0.78
Treatment Group	10km Zone	10km Zone	10km Zone	10km Zone	10km Zone	10km Zone
Control Group	10km Outside	10km Outside	10km Outside	10km Outside	10km Outside	10km Outside
Observations	5438647	5438647	5438647	5438647	5438647	5438647
R-sq	0.02	0.13	0.01	0.10	0.03	0.19

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.8: FSC Baseline: 60 km

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-1.450***		-0.711***		-5.546***	
	(0.254)		(0.132)		(0.899)	
T	-0.303	-0.318	-0.178	-0.181	-0.720	-0.724
	(0.243)	(0.245)	(0.127)	(0.128)	(0.772)	(0.782)
Inside × T	0.987***	1.115***	0.553***	0.585***	4.123***	4.159***
	(0.305)	(0.215)	(0.156)	(0.120)	(1.122)	(0.973)
Total Effect	-0.77	0.80	-0.34	0.40	-2.14	3.43
Control Group	60km Outside	60km Outside	60km Outside	60km Outside	60km Outside	60km Outside
Observations	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m
R-sq	0.03	0.17	0.03	0.14	0.05	0.26

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.9: RESEX Baseline: 60 km

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-0.456***		-0.191**		-1.823***	
	(0.117)		(0.077)		(0.462)	
T	0.182***	0.179***	0.075**	0.076**	0.446***	0.436***
	(0.061)	(0.061)	(0.035)	(0.036)	(0.166)	(0.163)
Inside × T	0.317***	0.331***	0.124***	0.122***	1.286***	1.328***
	(0.071)	(0.064)	(0.040)	(0.035)	(0.278)	(0.254)
Total Effect	0.04	0.51	0.01	0.20	-0.09	1.76
Control Group	60km	60km	60km	60km	60km	60km
Observations	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m
R-sq	0.02	0.13	0.01	0.11	0.03	0.21

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.10: FSC Baseline: Spatial Autocorrelation

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-1.795***		-0.890***		-6.839***	
	(0.190)		(0.107)		(0.512)	
T	-0.659**	-0.674**	-0.385**	-0.385**	-1.601*	-1.502*
	(0.274)	(0.272)	(0.152)	(0.154)	(0.834)	(0.788)
Inside × T	1.292***	1.361***	0.717***	0.715***	5.332***	4.872***
	(0.240)	(0.248)	(0.137)	(0.143)	(0.680)	(0.874)
Total Effect	-1.16	0.69	-0.56	0.33	-3.11	3.37
Control Group	30km	30km	30km	30km	30km	30km
Observations	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m
R-sq	0.04	0.17	0.04	0.15	0.07	0.27

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the state-year level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.11: RESEX Baseline: Spatial Autocorrelation

	Df %		Df ha		Df 1/0	
	(1)	(2)	(3)	(4)	(5)	(6)
Inside	-0.347***		-0.143***		-1.345***	
	(0.064)		(0.042)		(0.221)	
T	0.136**	0.133**	0.051	0.051	0.335*	0.320**
	(0.062)	(0.057)	(0.037)	(0.036)	(0.194)	(0.162)
Inside × T	0.229***	0.238***	0.083*	0.081**	0.893***	0.939***
	(0.075)	(0.056)	(0.049)	(0.038)	(0.248)	(0.150)
Total Effect	0.02	0.37	-0.01	0.13	-0.12	1.26
Control Group	30km	30km	30km	30km	30km	30km
Observations	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m
R-sq	0.02	0.13	0.01	0.11	0.03	0.21

Note: Dependent variables are: Deforestation rate (columns 1,2), deforestation area in hectare (column 3 and 4), deforestation probability (columns 5 and 6). Columns 1, 3 and 5 include zone fixed effects and columns 2, 4, and 6 include grid fixed effects. All columns include year fixed effects. Standard errors in parentheses are clustered on the state-year level. ***, **, *=significant at 1, 5 and 10 % level.

A.4.2 Spatial

Table A.12: Spatial Difference-in-Difference: Df in ha as dependent Variable

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	0.663***	0.726***	0.992***	0.022	0.023	0.095
	(0.206)	(0.243)	(0.306)	(0.037)	(0.034)	(0.074)
Inside × D × T	1.219*	1.154	-0.062	0.391	0.321	-0.016
	(0.659)	(1.076)	(1.353)	(0.287)	(0.388)	(0.502)
D × T	0.645	0.957	2.173*	-0.411***	-0.480***	-0.143
	(0.446)	(0.953)	(1.293)	(0.124)	(0.166)	(0.254)
T	-0.388*	-0.537**	-0.803**	0.180***	0.123***	0.051
	(0.215)	(0.241)	(0.311)	(0.052)	(0.042)	(0.060)
Outside × T			0.431*			0.119
			(0.217)			(0.090)
Outside × D × T			-3.160			-1.003
			(1.957)			(0.771)
Total Effect	0.27	0.19	0.19	0.20	0.15	0.15
TE Distance	0.82	0.81	0.81	0.20	0.11	0.11
Control group	60km	30 km	30(-10)km	60km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	2.83m	1.42m	1.42m	17.3m	11.9m	11.9m
R-sq	0.14	0.15	0.15	0.11	0.11	0.11

Note: Dependent variable is deforested area in hectare. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.13: Spatial Difference-in-Difference: Second Polynomial Order

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × D × T	2.428	3.281	1.231	1.524**	3.013***	2.576***
	(3.331)	(3.897)	(3.947)	(0.723)	(0.780)	(0.822)
(Inside × D × T)^2	-3.335	-4.870	-4.876	-1.429	-7.542*	-7.541*
	(11.024)	(12.502)	(12.499)	(1.361)	(4.155)	(4.155)
Inside × T	1.263***	1.275***	1.729***	0.066	-0.001	0.092
	(0.378)	(0.421)	(0.525)	(0.076)	(0.047)	(0.113)
D × T	1.135	1.001	3.053	-0.932***	-1.156***	-0.719*
	(0.780)	(1.498)	(1.978)	(0.237)	(0.328)	(0.435)
T	-0.682*	-0.833**	-1.286**	0.416***	0.307***	0.214**
	(0.392)	(0.395)	(0.513)	(0.091)	(0.071)	(0.104)
Outside × D × T			11.473			2.484
			(11.379)			(2.258)
(Outside× D × T)^2			-125.112			-34.540*
			(89.370)			(18.666)
Outside × T			0.288			0.078
			(0.502)			(0.139)
Control group	60km	30 km	30(-10)km	60km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	2.8m	1.42m	1.42m	1.73m	11.9	11.9m
R-sq	0.17	0.17	0.17	0.13	0.13	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.14: Spatial Difference-in-Difference: Different Distances

