Deforestation Slowdown in the Legal Amazon: Prices or Policies?*

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Abstract

This paper investigates to what extent soybean prices and conservation policies have contributed to the recent deforestation slowdown in the Legal Amazon. A difference-in-differences strategy at the municipality level is used on a sample of 395 municipalities. Results suggest that the adoption of the conservation policies seems to be effective in restraining deforestation in the Legal Amazon and in weakening the causal mechanisms between agricultural commodity prices and forest clearings. The deforestation cycle in the 2000s can apparently be explained by prices up to late 2003, a combination of prices and policies from 2004 to 2007, and policies from 2008 onwards.

Este artigo investiga como o preço da soja e políticas de conservação ambiental contribuíram para a recente queda no desmatamento na Amazônia Legal. Utiliza-se uma estratégia de diferença-em-diferenças a nível municipal com uma amostra de 395 municípios. Resultados sugerem que políticas de conservação parecem ser eficazes para conter o desmatamento na Amazônia Legal e para enfraquecer o mecanismo causal entre o preço de produtos agrícolas e desmatamento. O ciclo de desmatamento dos anos 2000 pode ser explicado por preços até o final de 2003, uma combinação de preços e políticas de 2004 a 2007 e políticas a partir de 2008.

Key words: Deforestation, Land Use, Amazon Forest
Palavras-chave: Desmatamento, Uso da Terra, Floresta Amazônica

Área ANPEC: Área 10 - Economia Agrícola e do Meio Ambiente
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1 Introduction

The Brazilian Legal Amazon has long been the most active land use frontier in the world in terms of total forest loss and CO^2 emissions (FAO [2006], Santilli et al. [2005], Morton et al. [2006]).[1] Yet, deforestation in the region has declined sharply since the mid-2000s. The annual deforestation rate dropped from a peak of 27.7 thousand square kilometers in 2004 to less than 6.5 thousand in 2010.[2] Understanding the causes of this slowdown is therefore crucial from a policy perspective. However, empirical knowledge about the causal mechanisms behind the recent trends of land use and forest clearings in the Legal Amazon is still scant.

This paper investigates to what extent agricultural output prices and conservation policies have contributed to the deforestation slowdown in the Legal Amazon. Researchers have shown that agricultural market conditions are highly correlated with the pace of forest clearings (Ewers et al. [2008], Nepstad et al. [2008], Barona et al. [2010], Arima et al. [2011]). Indeed, during the first half of the last decade, the price of soybean and the deforestation rate in the Legal Amazon follow very similar trajectories, as seen in Figure 1. From mid-2006 onwards, however, this pattern no longer appears to hold - despite the sharp rise in the price of soybean, the overall decline in the deforestation rate persists.

Deforestation slowdown in the Legal Amazon has therefore occurred within two very distinct contexts - falling soybean prices from 2004 to mid-2006 and rising soybean prices from 2008 to 2009. Whilst the former might well be a response to unfavorable market conditions at the time, the latter indicates that factors other than the price of soybean were affecting the pace of forest clearings. As of early 2004, Brazilian legislation targeting control and prevention of deforestation underwent significant revisions. Amongst the many resulting changes to environmental laws and procedures, two sets of policies stand out as likely contributors to the slowdown of deforestation in the Legal Amazon: the Action Plan for Prevention and Control of Deforestation in the Legal Amazon (*Plano de Ação para a Prevenção e Controle do Desmatamento na Amazônia Brasileira*, PPCDAM), initiated in early 2004, and the combination of Decree Number 6,321 and Ordinance Number 28, dating from December 2007 and January 2008, respectively. Figure 1 shows that the timing of adoption of these policies coincide with sharp subsequent decreases in the recorded

[1] The Brazilian Legal Amazon refers to the area within the nine Brazilian states that are located in the Amazon Basin. Currently, the Legal Amazon is composed of the western territory of the state of Maranhão and the entire territory of the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins.

[2] Aggregate data for the Legal Amazon from the National Institute of Spacial Research (*Instituto Nacional de Pesquisa Espacial*, INPE), based on the methodology established by the Program for Calculation of Amazon Deforestation (*Programa de Cálculo do Desflorestamento da Amazônia*, PRODES). Annual deforestation increment relates to the area of forest cleared over the last twelve months up to August of the given current year.

rate of deforestation.

We use a difference-in-differences strategy at the municipality level to examine the causal link between the implementation of the new conservation policies and the observed downward trend in deforestation in the Legal Amazon. We also interact policy variables with soybean prices in order to investigate whether policies have changed the relationship between market forces (agricultural output prices) and forest clearings.

Our results suggest that conservation policies seem to be effective in restraining deforestation in the Legal Amazon. Moreover, the changes made to Brazilian environmental legislation appear to have weakened the causal mechanisms between commodity prices and forest clearings. The Brazilian deforestation cycle - and its recent slowdown - can apparently be explained by prices up to late 2003, a combination of prices and policies from 2004 to 2007, and policies from 2008 onwards.

This paper is organized as follows. The next section provides the economic and institutional backgrounds for the analysis. Section 3 describes the data set. Section 4 details our empirical strategy. Section 5 presents and discusses the results. Section 6 concludes.

2 Background

To better understand how new conservation policies might have influenced deforestation in the Legal Amazon, we present an overview of the regional economic landscape during the period of interest, followed by a brief description of relevant recent changes to Brazilian environmental legislation.

2.1 Recent Trends in Prices, Production and GDP

The oscillating price of agricultural goods correlate with real effects in the regional economy. Figure 2 indicates that compared to its previously accelerated growth rate, per capita GDP in the Legal Amazon increased at a considerably lower rate from 2004 through 2006, regaining speed in 2007. The timing of this behavior matches the cycle for the price of soybean: years of low per capita GDP growth coincide with the period of accentuated price decrease, and recovery of growth occurs at the same time as the upward trend in price level resumes. The pattern of growth for the rest of Brazil, on the other hand, appears to have remained mostly unchanged throughout the decade. This suggests that the slowdown in per capita GDP and, consequently, the negative impact on the well-being of people living in the Legal Amazon, was associated to relevant changes within the local economies, rather than to a country-wide cycle.

Figure 3 provides further graphical evidence of the relationship between agricultural prices and the economy. Panel 3a shows that the value of production decreased significantly during the period of falling prices. Moreover, Panels 3b to 3d indicate that the participation of agriculture in regional GDP experienced a sharp decline from 2004 to 2006, while that of industry remained stable and that of services strongly increased. The overlap of the decrease in share of agricultural GDP and decrease in soybean prices again suggests that agricultural commodity price cycles and real outcomes are correlated in economy of the Legal Amazon.