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	1.348***	1.121***	1.127***	0.085	0.012	-0.061
	(0.373)	(0.398)	(0.419)	(0.067)	(0.056)	(0.059)
Inside × D × T	1.461	4.008*	2.270	1.071***	1.872***	3.366**
	(1.129)	(2.364)	(4.456)	(0.408)	(0.573)	(1.300)
D × T	1.454*	-0.812	0.441	-0.936***	-1.460**	-2.091*
	(0.867)	(1.911)	(3.832)	(0.236)	(0.569)	(1.058)
T	-0.828**	-0.652*	-0.771**	0.412***	0.261***	0.241***
	(0.402)	(0.355)	(0.371)	(0.090)	(0.074)	(0.083)
Total Effect	0.52	0.47	0.36	0.50	0.27	0.18
TE Distance	1.38	1.41	1.15	0.53	0.36	0.45
Control group	50 km	20 km	10km	50 km	20 km	10 km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	2.4m	1.01m	0.56m	17.1m	9.14m	0.54m
R-sq	0.17	0.17	0.17	0.13	0.13	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

A.4.3 Time

Table A.15: Time Difference-in-Difference: Df in ha as dependent variable

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	0.824***	1.516***	0.860***	-0.161***	-0.034	-0.163***
	(0.210)	(0.431)	(0.235)	(0.050)	(0.034)	(0.058)
Inside × YT	-0.074**	-0.365***	-0.087***	0.089***	0.056**	0.101***
	(0.030)	(0.123)	(0.032)	(0.024)	(0.024)	(0.028)
Inside × YT × T	0.124**	0.376***	0.134***	-0.088***	-0.077**	-0.099***
	(0.051)	(0.128)	(0.050)	(0.031)	(0.036)	(0.034)
T	-0.404**	-0.756***	-0.441**	0.144**	0.025	0.147**
	(0.175)	(0.248)	(0.194)	(0.064)	(0.052)	(0.072)
YT × T	-0.041	0.016	-0.051	0.043	-0.014	0.054
	(0.045)	(0.120)	(0.045)	(0.030)	(0.037)	(0.033)
Outside × YT			-0.049*			0.035**
			(0.028)			(0.015)
Outside × YT × T			0.038			-0.033**
			(0.051)			(0.016)
Outside × T			0.139			-0.010
			(0.172)			(0.042)
Total Effect	0.43	0.79	0.41	0.03	-0.04	0.04
TE Over Time	0.42	0.76	0.42	-0.02	-0.01	-0.02
Sample	10 years	5 years	10 years	10 years	5 years	10 years
Control group	30km	30 km	30(-10)km	30km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	1.42m	0.82m	1.42m	11.9m	7.2m	11.9m
R-sq	0.15	0.22	0.15	0.29	0.38	0.29

Note: Dependent variable is deforested area in hectare. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.16: Time Difference-in-Difference: Second Polynomial included

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × T	2.050***	2.330	2.114***	-0.321***	0.107	-0.345***
	(0.688)	(1.492)	(0.734)	(0.108)	(0.106)	(0.116)
Inside × YT	-0.625***	-0.665	-0.641***	0.222***	0.015	0.256***
	(0.209)	(0.683)	(0.215)	(0.063)	(0.059)	(0.068)
Inside × YT × T	1.225***	1.715*	1.244***	-0.261***	-0.008	-0.295***
	(0.319)	(0.938)	(0.322)	(0.088)	(0.079)	(0.091)
$(\text{Inside} \times \text{YT})^2$	-0.062***	-0.014	-0.062***	0.007	-0.031*	0.009
	(0.023)	(0.136)	(0.023)	(0.011)	(0.016)	(0.012)
$(\text{Inside} \times \text{YT} \times \text{T})^2$	0.015	-0.313*	0.014	-0.004	0.046*	-0.006
	(0.029)	(0.185)	(0.029)	(0.013)	(0.025)	(0.013)
T	-0.660**	-1.367***	-0.734**	0.352***	0.063	0.355***
	(0.329)	(0.456)	(0.364)	(0.101)	(0.092)	(0.113)
YT × T	-0.080	0.088	-0.092	0.122**	-0.025	0.140**
	(0.073)	(0.203)	(0.077)	(0.049)	(0.061)	(0.055)
$(\text{Outside} \times \text{YT} \times \text{T})^2$			-0.040			-0.051***
			(0.024)			(0.013)
$(\text{Outside} \times \text{YT})^2$			0.013			0.048***
			(0.017)			(0.013)
Outside × YT			0.082			0.414***
			(0.181)			(0.090)
Outside × YT × T			0.120			-0.387***
			(0.250)			(0.100)
Outside × T			-0.195			-0.511***
			(0.430)			(0.130)
Sample	10 years	5 years	10 years	10 years	5 years	10 years
Control group	30km	30 km	30(-10)km	30km	30 km	30(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	1.42m	0.82m	1.42m	11.9m	7.2m	11.9m
R-sq	0.17	0.25	0.17	0.13	0.22	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.17: Time Difference-in-Difference: 60km

	Private Zones (FSC)			Public Zones (Resex)		
	(1)	(2)	(3)	(4)	(5)	(6)
Inside × YT	-0.065*	-0.503***	-0.068*	0.229***	0.141***	0.248***
	(0.034)	(0.162)	(0.037)	(0.044)	(0.037)	(0.048)
Inside × YT × T	0.253***	0.669***	0.263***	-0.221***	-0.154***	-0.240***
	(0.069)	(0.182)	(0.070)	(0.050)	(0.051)	(0.054)
Inside × T	0.860***	1.855***	0.821***	-0.323***	-0.062	-0.322***
	(0.263)	(0.576)	(0.271)	(0.081)	(0.064)	(0.091)
T	-0.272	-0.913***	-0.234	0.399***	0.012	0.399***
	(0.244)	(0.304)	(0.248)	(0.108)	(0.087)	(0.115)
YT × T	-0.125**	-0.076	-0.136**	0.144***	-0.039	0.161***
	(0.058)	(0.160)	(0.061)	(0.054)	(0.055)	(0.058)
Outside × YT			-0.023			0.105***
			(0.044)			(0.039)
Outside × YT × T			0.086			-0.104***
			(0.095)			(0.040)
Outside × T			-0.300			-0.029
			(0.252)			(0.094)
Total Effect	0.65	1.03	0.65	0.23	-0.10	0.25
TE Over Time	0.59	0.94	0.59	0.08	-0.05	0.08
Sample	10 years	5 years	10 years	10 years	5 years	10 years
Control group	60km	60 km	60(-10)km	60km	60 km	60(-10)km
Treatment group	FSC	FSC	FSC	RESEX	RESEX	RESEX
Observations	2.8m	1.6m	2.8m	17.3m	10.5m	17.3
R-sq	0.17	0.25	0.17	0.13	0.21	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.18: Time Difference-in-Difference: 10km

	FSC		RESEX	
	(1)	(2)	(3)	(4)
Inside × T	1.027***	1.697***	-0.259***	-0.145*
	(0.318)	(0.618)	(0.071)	(0.075)
Inside × YT	-0.033	-0.408**	0.126***	0.085**
	(0.038)	(0.185)	(0.032)	(0.035)
Inside × YT × T	0.141	0.662***	-0.116***	-0.064*
	(0.113)	(0.245)	(0.034)	(0.037)
YT × T	-0.061	-0.215	0.081	-0.041
	(0.096)	(0.248)	(0.050)	(0.067)
T	-0.672**	-1.222**	0.325***	0.133
	(0.291)	(0.493)	(0.089)	(0.082)
Total Effect	0.40	0.52	0.16	-0.03
TE Over Time	0.35	0.47	0.07	-0.01
Sample	10 years	5 years	10 years	5 years
Control group	10km	10 km	10km	10 km
Observations	0.55m	0.32m	5.4m	3.3m
R-sq	0.17	0.25	0.13	0.21

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

A.4.4 Local Heterogeneity

Table A.19: Local heterogeneity: Private Zones 60km

	(1) City	(2) City	(3) Roads	(4) Roads	(5) Sawmill	(6) Sawmill	(7) River	(8) River
Inside	-0.859***	-0.852***	-0.644**	-0.678**	-0.260	-0.282	-1.008***	-1.022***
	(0.310)	(0.298)	(0.270)	(0.288)	(0.277)	(0.287)	(0.293)	(0.308)
Inside × Dist. Site	-1.240***	-1.228***	-1.577***	-1.418***	-1.953***	-1.871***	-0.557	-0.488
	(0.316)	(0.298)	(0.348)	(0.337)	(0.393)	(0.381)	(0.466)	(0.451)
Inside × T × Dist. Site	-0.405	-0.481	-0.241	-0.400	-0.029	-0.235	-0.488	-0.475
	(0.496)	(0.530)	(0.514)	(0.534)	(0.471)	(0.476)	(0.481)	(0.506)
Inside × T	1.021**	1.006**	0.730**	0.727**	0.565*	0.596*	0.906**	0.835**
	(0.420)	(0.451)	(0.309)	(0.333)	(0.292)	(0.306)	(0.366)	(0.389)
T	0.053	0.063	0.107	0.100	0.389*	0.356*	0.046	0.097
	(0.194)	(0.196)	(0.178)	(0.179)	(0.206)	(0.209)	(0.210)	(0.217)
T × Dist. Site	-0.136	-0.090	-0.226	-0.130	-0.678***	-0.544**	-0.139	-0.166
	(0.204)	(0.219)	(0.242)	(0.244)	(0.221)	(0.228)	(0.232)	(0.240)
Outside		0.070		-0.280*		-0.197		-0.061
		(0.357)		(0.167)		(0.165)		(0.182)
Outside × T × Dist. Site		0.095		0.900**		0.559		0.378
		(0.488)		(0.364)		(0.375)		(0.381)
Outside × T × Dist. Site		-0.447		-1.235**		-1.286***		-0.077
		(0.624)		(0.549)		(0.469)		(0.474)
Outside × T		-0.084		0.217		0.302		-0.284
		(0.391)		(0.294)		(0.217)		(0.276)
Post Dist< 0.5	-1.57	-1.58	-1.85	-1.80	-1.97	-1.98	-1.24	-1.22
Post Dist> 0.5	0.16	0.15	0.09	0.05	0.30	0.31	-0.10	-0.19
Pre Dist< 0.5	-2.10	-2.08	-2.22	-2.10	-2.21	-2.15	-1.57	-1.51
Control Group	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km
Observations	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m
R-sq	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Note: Dependent variable is deforestation rate. All columns include zone and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.20: Local heterogeneity: Public Zones 60km