2.2 Institutional Context

Allegedly alarmed by the accentuated increase in the deforestation rate recorded for the Legal Amazon in the early years of the 2000s, the federal government of Brazil approved the creation of the Permanent Group of Interministerial Work (*Grupo Permanente de Trabalho Interministerial*) via a Presidential Decree in July 2003. Composed by the heads of fourteen key Ministries, the group's goal was to propose and coordinate actions aimed at reducing deforestation in the Amazon. In March 2004, the group presented the operational project for the PPCDAM, a large set of strategic conservation measures to be implemented and executed as part of a collaborative effort between federal, state and municipal governments, alongside specialized organs and the civil society. The PPCDAM's action plan focused on three main areas: territorial management and land use, command and control, and promotion of sustainable practices. Activities within each of these areas were assigned to different geographic regions, ranging from the entirety of the Legal Amazon to specific municipalities considered as having a greater risk of showing high deforestation.[3] Most activities were due to be executed in 2004, with some projects carrying on into 2005 and 2006.

Further changes to Brazilian environmental legislation occurred in December 2007, when Decree 6,321 was passed. Unlike the PPCDAM, which was designed as a wide-ranging and far-reaching conservation program, Decree 6,321 established the legal basis needed to single out municipalities with very high deforestation rates and take differentiated action towards them. In January 2008, the Ministry of Environment published Ordinance 28, listing the first thirty-six municipalities classified as in need of priority action to prevent, monitor and combat illegal deforestation.[4] The identification of these

[3]The high risk municipalities include those located along the Arc of Deforestation, a region denoting the frontier of agricultural occupation, and within the area of influence of the BR-163, a longitudinal highway linking Rio Grande do Sul to Pará and cutting straight through the Amazon forest.

[4]The thirty-six municipalities were: Lábrea, in Amazonas; Alta Floresta, Aripuanã, Brasnorte, Colniza, Confresa, Cotriguaçu, Gaúcha do Norte, Juara, Juína, Marcelândia, Nova Bandeirantes, Nova Ubiratã, Paranaíta, Peixoto de Azevedo, Porto dos Gaúchos, Querência, São Félix do Araguaia, Vila

municipalities, henceforth referred to as 'top deforesters', was based on three criteria: total deforested area, total area deforested in the past three years, and increase in deforestation rate in at least three of the past five years. Any municipality in the Legal Amazon could be included in the list of top deforesters. This list was due to be periodically updated by the Ministry of Environment. According to Decree 6,321, rural establishments in top deforesters became subject to stricter command and control policies, including harsher registration and georeferencing requirements, and more rigorous monitoring of irregular activity.

In addition to tightening command and control, Decree 6,321 also affected credit policies. Previous legislation had already determined that economic activities in areas that suffered from illegal deforestation or irregular burning of natural vegetation were to be embargoed. As of the passing of Decree 6,321, official federal credit agencies were forbidden to approve credit of any kind not only to agricultural or forest activities performed within such areas, but also to any service and commercial or industrial activity that involved the acquisition, intermediation, transport or commercialization of goods produced in embargoed establishments. Moreover, in Resolution Number 3,545 of February 2008, the Central Bank of Brazil conditioned agricultural financing in the Legal Amazon to the presentation of documentation that proved the borrower's legal status from an environmental and a territorial point of view.

Overall, the two sets of institutional changes aimed at reducing deforestation by increasing the cost of clearing forest land in the Legal Amazon. They were, however, implemented within very different economic scenarios. On the one hand, the PPCDAM was announced and executed during a period of downward trend in soybean prices, such that both policy and price cycles may have potentially contributed to slow down the rate of deforestation. On the other, Decree 6,321 and all subsequent legislation were approved after prices had bounced back, thereby exerting opposing pressures on land use practices - while high commodity prices pushed for greater deforestation, stricter conservation policies implied a greater cost for those engaging in forest burning and clearing.

The fact that deforestation rates continued to decrease despite the upward trend in prices suggests that policy might have changed the relationship between deforestation and agricultural commodity prices. Figure 4 appears to support this claim, showing a comparison between the mean standardized annual increase in deforestation of top deforesters and that of other municipalities in the states of Amazonas, Mato Grosso, Pará and Rondônia. Mean increases tend to fall for both types of municipalities after

Rica and Nova Maringá, in Mato Grosso; Altamira, Brasil Novo, Cumaru do Norte, Dom Eliseu, Novo Progresso, Novo Repartimento, Paragominas, Rondon do Pará, Santa Maria das Barreiras, Santana do Araguaia, São Félix do Xingu and Ulianópolis, in Pará; Machadinho d'Oeste, Pimenta Bueno, Porto Velho and Nova Mamoré, in Rondônia.

2004, but top deforesters show a slightly more accentuated rate of decrease starting in 2008, precisely the time when targeting of top deforesters became institutionally viable. Our analysis empirically tests whether policy interventions indeed exerted this sort of influence on deforestation rates.

3 Data and Descriptive Statistics

Our analysis is based on a municipality-by-year panel data set that includes municipalities located in the Legal Amazon states of Amazonas, Mato Grosso, Pará and Rondônia. This selection restricts the sample to the states that had at least one top deforester in their territory, as published by the Ministry of Environment in Ordinance 28.[5] The final sample comprises 395 municipalities.

The data set is built from municipality level information covering the 2002 to 2009 period. Below, we introduce the main variables used in the analysis and describe how they were constructed.

3.1 Deforestation

Data on deforestation is built from satellite-based images that are digitally processed and publicly released at the municipality level by INPE/PRODES. We focus on the annual deforestation increment, which consists of the area in square kilometers of forest cleared over the twelve months up to August of a given current year. Thus, the annual deforestation increment of year t relates to the area of land deforested between August of $t-1$ and August of t. Due to cloud cover during the period of remote sensing, lags between images from different years may span from less to more than twelve months. Variables indicating areas covered by clouds and other unobservable areas, both of which are made publicly available by INPE/PRODES, are included in all regressions to control for measurement error.

In order to smoothen sharp variations in the annual deforestation increment recorded in large municipalities under high pressure of deforestation, we build a standardized measure of annual increment. It follows the formula:

$$D_{i,t} = \frac{ADI_{i,t} - \overline{ADI}_{i,t}}{SD\left(ADI_{i,t}\right)} \tag{1}$$

[5] All municipalities from the four states were included in the data set, with the exception of Sorriso. This Mato Grosso municipality was Brazil's largest producer of soybean in 2004, despite the severe climate shocks that affected the area at the time. In our sample, Sorriso was clearly an outlier and was therefore excluded.

where $ADI_{i,t}$ is the annual deforestation increment measured in municipality i between August of $t-1$ and August of t, and $\overline{ADI}_{i,t}$ and $SD\left(ADI_{i,t}\right)$ are, respectively, the mean and the standard deviation of the annual deforestation increment calculated for each i over the period 2002 to 2009.

3.2 Prices

This analysis focuses on two groups of variables of interest: (i) agricultural output prices and policies, and (ii) the interactions between them. In terms of prices, we restrict attention to soybean not only because Brazil recently experienced an accentuated expansion of industrial farmland dedicated to the crop, which potentially accounted for a large share of forest clearings, but also because soybean price has shown substantial variation over the past decade. Indeed, soybean price fluctuation generates different economic incentives at the local level, depending on the relative relevance of soybean cropland in a municipality's agricultural production. To capture this cross-sectional feature, we interact a soybean price time series with a measure of soybean production intensity at the municipal level. The resulting variable is defined as follows:

$$PP_{i,t-1} = PO_i * PI_{t-1} = \frac{\overline{SoyArea}_{i,2000-02}}{Area_i} * \overline{SoyPrice}_{t-1} \tag{2}$$

where $\overline{SoyArea}_{i,2000-02}$ is the average area of soybean cropland calculated over the years between 2000 and 2002.[6] The variable $Area_i$ is the municipality's area size, while $\overline{SoyPrice}_{t-1}$ is the lagged soybean prices averaged over the twelve calendar months of year $t-1$.[7]

Lagged prices are used because deforestation in t is measured over the period between August of t and August of $t-1$. Thus, lagged prices should coincide with the timing of the farmers' decision on forest clearings, field preparation and sowing.[8] The resulting variable $PP_{i,t-1}$ is therefore an interaction between a baseline measure for soybean intensity calculated years before any policy intervention and a commodity price time series that varies according to international conditions. This should give us an exogenous source of variation for economic incentives driven by relative prices across Brazilian municipalities and over time.

[6]The area of soybean cropland is originally recorded in the annual Municipal Agricultural Survey (*Pesquisa Municipal Agrícola*, PAM) conducted by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*, IBGE).

[7]Information on soybean prices is taken from the Paraná State Secretariat of Agriculture and Supply (*Secretaria da Agricultura e do Abastecimento do Paraná*, SEAB-PR/Ipeadata).

[8]In the northern region of Brazil, soybean sowing usually takes place in the last quarter of each year.

3.3 Policies

As discussed in Section 2, many of the stricter conservation practices and more intense command and control operations proposed in the PPCDAM were destined to specific regions in the Legal Amazon. The geographical targeting of environmental legislation became even clearer after Decree 6,321 allowed a well defined set of municipalities to be singled out for differentiated action. We exploit both the timing and the cross-sectional variation of these initiatives to construct our three policy variables.

We start by building a dummy variable, $TopDef_i$, indicating the thirty-six municipalities that were included in the Ministry of Environment's 2008 list of top deforesters. Note that the variable is equal to one not only from 2008 onwards, but in all sample years. Given that the top deforesters were chosen based on criteria that considered their deforestation rates over the past five years, $TopDef_i$ serves as a means to identify municipalities where deforestation occurred more heavily over our period of interest. As many of the PPCDAM policies were directed specifically to municipalities with a high risk of deforestation, it is likely that the 2008 top deforesters were also the ones being targeted from 2004 onwards.[9]

The second dummy variable, $Pos2004_t$, simply signals when $t > 2004$ for all municipalities. This marks the year when the PPCDAM strategies were due to be initiated; that is, when intensification of conservation practices and command and controls operations probably occurred in the municipalities under high risk of deforestation.

Finally, given the timing and the geographical focus of the environmental policies, we use the interaction $PPCDAM_{i,t} = Pos2004_t * TopDef_i$ to capture where and when the interventions had the highest probability of taking place under the PPCDAM strategy.

4 Empirical Strategy

In order to examine the effect that soybean prices and conservation policies have had on the rate of deforestation in the Legal Amazon, we use a difference-in-differences strategy where policy dummies are interacted with prices. More specifically, our baseline model is defined by the following equation:

$$D_{it} = \alpha_i + \phi_t + \beta_1 PP_{it} + \beta_2 TopDef * Pos2004 + \tag{3}$$

$$+\beta_3 PP_{it} * TopDef + \beta_4 PP_{it} * Pos2004 + \beta_5 PP_{it} * TopDef * Pos2004 + \epsilon_{it}$$

[9]Indeed, there is some overlap between municipalities regarded as being high risk during the implementation of the PPCDAM and municipalities listed as top deforesters in 2008. For example, many of the top deforesters are found within the Arc of Deforestation or the area of influence of the BR-163.

where D_{it} is defined in Equation (1), and $PP_{it} = PO_i * PI_{t-1}$, as defined by Equation (2). The first two terms of the right-hand side of Model (3) are municipality and year fixed-effects, which control for unobservable municipality characteristics and common time trends, respectively. The remaining two coefficients of the first line of the model measure the price (β_1) and policy effects (β_2). In the second line, we include the interaction terms. The first coefficient β_3 simply captures whether prices have a distinct marginal effect on deforestation in top deforesters. The coefficient β_4 indicates whether the relationship between prices and deforestation has changed from 2004 onwards, while β_5 indicates if this change is marginally different for top deforesters.

We include two additional interactions in full specifications. First, we add the dummy variable $TopDef * 2009$, which captures whether the policy measures implemented from early 2008 onwards have any independent effect on deforestation. We then add the variable $TopDef * 2009 * PP_{it}$ to further test whether the relationship between prices and deforestation has changed due to policy interventions.

All regressions include variables indicating areas covered by clouds and other unobservable areas. Robust standard errors are always clustered at the municipality level to account for spatial correlation in error terms.

In robustness checks, we include the lagged municipal share of deforested area as an additional control. This is important under the hypotheses that (i) deforestation rates tend to be decreasing over time when forest cover becomes sparse; and (ii) policies are targeted at municipalities that have faced high deforestation rates. In this case, omitting lagged deforestation may bias the estimated policy coefficients upwards.