	(1) City	(2) City	(3) Roads	(4) Roads	(5) Sawmill	(6) Sawmill	(7) River	(8) River
Inside	-0.232*	-0.300**	-0.429***	-0.501***	-0.401***	-0.453***	-0.310*	-0.352**
	(0.139)	(0.144)	(0.063)	(0.076)	(0.076)	(0.085)	(0.160)	(0.162)
Inside × Dist. Site	-0.274*	-0.252	0.153	0.189	0.131	0.125	-0.151	-0.184
	(0.158)	(0.162)	(0.189)	(0.190)	(0.159)	(0.160)	(0.176)	(0.178)
Inside × T × Dist. Site	0.032	0.041	0.024	0.050	0.249***	0.277***	-0.011	-0.017
	(0.116)	(0.127)	(0.121)	(0.130)	(0.095)	(0.098)	(0.107)	(0.117)
Inside × T	0.272***	0.316***	0.299***	0.335***	0.178***	0.206***	0.335***	0.389***
	(0.057)	(0.069)	(0.061)	(0.068)	(0.054)	(0.062)	(0.102)	(0.116)
T	0.360***	0.321***	0.332***	0.295***	0.458***	0.434***	0.146*	0.092
	(0.110)	(0.114)	(0.102)	(0.103)	(0.108)	(0.113)	(0.082)	(0.087)
T × Dist. Site	-0.248*	-0.257*	-0.246**	-0.271**	-0.492***	-0.521***	0.092	0.098
	(0.126)	(0.136)	(0.119)	(0.121)	(0.127)	(0.128)	(0.092)	(0.098)
Outside		-0.320***		-0.477***		-0.159**		-0.080
		(0.086)		(0.081)		(0.067)		(0.098)
Outside × T × Dist. Site		0.170		0.516***		-0.154		-0.320***
		(0.120)		(0.115)		(0.152)		(0.115)
Outside × T × Dist. Site		-0.031		-0.240**		0.257***		0.175*
		(0.128)		(0.108)		(0.098)		(0.104)
Outside × T		0.243***		0.339***		0.087		0.147
		(0.074)		(0.063)		(0.063)		(0.092)
Post Dist< 0.5	-0.09	-0.13	0.13	0.10	0.12	0.07	0.10	0.03
Post Dist> 0.5	0.04	0.02	-0.13	-0.17	-0.22	-0.25	0.02	0.04
Pre Dist< 0.5	-0.51	-0.55	-0.28	-0.31	-0.27	-0.33	-0.46	-0.54
Control Group	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km
Observations	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m
R-sq	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Note: Dependent variable is deforestation rate. All columns include zone and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.21: Local heterogeneity: FSC with Grid FE

	City (1)	City (2)	Roads (3)	Roads (4)	Sawmill (5)	Sawmill (6)	River (7)	River (8)
Inside × T	1.447***	1.403***	0.792**	0.725**	0.801**	0.827**	1.769***	1.675***
	(0.430)	(0.468)	(0.350)	(0.352)	(0.318)	(0.361)	(0.368)	(0.379)
Inside × T × Dist. Site	-0.234	-0.166	0.917*	1.003**	0.864*	0.821*	-0.796*	-0.621
	(0.473)	(0.493)	(0.477)	(0.468)	(0.437)	(0.465)	(0.464)	(0.475)
Outside × T		-0.139		-0.212		0.089		-0.303
		(0.319)		(0.251)		(0.264)		(0.349)
Outside × T × Dist. Site		0.222		0.283		-0.147		0.592
		(0.497)		(0.471)		(0.435)		(0.488)
T × Dist. Site	-0.246	-0.313	-1.508***	-1.595***	-1.511***	-1.468***	0.175	0.000
	(0.482)	(0.501)	(0.498)	(0.491)	(0.477)	(0.496)	(0.462)	(0.459)
T	-0.528	-0.484	0.155	0.222	0.179	0.153	-0.764**	-0.671*
	(0.467)	(0.508)	(0.473)	(0.482)	(0.458)	(0.485)	(0.380)	(0.397)
TE Dist> 0.5	0.92	0.92	0.95	0.95	0.98	0.98	1.01	1.00
TE Dist< 0.5	0.44	0.44	0.36	0.36	0.33	0.33	0.38	0.38
Control group	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km	30km	30(-10)km
Observations	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m
R-squared	0.170	0.170	0.171	0.171	0.171	0.171	0.170	0.170

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.22: Local heterogeneity: RESEX with Grid FE

	City (1)	City (2)	Roads (3)	Roads (4)	Sawmill (5)	Sawmill (6)	River (7)	River (8)
Inside × T	0.033	0.053	-0.011	-0.016	0.109***	0.129**	0.244***	0.312***
	(0.035)	(0.050)	(0.009)	(0.010)	(0.040)	(0.062)	(0.058)	(0.082)
Inside × T × Dist. Site	0.372***	0.448***	0.512***	0.650***	0.259**	0.329**	-0.019	-0.026
	(0.096)	(0.125)	(0.099)	(0.127)	(0.126)	(0.158)	(0.104)	(0.132)
T × Dist. Site	-0.517***	-0.594***	-0.714***	-0.852***	-0.449***	-0.519***	-0.001	0.006
	(0.126)	(0.150)	(0.124)	(0.141)	(0.155)	(0.181)	(0.130)	(0.154)
T	0.433***	0.414***	0.485***	0.493***	0.350***	0.332***	0.134	0.067
	(0.098)	(0.105)	(0.097)	(0.099)	(0.094)	(0.108)	(0.087)	(0.104)
Outside × T		0.056		-0.015		0.051		0.184**
		(0.044)		(0.011)		(0.072)		(0.086)
Outside × T × Dist. Site		0.227*		0.399***		0.230*		-0.001
		(0.118)		(0.116)		(0.121)		(0.107)
TE Dist> 0.5	0.47	0.47	0.47	0.48	0.46	0.46	0.38	0.38
TE Dist< 0.5	0.32	0.32	0.27	0.28	0.27	0.27	0.36	0.36
Control group	Outside 30km	Outside 30(-10)km	Outside 30km	Outside 30(-10)km	Outside 30km	Outside 30(-10)km	Outside 30km	Outside 30(-10)km
Observations	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m
R-squared	0.132	0.132	0.132	0.132	0.132	0.132	0.131	0.131