Table 1 presents a general characterization of the thirty-six municipalities listed in Ordinance 28. Variables are averaged across municipalities over the 2002 to 2009 period. Descriptive statistics show that top deforesters are, on average, significantly larger and less densely populated than non-deforesters. Moreover, they represent frontier agricultural expansion territory and deforest ten times as much as non-top deforesters.

5 Deforestation: Prices or Policies?

Table 2 presents the first set of results. In the first column of Panel A, we observe a positive and significant relation between prices and deforestation. In the second column, which tests whether this relationship has changed after 2004, we find that the interaction between prices and the variable $Pos2004$ is negatively correlated, but not statistically significant. One likely explanation for this result is that while prices decreased from 2004 to 2006, policy effectiveness might have been a non-binding constraint on forest clearings. We therefore run separate regressions for the two different periods of sharp price increase,

2002 to 2004 and 2007 to 2009, and show the results in Columns 3 and 5, respectively. The larger coefficient in Column 3 - more than threefold that in Column 5 - indicates that the relationship between rising prices and increasing deforestation is weaker in the 2007 to 2009 than in the 2002 to 2004 period. Recalling that the latter refers to the period just before the implementation of the new PPCDAM conservation efforts, our findings suggest that the causal mechanisms between commodity prices and forest clearings may have changed as a response to environmental policy. In the late 2000s, deforestation does not seem to be as sensitive to variations in agricultural output prices as it was in the first half of the decade.

The first set of specifications are repeated in Table 3, but we now add the interactions with the dummy variable $TopDef_i$. In the first column of Panel A, we simply include an interaction between prices and $TopDef_i$. We observe that the relationship between deforestation and prices tends to be stronger in these municipalities, although the interaction is not statistically significant. Our main specification is presented in the second column. We find a negative and significant coefficient for the term $Pos2004_t * TopDef_i$, as well as a negative and significant coefficient for the interaction $PP_{it} * Pos2004_t * TopDef_i$. These results suggest that policies have been effective in curbing deforestation in top deforesters not only directly, but also by weakening the relationship between agricultural commodity prices and forest clearings. The comparison between Columns 3 and 5 of Table 3, which reveals that estimated price coefficients are smaller in the 2007 to 2009 period, supports this same view. These results are robust in Panel B, with the exception of the direct policy effect $Pos2004_t * TopDef_i$, which is no longer negative and statistically significant. Interestingly, Column 5 of Panel B shows that soybean prices do not seem to drive deforestation in the late 2000s, as the coefficient for PP_{it} is not statistically significant. This suggests that policies may have been effective in constraining forest clearings during the more recent rise in commodity prices.

Finally, in Table 4, we include the interaction terms $TopDef * 2009$ and $TopDef * 2009 * PP_{it}$ to capture whether the latest policy interventions had any direct or price effects. In Panel A, we observe that both terms are negative and statistically significant. The direct effect, however, does not seem robust in Panel B, where lagged deforested area is controlled for. The relationship between soybean prices and deforestation still appears to be weaker, as suggested by the robustness of the $TopDef * 2009 * PP_{it}$ coefficient.

Overall, the results presented so far indicate that the new conservation policies adopted as of 2004 seem to have been effective in restraining deforestation in the Legal Amazon. Empirical evidence further suggests that, in addition to this direct effect, the changes made to Brazilian environmental legislation also appear to have weakened the causal mechanisms linking agricultural commodity prices and forest clearings. There are there-

fore three different combinations of elements apparently capable of explaining the 2000s deforestation cycle in the Legal Amazon and its recent slowdown: (i) commodity prices up to late 2003; (ii) a mix of commodity prices and conservation policies from 2004 to 2007; and (iii) conservation policies from 2008 onwards.

6 Final Comments

Understanding the determinants of deforestation and disentangling their specific effects is a non-trivial task. This paper take a step in this direction, applying a difference-in-differences strategy at the municipality level to assess the causal link between the implementation of new conservation policies and the recent deforestation slowdown in the Brazilian Legal Amazon. Our results suggest that changes to Brazilian environmental policies - more specifically, the introduction of the PPCDAM strategy and the direct targeting of top deforesters after the passing of Decree 6,321 and subsequent related legislation - affected deforestation levels directly, curbing forest clearings. Furthermore, evidence indicates that the policy interventions also weakened the relationship between agricultural commodity prices and deforestation.

Our empirical findings seem to offer a plausible explanation for the deforestation cycle in the Legal Amazon within the past decade. They highlight the influence of (i) commodity prices up to late 2003, (ii) a combination of commodity prices and conservation policies from 2004 to 2007, and (iii) conservation policies from 2008 onwards, thereby accounting for the deforestation slowdown observed alongside both falling soybean prices from 2004 to mid-2006 and rising soybean prices from 2008 to 2009.

Several refinements and extensions of this exercise are left as future work.

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Figure 1: Price of Soybean and Deforestation Rate in the Legal Amazon, 2000-2010