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

A.4.5 Prices

Table A.23: Exogenous Price Shocks: Private Zones Deforestation in ha

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
L.Inside × T	0.466**	0.462**	0.586**	0.458**	0.449**	0.587**	0.669***	0.617***
	(0.198)	(0.211)	(0.232)	(0.217)	(0.219)	(0.231)	(0.194)	(0.199)
L.Price Index	8.643	10.034	0.838*	1.239**	-0.173	-0.154	0.457	0.707
	(5.659)	(7.143)	(0.489)	(0.521)	(0.886)	(1.018)	(1.209)	(1.221)
L.Inside × T × Price Index	3.669	3.882	0.691**	1.078***	0.500	0.233	-0.249	0.102
	(2.824)	(3.152)	(0.253)	(0.287)	(0.494)	(0.493)	(1.086)	(1.054)
L.T	-0.081	-0.078	-0.079	0.049	-0.296	-0.429*	-0.476**	-0.424*
	(0.229)	(0.238)	(0.273)	(0.274)	(0.206)	(0.215)	(0.227)	(0.235)
L.Inside × Price Index	2.812	1.379	-1.275***	-1.673***	0.247	0.244	-0.574	-0.829
	(13.780)	(14.307)	(0.396)	(0.472)	(0.805)	(0.930)	(1.651)	(1.668)
L.T × Price Index	-5.508***	-5.714**	-0.766**	-1.147***	-0.153	0.107	0.918	0.569
	(1.993)	(2.218)	(0.284)	(0.312)	(0.383)	(0.403)	(1.105)	(1.055)
L.Outside × T		-0.007		-0.381*		0.433***		-0.181
		(0.123)		(0.192)		(0.122)		(0.191)
L.Outside × Price Index		-5.455		-1.342***		-0.046		-0.936
		(7.373)		(0.342)		(0.682)		(0.583)
L.Outside × T × Price Index		0.569		1.169***		-0.894**		1.207*
		(2.024)		(0.320)		(0.356)		(0.664)
PI Effect Post	0.43	0.36	0.01	-0.14	0.46	0.46	0.21	0.17
PI Effect Pre	0.50	0.50	-0.16	-0.16	0.04	0.05	-0.02	-0.02
Ex. PI Post		-0.55		-0.82		-0.42		-0.50
Ex. PI Pre		0.20		-0.04		-0.10		-0.03
Observations	1421758	1421758	1421758	1421758	1421758	1421758	1421758	1421758
R-sq	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Note: Dependent variable is deforested area in hectare. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.24: Exogenous Price Shocks: Public Zones Deforestation in ha

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
L.Inside × T	0.051**	0.065**	0.045*	0.063*	0.159***	0.203***	0.113**	0.144**
	(0.023)	(0.031)	(0.026)	(0.036)	(0.054)	(0.070)	(0.049)	(0.057)
L.Price Index	0.804	1.341	0.209	0.223	-0.429*	-0.536*	-0.202	-0.168
	(1.752)	(1.932)	(0.156)	(0.187)	(0.231)	(0.285)	(0.199)	(0.259)
L.Inside × T × Price Index	0.727	1.050	0.184	0.221	-0.366***	-0.426***	-0.185*	-0.184
	(0.933)	(1.034)	(0.201)	(0.233)	(0.116)	(0.133)	(0.109)	(0.141)
L.T	0.133***	0.120***	0.092**	0.074*	0.052	0.009	-0.012	-0.042
	(0.043)	(0.043)	(0.041)	(0.041)	(0.043)	(0.049)	(0.073)	(0.078)
L.Inside × Price Index	-0.096	-0.635	-0.126	-0.141	0.838***	0.947***	0.273*	0.239
	(1.703)	(1.891)	(0.314)	(0.341)	(0.240)	(0.297)	(0.139)	(0.181)
L.T × Price Index	-2.653***	-2.975***	-0.227*	-0.265	0.063	0.123	0.271*	0.269
	(0.924)	(1.018)	(0.135)	(0.169)	(0.102)	(0.121)	(0.162)	(0.201)
L.Outside × T		0.037		0.047		0.133**		0.090**
		(0.035)		(0.039)		(0.058)		(0.037)
L.Outside × Price Index		-1.791*		-0.084		0.334		-0.079
		(0.950)		(0.176)		(0.244)		(0.207)
L.Outside × T × Price Index		1.143**		0.155		-0.190**		-0.011
		(0.566)		(0.152)		(0.087)		(0.152)
In. PI Effect Post	0.12	0.10	0.10	0.09	0.47	0.53	0.18	0.17
In. PI Effect Pre	0.02	0.02	0.02	0.02	0.20	0.20	0.02	0.02
Ex. PI Effect Post		0.04		0.07		0.27		0.09
Ex. PI Effect Pre		-0.01		0.03		-0.10		-0.05
Observations	1.19e+07	1.19e+07	1.19e+07	1.19e+07	1.19e+07	1.19e+07	1.19e+07	1.19e+07
R-sq	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Note: Dependent variable is deforested area in hectare. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.25: Exogenous Price Shocks: Private Zones 60km

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
L.Inside × T	0.719**	0.714**	0.886**	0.785**	0.775**	0.833**	0.903***	0.860***
	(0.303)	(0.311)	(0.355)	(0.352)	(0.356)	(0.355)	(0.221)	(0.208)
L.Price Index	5.766	5.118	1.765***	1.951***	-2.111	-2.196	1.049	0.916
	(6.279)	(6.880)	(0.436)	(0.520)	(1.742)	(1.834)	(1.612)	(1.518)
L.Inside × T × Price Index	5.296	4.879	1.073**	1.304**	0.277	0.100	-0.160	-0.089
	(4.261)	(4.451)	(0.459)	(0.525)	(0.782)	(0.773)	(1.797)	(1.717)
L.T	0.075	0.078	0.314	0.414	-0.524	-0.575	-0.345	-0.301
	(0.358)	(0.356)	(0.446)	(0.438)	(0.498)	(0.498)	(0.361)	(0.352)
L.Inside × Price Index	12.097	12.679	-1.596***	-1.778***	1.956	2.069	1.825	1.963
	(18.434)	(18.692)	(0.534)	(0.631)	(1.697)	(1.803)	(3.443)	(3.480)
L.T × Price Index	-7.822**	-7.396**	-1.518***	-1.741***	0.399	0.564	0.447	0.376
	(2.880)	(2.947)	(0.489)	(0.551)	(0.693)	(0.688)	(1.667)	(1.569)
L.Outside × T		-0.058		-0.691**		0.470*		-0.364*
		(0.159)		(0.331)		(0.242)		(0.197)
L.Outside × Price Index		2.362		-1.182*		1.117		1.430
		(10.236)		(0.598)		(1.480)		(1.531)
L.Outside × T × Price Index		-2.047		1.460*		-1.590***		0.526
		(2.700)		(0.716)		(0.498)		(1.196)
PI Effect Post	1.21	1.24	0.48	0.42	1.70	1.76	0.79	0.80
PI Effect Pre	0.78	0.78	0.06	0.06	-0.08	-0.07	0.31	0.31
Ex. PI Post		-0.29		-0.79		-0.06		-0.41
Ex. PI Pre		0.33		0.27		-0.59		0.26
Control Group	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km
Observations	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m	2.8m
R-sq	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.26: Exogenous Price Shocks: Public Zones 60km