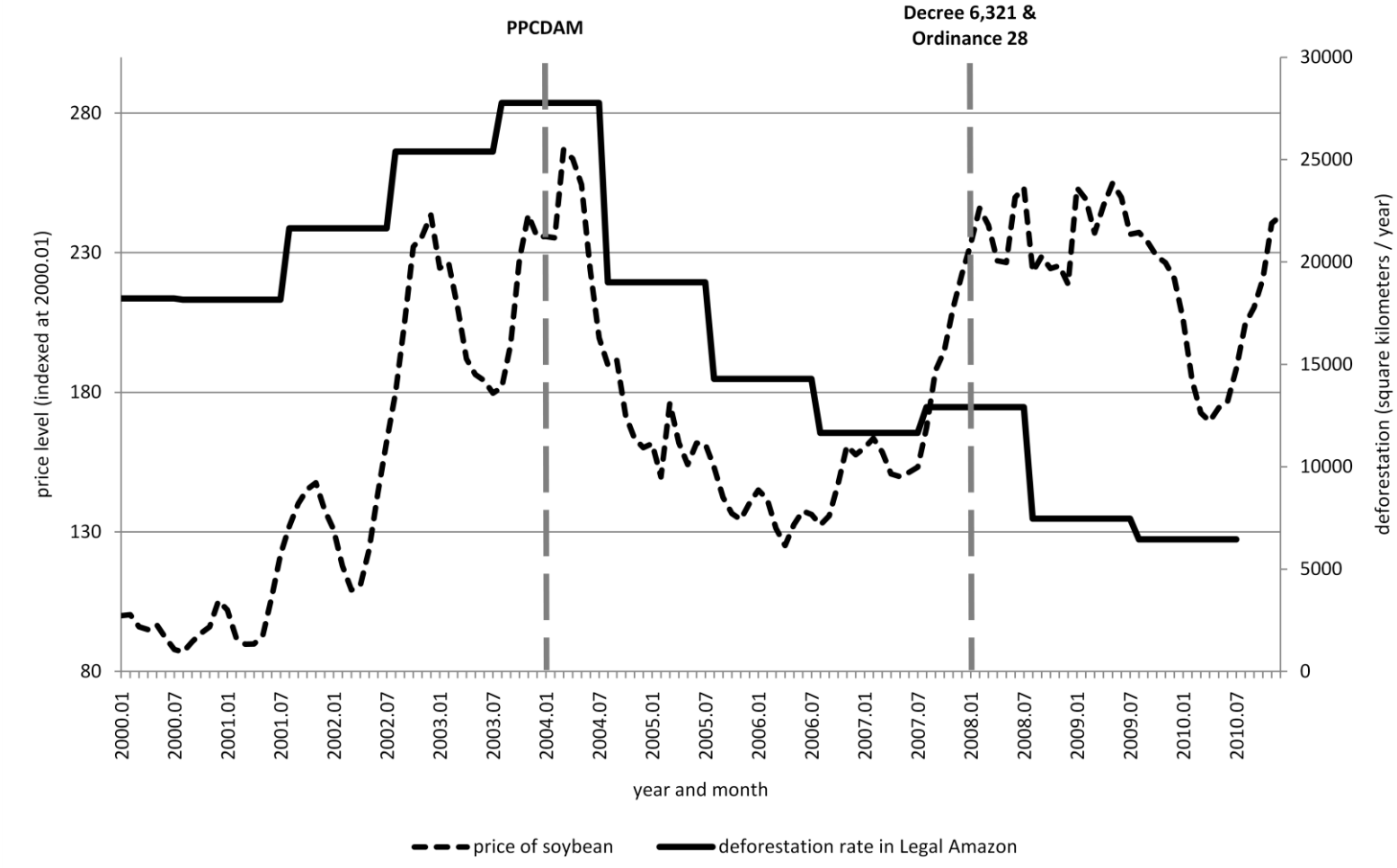


Figure 2: Per Capita GDP, 2000-2009

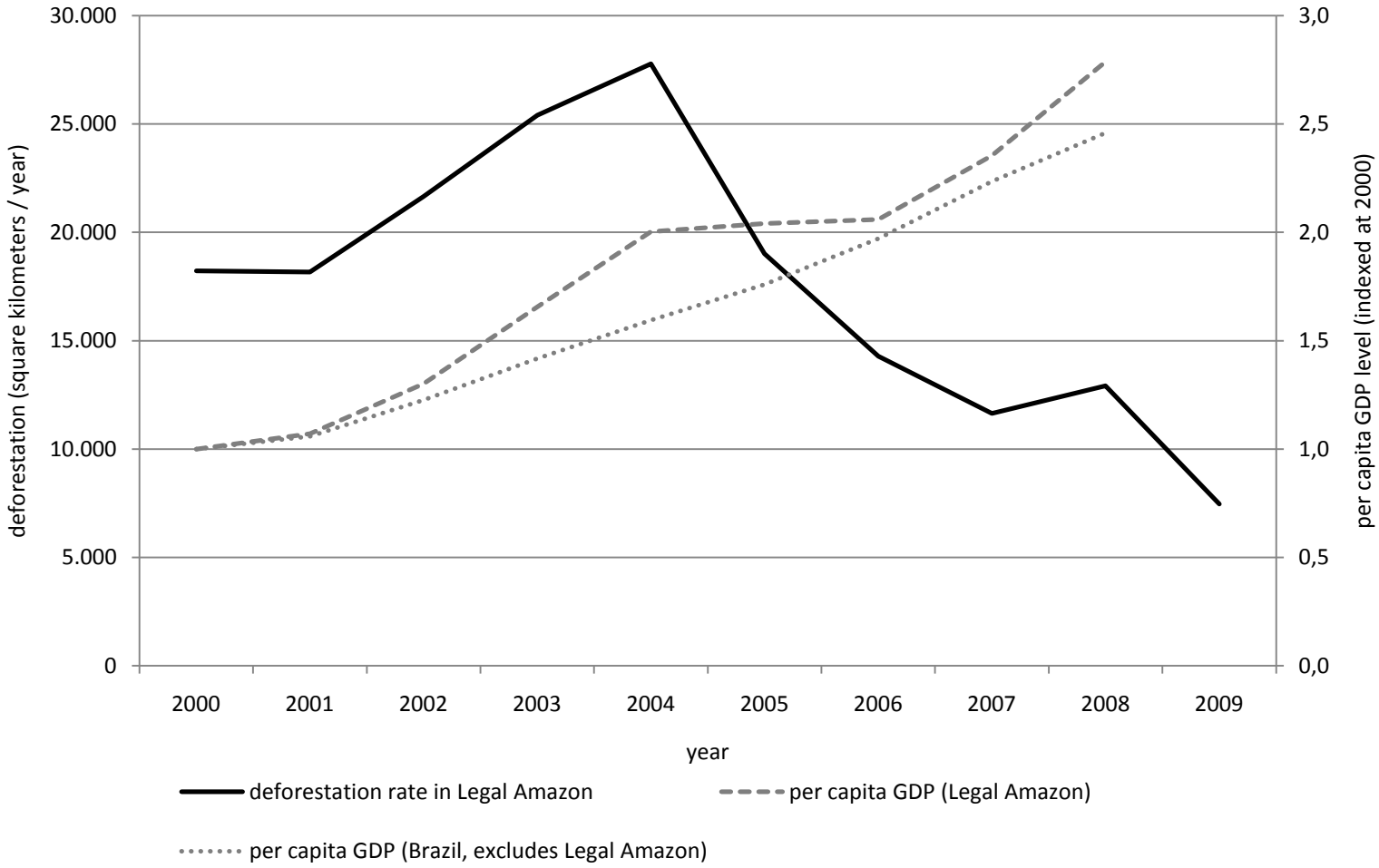
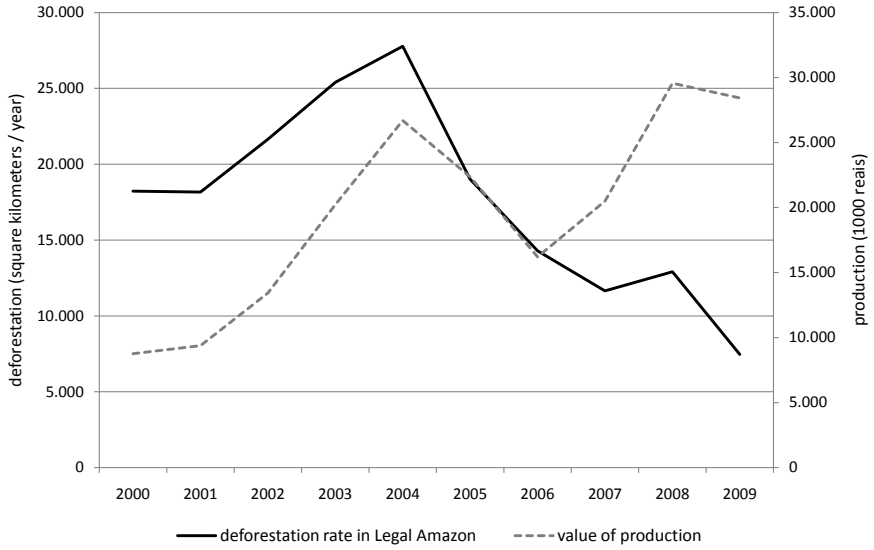