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.194***	0.222***	0.205***	0.244***	0.477***	0.543***	0.455***	0.518***
	(0.063)	(0.075)	(0.076)	(0.090)	(0.146)	(0.167)	(0.118)	(0.135)
Price Index	2.735	3.392	0.125	0.139	-0.392	-0.594	-0.919*	-0.944*
	(3.397)	(3.573)	(0.425)	(0.469)	(0.517)	(0.557)	(0.503)	(0.552)
Inside × T × Price Index	4.039*	4.514**	0.555	0.598	-0.793***	-0.875***	-0.872***	-0.922***
	(2.124)	(2.243)	(0.444)	(0.492)	(0.236)	(0.260)	(0.263)	(0.304)
T	0.385***	0.361***	0.272***	0.234**	0.172	0.107	0.005	-0.054
	(0.105)	(0.106)	(0.092)	(0.094)	(0.106)	(0.115)	(0.132)	(0.140)
Inside × Price Index	-4.863*	-5.528*	-0.292	-0.308	1.894***	2.103***	1.368***	1.395**
	(2.827)	(3.026)	(0.505)	(0.552)	(0.442)	(0.514)	(0.495)	(0.541)
T × Price Index	-5.687**	-6.158***	-0.457	-0.498	0.125	0.206	0.821***	0.870**
	(2.190)	(2.302)	(0.402)	(0.450)	(0.170)	(0.191)	(0.297)	(0.334)
Outside × T		0.122		0.162*		0.350***		0.316***
		(0.074)		(0.082)		(0.128)		(0.111)
Outside × Price Index		-4.035*		-0.285		1.088**		0.200
		(2.113)		(0.441)		(0.514)		(0.435)
Outside × T × Price Index		3.336**		0.433		-0.477**		-0.307
		(1.519)		(0.386)		(0.186)		(0.273)
In. PI Effect Post	0.35	0.33	0.43	0.42	1.23	1.33	0.75	0.75
In. PI Effect Pre	-0.07	-0.07	-0.04	-0.04	0.71	0.71	0.10	0.10
Ex. PI Effect Post		0.24		0.31		0.84		0.43
Ex. PI Effect Pre		-0.02		-0.04		0.23		-0.16
Control Group	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km	60 km	60(-10)km
Observations	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m	17.3m
R-sq	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.27: Exogenous Price Shocks: Private Zones NTFP

	(1) Acai	(2) Acai	(3) Brazil Nuts	(4) Brazil Nuts	(5) Rubber	(6) Rubber
Inside × T	1.342***	1.335***	1.201***	1.187***	1.401***	1.392***
	(0.359)	(0.373)	(0.328)	(0.347)	(0.381)	(0.402)
Price Index	3.713	4.288	-0.890	-0.741	-1.144	0.289
	(6.049)	(6.129)	(5.312)	(5.067)	(10.896)	(9.986)
Inside × T × Price Index	-1.020	-0.431	0.234	0.456	-5.607	-5.682
	(4.269)	(4.195)	(3.212)	(3.310)	(13.306)	(13.185)
T	-0.683*	-0.676*	-0.728	-0.714	-0.690	-0.680
	(0.378)	(0.394)	(0.433)	(0.455)	(0.409)	(0.429)
Inside × Price Index	0.775	0.196	0.485	0.329	-4.154	-5.630
	(5.641)	(5.695)	(7.434)	(7.260)	(17.243)	(17.233)
T × Price Index	0.596	0.009	1.012	0.792	2.123	2.156
	(4.155)	(4.141)	(3.103)	(3.209)	(7.814)	(7.601)
Outside × T		-0.024		-0.051		-0.030
		(0.235)		(0.252)		(0.250)
Outside × Price Index		-2.124*		-0.642		-6.190
		(1.156)		(3.767)		(11.475)
Outside × T × Price Index		2.146		0.744		-0.739
		(1.316)		(1.196)		(6.347)
PI Effect Post	0.67	0.65	0.62	0.61	0.58	0.55
PI Effect Pre	0.12	0.12	-0.04	-0.04	-0.09	-0.09
Ex. PI Post		-0.70		-0.69		-0.79
Ex. PI Pre		0.06		-0.12		-0.10
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km
Observations	1421758	1421758	1421758	1421758	1421758	1421758
R-sq	0.17	0.17	0.17	0.17	0.17	0.17

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.28: Exogenous Price Shocks: Public Zones NTFP

	(1) Acai	(2) Acai	(3) Brazil Nuts	(4) Brazil Nuts	(5) Rubber	(6) Rubber
Inside × T	0.243***	0.311***	0.337***	0.408***	0.246***	0.301***
	(0.069)	(0.091)	(0.090)	(0.110)	(0.071)	(0.087)
Price Index	-1.224*	-0.803*	1.417***	1.215**	-3.706*	-2.807
	(0.626)	(0.457)	(0.452)	(0.492)	(1.940)	(2.957)
Inside × T × Price Index	-0.518	-0.317	-0.894***	-1.004***	-0.643	-0.763
	(0.348)	(0.414)	(0.252)	(0.289)	(0.791)	(0.929)
T	0.094	0.028	0.085	0.017	0.153*	0.099
	(0.069)	(0.078)	(0.097)	(0.108)	(0.085)	(0.092)
Inside × Price Index	0.948*	0.526	1.041**	1.245**	-0.164	-1.064
	(0.567)	(0.575)	(0.439)	(0.567)	(1.719)	(2.955)
T × Price Index	0.850***	0.650**	0.405	0.514*	-0.822	-0.704
	(0.295)	(0.267)	(0.257)	(0.303)	(1.033)	(1.165)
Outside × T		0.195**		0.207**		0.161**
		(0.083)		(0.087)		(0.072)
Outside × Price Index		-1.165*		0.612		-2.341
		(0.660)		(0.438)		(3.272)
Outside × T × Price Index		0.537		-0.351		-0.500
		(0.355)		(0.236)		(0.592)
In. PI Effect Post	0.42	0.40	0.50	0.52	0.36	0.35
In. PI Effect Pre	-0.02	-0.02	0.33	0.33	-0.08	-0.08
Ex. PI Effect Post		0.22		0.33		0.18
Ex. PI Effect Pre		-0.13		0.24		-0.11
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km
Observations	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m
R-sq	0.13	0.13	0.13	0.13	0.13	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.29: Exogenous Price Shocks: Private Zones Lagged Prices