Figure 3: Production and Sector Per Capita GDP, 2000-2009

(a)



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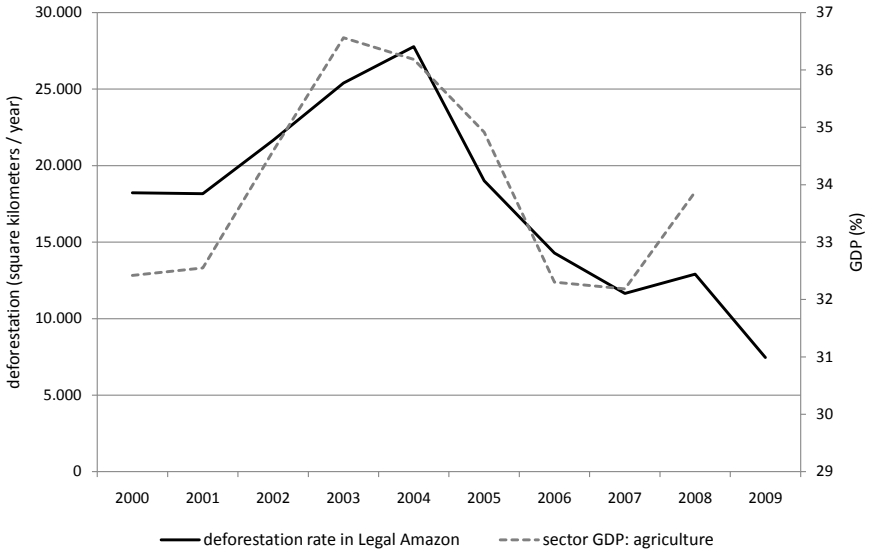

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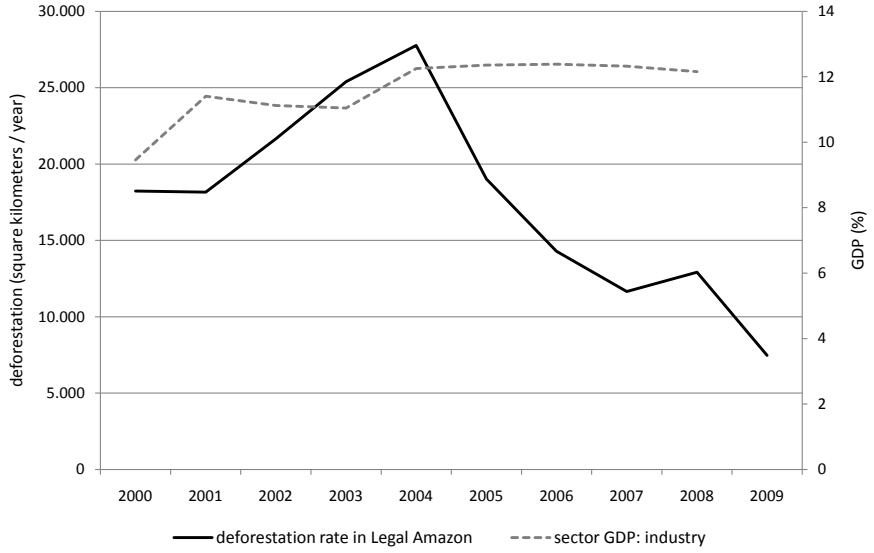


(d)

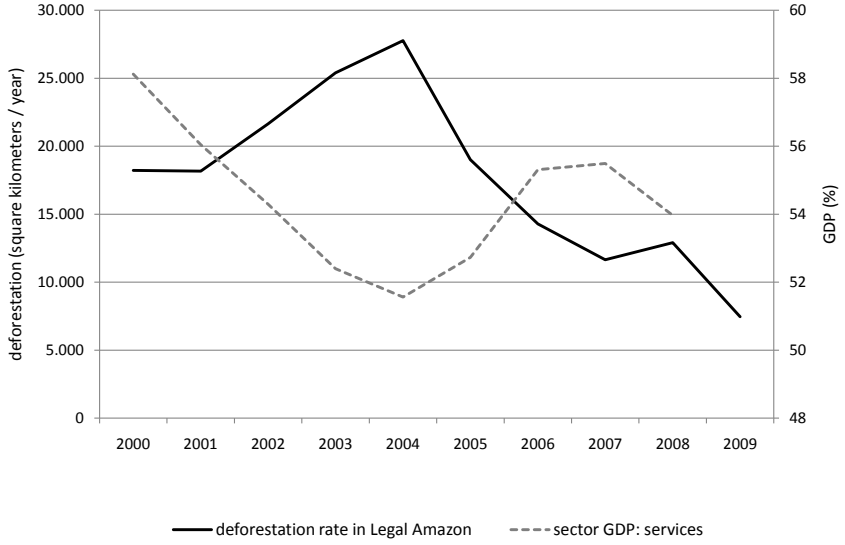
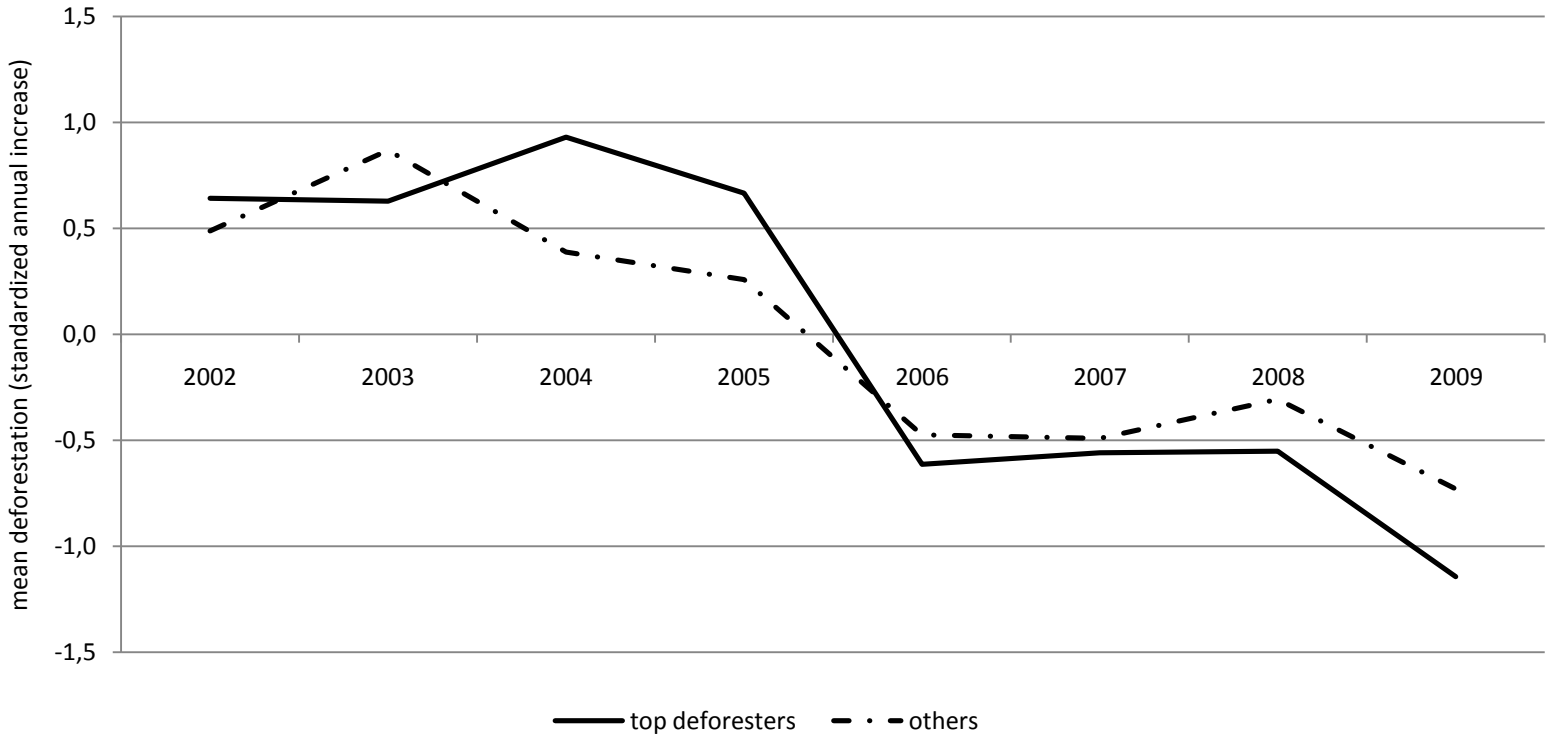


Figure 4: Mean Deforestation, 2000-2009



Note: Sample restricted to the states of Amazonas, Mato Grosso, Pará and Rondônia.

Table 1: Descriptive Statistics: Socioeconomic Characterization of Top Deforesters

	Brazil (Non-Legal Amazon)	Non-Top Deforesters	Top Deforesters	Dif.	Signif.
	(1)	(2)	(3)	(3)-(2)	
Area in Km2	730	8927	21749	12822	***
Population	33643	36547	36754	208	
Pop Density	120	25	2,4	-22,7	***
% Deforested Area	.	0,42	0,34	-0,08	**
Annual Deforestation (in Km2)	.	23,81	217,55	194	***
GDP per capita	28,60	7,98	8,63	0,64	
% GDP Agriculture	24,09	33,73	39,80	6,07	**
% GDP Industry	16,94	12,73	12,45	-0,29	
% GDP Services	58,97	53,54	47,75	-5,78	**
% Area of temporary plantation	0,194	0,051	0,024	-0,027	***
% Area of permanent plantation	0,033	0,006	0,002	-0,005	***
% Area of soybean plantation	0,048	0,023	0,012	-0,011	*
Cattle (1.000)	27	113	349	236	***
Cattle / Population	2,7	9,9	16,4	6,50	***
Cattle/Km2	42,76	36,71	26,23	-10,48	***
Soybean Productivity (R$ per Ha)	1,27	1,33	1,39	0,06	
Soybean Productivity (Tons per Ha)	2,30	2,80	2,91	0,11	**

Notes: This table presents descriptive statistics comparing the thirty-six top deforesters to non-top deforesters in the states of Amazonas, Mato Grosso, Pará and Rondônia. Variables are averaged across municipalities over the 2002 to 2009 period.