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	1.046***	1.101***	0.950**	0.760**	0.815*	1.038**	0.952**	0.993**
	(0.342)	(0.382)	(0.351)	(0.360)	(0.450)	(0.480)	(0.358)	(0.401)
Price Index	7.502	6.710	0.575	0.901*	-0.402	-0.636	6.576*	6.941*
	(7.344)	(8.993)	(0.464)	(0.474)	(0.996)	(1.147)	(3.769)	(3.764)
L.Price Index	-11.069	-8.465	1.743**	2.090**	-1.263	-1.384	-6.632*	-7.277**
	(15.370)	(18.818)	(0.727)	(0.855)	(1.483)	(1.640)	(3.555)	(3.406)
Inside × T × Price Index	-4.367	-3.550	1.981**	2.620***	-0.357	-0.669	1.158	1.114
	(9.081)	(10.384)	(0.746)	(0.922)	(0.983)	(0.976)	(2.888)	(2.936)
L.Inside × T × Price Index	7.368**	5.990**	0.529	0.639	1.238*	1.055*	1.511	1.321
	(3.172)	(2.750)	(0.445)	(0.448)	(0.622)	(0.617)	(1.894)	(1.832)
T	-0.367	-0.419	0.042	0.234	-0.384	-0.600	-0.545	-0.586
	(0.394)	(0.417)	(0.523)	(0.530)	(0.408)	(0.434)	(0.444)	(0.479)
Inside × Price Index	8.463	9.227	0.007	-0.304	0.729	0.973	-8.505*	-8.875*
	(12.297)	(13.525)	(0.496)	(0.518)	(1.113)	(1.230)	(4.483)	(4.477)
L.Inside × Price Index	0.717	-1.907	-3.626***	-3.989***	0.231	0.356	2.843	3.492
	(26.965)	(29.642)	(1.032)	(1.216)	(1.254)	(1.455)	(3.495)	(3.364)
T × Price Index	-2.660	-3.485	-1.579***	-2.207***	-0.764	-0.458	-2.090	-2.046
	(4.771)	(6.185)	(0.539)	(0.607)	(0.678)	(0.704)	(2.476)	(2.526)
L.T × Price Index	-2.146	-0.763	-0.314	-0.421	0.887	1.066	3.176**	3.367**
	(2.877)	(3.003)	(0.413)	(0.409)	(0.705)	(0.766)	(1.408)	(1.326)
Outside × T		0.196		-0.574*		0.673***		0.140
		(0.216)		(0.294)		(0.230)		(0.270)
Outside × Price Index		1.647		-0.813*		0.788		-1.226
		(7.314)		(0.449)		(0.957)		(1.864)
L.Outside × Price Index		-8.254		-1.496**		0.529		2.213
		(16.305)		(0.570)		(0.973)		(1.677)
Outside × T × Price Index		2.531		2.030***		-0.980**		-0.154
		(3.896)		(0.653)		(0.406)		(1.179)
L.Outside × T × Price Index		-4.421		0.368		-0.665		-0.640
		(3.066)		(0.266)		(0.613)		(0.718)
PI Effect Post	0.74	0.78	1.14	1.03	0.23	0.36	-0.82	-0.87
PI Effect Pre	0.70	0.70	0.21	0.22	0.17	0.17	-0.25	-0.25
Ex. PI Post		-0.19		-0.70		-0.26		-0.89
Ex. PI Pre		0.36		0.03		0.08		0.74
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km m	30 km	30(-10)km
Observations	1.29m	1.29m	1.29m	1.29m	1.29m	1.29m	1.29m	1.29m
R-sq	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.30: Exogenous Price Shocks: Public Zones Lagged Prices

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.109***	0.139**	0.103**	0.143**	0.243***	0.306***	0.199***	0.249***
	(0.039)	(0.055)	(0.046)	(0.064)	(0.083)	(0.108)	(0.068)	(0.080)
Price Index	-0.889	-1.147	0.086	0.054	-0.331	-0.461	0.332	0.304
	(1.798)	(2.109)	(0.238)	(0.279)	(0.314)	(0.339)	(0.330)	(0.327)
L.Price Index	-0.178	0.957	-0.360	-0.283	-0.043	-0.185	-1.020**	-0.806*
	(2.188)	(2.668)	(0.282)	(0.312)	(0.530)	(0.558)	(0.413)	(0.481)
Inside × T × Price Index	3.543***	3.593***	0.300	0.299	-0.277*	-0.307	-0.360**	-0.365*
	(0.903)	(1.057)	(0.335)	(0.358)	(0.153)	(0.191)	(0.171)	(0.206)
L.Inside × T × Price Index	-4.280***	-3.927***	-0.496	-0.449	-0.461*	-0.547**	-0.084	-0.032
	(0.726)	(0.733)	(0.569)	(0.561)	(0.269)	(0.270)	(0.122)	(0.119)
T	0.250***	0.221***	0.200***	0.160**	0.160**	0.098	0.098	0.049
	(0.067)	(0.070)	(0.060)	(0.065)	(0.077)	(0.088)	(0.081)	(0.086)
Inside × Price Index	-3.940***	-3.680**	-0.084	-0.050	1.227***	1.360***	0.692**	0.715**
	(1.389)	(1.693)	(0.412)	(0.446)	(0.303)	(0.349)	(0.333)	(0.335)
L.Inside × Price Index	9.229***	8.086***	0.657	0.577	0.611	0.758	0.058	-0.149
	(2.111)	(2.745)	(0.767)	(0.759)	(0.483)	(0.515)	(0.297)	(0.420)
T × Price Index	-2.710***	-2.761***	-0.254	-0.254	0.047	0.076	0.135	0.139
	(0.829)	(1.008)	(0.219)	(0.259)	(0.115)	(0.141)	(0.191)	(0.237)
L.T × Price Index	-0.473	-0.823	0.236	0.191	0.096	0.180	0.385**	0.333**
	(0.701)	(0.757)	(0.210)	(0.243)	(0.146)	(0.178)	(0.149)	(0.152)
Outside × T		0.081		0.107		0.190*		0.147**
		(0.060)		(0.065)		(0.096)		(0.058)
Outside × Price Index		0.878		0.056		0.418		0.092
		(1.960)		(0.305)		(0.270)		(0.259)
L.Outside × Price Index		-3.807		-0.260		0.427		-0.580
		(3.040)		(0.257)		(0.354)		(0.594)
Outside × T × Price Index		0.301		0.046		-0.115		-0.032
		(0.802)		(0.242)		(0.189)		(0.165)
L.Outside × T × Price Index		1.152		0.157		-0.247		0.135
		(0.849)		(0.221)		(0.169)		(0.162)
In. PI Effect Post	0.26	0.27	0.29	0.30	0.89	0.96	0.40	0.41
In. PI Effect Pre	-0.16	-0.16	0.00	0.00	0.44	0.44	0.23	0.22
Ex. PI Effect Post		0.25		0.23		0.47		0.24
Ex. PI Effect Pre		-0.01		0.03		-0.02		0.09
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km m	30 km	30(-10)km
Observations	10.9m	10.9m	10.9m	10.9m	10.9m	10.9m	10.9m	10.9m
R-sq	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the municipality level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.31: Exogenous Price Shocks: Private Zones Spatial Autocorrelation