Table 2: Deforestation, Prices and Policies: Changing Patterns in 2004

	Dep. Variable: Deforestation (Stdzed Annual Increase)				
	(1)	(2)	(3)	(4)	(5)
	Panel A: Baseline Specification				
Soybean Price*Production ($P_t * P_i$)	0.110	0.141	0.222	0.063	0.061
	(0.031)***	(0.035)***	(0.065)***	(0.148)	(0.021)***
($P_t * P_i$)*Pos2004		-0.030			
		(0.025)			
Observations	3,032	3,032	1,137	758	1,137
R-squared	0.349	0.350	0.224	0.560	0.455
	Panel B: Control Lagged % Deforested Area				
Soybean Price*Production ($P_t * P_i$)	0.118	0.138	0.266	0.062	0.015
	(0.030)***	(0.034)***	(0.072)***	(0.123)	(0.020)
($P_t * P_i$)*Pos2004		-0.020			
		(0.022)			
Observations	3,032	3,032	1,137	758	1,137
R-squared	0.378	0.378	0.273	0.689	0.512
Common Specification:					
Years	2002-09	2002-09	2002-04	2005-06	2007-09
Year FE	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable is the standardized measure of annual deforestation increment. Variables of interest are soybean prices weighed by municipality soybean production, dummy variables indicating top deforesters and dummy variables indicating post-2004 periods, as well as their interaction terms. Sample includes all municipalities in the states of Amazonas, Mato Grosso, Pará and Rondônia, except for the outlier Sorriso. Panel A presents the baseline specification; Panel B offers a robustness check that adds lagged municipal share of deforested area as control variable. All regressions include year fixed effects, municipality fixed effects and controls for unobservable areas, and are calculated using robust standard errors clustered at the municipality level. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Deforestation, Prices and Policies: Changing Patterns in 2004 - Top Deforesters

	Dep. Variable: Deforestation (Stdzed Annual Increase)				
	(1)	(2)	(3)	(4)	(5)
			Panel A: Baseline Specification		
Soybean Price*Production ($P_t * P_i$)	0.108	0.138	0.219	0.058	0.060
	(0.031)***	(0.035)***	(0.066)***	(0.148)	(0.021)***
Pos2004*TopDef		-0.211			
		(0.076)***			
($P_t * P_i$)*TopDef	0.203	0.608	0.606	0.722	0.177
	(0.165)	(0.235)**	(0.432)	(0.476)	(0.090)*
($P_t * P_i$)*Pos2004		-0.030			
		(0.026)			
($P_t * P_i$)*Pos2004*TopDef		-0.333			
		(0.093)***			
Observations	3,032	3,032	1,137	758	1,137
R-squared	0.349	0.352	0.224	0.560	0.455
			Panel B: Control Lagged % Deforested Area		
Soybean Price*Production ($P_t * P_i$)	0.114	0.133	0.257	0.067	0.012
	(0.030)***	(0.034)***	(0.073)***	(0.124)	(0.020)
Pos2004*TopDef		0.162			
		(0.107)			
($P_t * P_i$)*TopDef	0.505	0.756	1.572	-0.806	0.465
	(0.191)***	(0.253)***	(0.601)***	(0.269)***	(0.083)***
($P_t * P_i$)*Pos2004		-0.016			
		(0.023)			
($P_t * P_i$)*Pos2004*TopDef		-0.277			
		(0.113)**			
Observations	3,032	3,032	1,137	758	1,137
R-squared	0.378	0.379	0.275	0.689	0.513
Common Specification:					
Years	2002-09	2002-09	2002-04	2005-06	2007-09
Year FE	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable is the standardized measure of annual deforestation increment. Variables of interest are soybean prices weighed by municipality soybean production, dummy variables indicating top deforesters and dummy variables indicating post-2004 periods, as well as their interaction terms. Sample includes all municipalities in the states of Amazonas, Mato Grosso, Pará and Rondônia, except for the outlier Sorriso. Panel A presents the baseline specification; Panel B offers a robustness check that adds lagged municipal share of deforested area as control variable. All regressions include year fixed effects, municipality fixed effects and controls for unobservable areas, and are calculated using robust standard errors clustered at the municipality level. Significance: *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Deforestation, Prices and Policies: Changing Patterns in 2004 - Top Deforesters & 2008 Policy

	Dep. Variable: Deforestation (Stdzed Annual Increase)				
	(1)	(2)	(3)	(4)	(5)
	Panel A: Baseline Specification				
Soybean Price*Production ($P_t * P_i$)	0.101	0.102	0.133	0.052	0.052
	(0.031)***	(0.031)***	(0.035)***	(0.021)**	(0.021)**
Pos2004*TopDef			-0.131		
			(0.084)		
2009*TopDef	-0.492	-0.470	-0.419	-0.272	-0.265
	(0.077)***	(0.081)***	(0.092)***	(0.105)***	(0.106)**
($P_t * P_i$)* 2009*TopDef		-0.189	-0.029		-0.269
		(0.075)**	(0.074)		(0.135)**
($P_t * P_i$)*TopDef	0.497	0.723	0.864	0.525	1.246
	(0.228)**	(0.301)**	(0.327)***	(0.166)***	(0.275)***
($P_t * P_i$)*Pos2004			-0.030		
			(0.026)		
($P_t * P_i$)*Pos2004*TopDef			-0.325		
			(0.096)***		
Observations	3,032	3,032	3,032	1,137	1,137
R-squared	0.352	0.352	0.353	0.459	0.460
	Panel B: Control Lagged % Deforested Area				
Soybean Price*Production ($P_t * P_i$)	0.111	0.111	0.129	0.012	0.012
	(0.030)***	(0.030)***	(0.034)***	(0.020)	(0.020)
Pos2004*TopDef			0.209		
			(0.109)*		
2009*TopDef	-0.219	-0.193	-0.274	0.015	0.022
	(0.080)***	(0.084)**	(0.087)***	(0.091)	(0.091)
($P_t * P_i$)* 2009*TopDef		-0.228	-0.105		-0.261
		(0.092)**	(0.077)		(0.095)***
($P_t * P_i$)*TopDef	0.629	0.902	1.008	0.448	1.146
	(0.223)***	(0.314)***	(0.341)***	(0.120)***	(0.275)***
($P_t * P_i$)*Pos2004			-0.017		
			(0.023)		
($P_t * P_i$)*Pos2004*TopDef			-0.251		
			(0.111)**		
Observations	3,032	3,032	3,032	1,137	1,137
R-squared	0.378	0.378	0.380	0.513	0.513
Common Specification:					
Years	2002-09	2002-09	2002-09	2007-09	2007-09
Year FE	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable is the standardized measure of annual deforestation increment. Variables of interest are soybean prices weighed by municipality soybean production, dummy variables indicating top deforesters and dummy variables indicating post-2004 periods, as well as their interaction terms. Sample includes all municipalities in the states of Amazonas, Mato Grosso, Pará and Rondônia, except for the outlier Sorriso. Panel A presents the baseline specification; Panel B offers a robustness check that adds lagged municipal share of deforested area as control variable. All regressions include year fixed effects, municipality fixed effects and controls for unobservable areas, and are calculated using robust standard errors clustered at the municipality level. Significance: *** p<0.01, ** p<0.05, * p<0.1.