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.932***	0.974***	1.091***	0.866***	1.006**	1.304***	1.211***	1.192***
	(0.260)	(0.281)	(0.303)	(0.300)	(0.434)	(0.468)	(0.309)	(0.322)
Price Index	8.361	9.289	1.479	2.017*	-0.889	-0.996	2.216	2.538
	(8.239)	(9.027)	(1.034)	(1.072)	(1.526)	(1.625)	(2.451)	(2.543)
Inside × T × Price Index	6.094*	5.825	1.196	1.894**	0.482	-0.054	0.126	0.363
	(3.390)	(3.613)	(0.754)	(0.808)	(0.865)	(0.922)	(1.571)	(1.634)
T	-0.195	-0.239	-0.043	0.181	-0.676	-0.966**	-0.724**	-0.706**
	(0.296)	(0.313)	(0.329)	(0.332)	(0.420)	(0.449)	(0.325)	(0.334)
Inside × Price Index	5.501	4.497	-1.823	-2.360*	1.232	1.365	-0.654	-0.980
	(18.332)	(18.661)	(1.287)	(1.370)	(1.348)	(1.467)	(3.396)	(3.508)
T × Price Index	-8.533***	-8.251***	-1.519**	-2.205***	0.070	0.593	0.493	0.258
	(2.798)	(3.031)	(0.609)	(0.644)	(0.647)	(0.712)	(1.347)	(1.360)
Outside × T		0.162		-0.665**		0.925***		-0.067
		(0.198)		(0.261)		(0.287)		(0.261)
Outside × Price Index		-4.449		-1.779***		0.417		-1.202
		(9.152)		(0.525)		(0.931)		(1.531)
Outside × T × Price Index		-1.060		2.102***		-1.772***		0.827
		(3.476)		(0.486)		(0.603)		(1.160)
PI Effect Post	0.87	0.82	0.26	0.06	1.24	1.31	0.48	0.44
PI Effect Pre	0.60	0.60	-0.13	-0.13	0.18	0.19	0.20	0.20
Ex. PI Post		-0.68		-1.18		-0.43		-0.79
Ex. PI Pre		0.21		0.09		-0.30		0.17
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km m	30 km	30(-10)km
Observations	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m	1.42m
R-sq	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the state-year level. ***, **, *=significant at 1, 5 and 10 % level.

Table A.32: Exogenous Price Shocks: Public Zones Spatial Autocorrelation

	(1) Cattle	(2) Cattle	(3) Corn	(4) Corn	(5) Timber	(6) Timber	(7) NTFP	(8) NTFP
Inside × T	0.154***	0.188***	0.147**	0.187***	0.393***	0.495***	0.330***	0.399***
	(0.056)	(0.061)	(0.062)	(0.068)	(0.075)	(0.085)	(0.080)	(0.091)
Price Index	0.650	1.354	-0.064	-0.069	-0.320	-0.538	-0.775***	-0.644**
	(2.466)	(2.642)	(0.314)	(0.354)	(0.374)	(0.399)	(0.290)	(0.293)
Inside × T × Price Index	2.766	3.381	0.286	0.350	-0.699***	-0.837***	-0.606**	-0.593**
	(2.057)	(2.171)	(0.328)	(0.362)	(0.178)	(0.202)	(0.253)	(0.268)
T	0.266***	0.234***	0.192***	0.153**	0.123*	0.023	-0.021	-0.088
	(0.055)	(0.056)	(0.061)	(0.063)	(0.069)	(0.075)	(0.079)	(0.087)
Inside × Price Index	-3.038	-3.744	0.049	0.055	1.493***	1.717***	0.942***	0.811**
	(4.819)	(4.878)	(0.557)	(0.585)	(0.410)	(0.452)	(0.348)	(0.356)
T × Price Index	-4.343***	-4.956***	-0.285	-0.350	0.139	0.276*	0.693***	0.680***
	(1.123)	(1.258)	(0.214)	(0.258)	(0.129)	(0.144)	(0.193)	(0.207)
Outside × T		0.092**		0.104**		0.307***		0.203***
		(0.038)		(0.044)		(0.064)		(0.058)
Outside × Price Index		-2.342		-0.049		0.688**		-0.332
		(2.266)		(0.312)		(0.310)		(0.251)
Outside × T × Price Index		2.216*		0.272		-0.436***		0.002
		(1.159)		(0.253)		(0.143)		(0.169)
In. PI Effect Post	0.27	0.25	0.35	0.35	0.97	1.08	0.54	0.51
In. PI Effect Pre	-0.08	-0.08	-0.00	-0.00	0.58	0.58	0.04	0.04
Ex. PI Effect Post		0.16		0.23		0.59		0.19
Ex. PI Effect Pre		-0.03		-0.03		0.07		-0.22
Control Group	30 km	30(-10)km	30 km	30(-10)km	30 km	30(-10)km m	30 km	30(-10)km
Observations	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m	11.9m
R-sq	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

Note: Dependent variable is deforestation rate. All columns include grid and year fixed effects. Standard errors in parentheses are clustered on the state-year level. ***, **, *=significant at 1, 5 and 10 % level.