Protecting the Rainforest? The Case of Mahogany Prohibition and Deforestation

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Tropical Deforestation

- Biodiversity
- Forest products
  - Timber
  - Non-timber
- Climate regulation (Paris Agreement)
- Carbon storage (Paris Agreement)

Prohibition Policies - Effective?

- Alcohol
- Narcotics
- CFCs
- Logging bans
  - Durst et al (2001): New Zealand, China, Vietnam, Phillipines, Sri Lanka, Thailand.
  - Africa (Mozambique), Latin America, Europe (Poland, Albania), North America (petition in Walbran Valley, BC, Canada).
  - Nellemann/Interpol: Large illegal logging markets.

Logging Industry and Tropical Deforestation in the World

- "Indirect role of timber production in opening up inaccessible forest areas, which then encourages other economic uses of forest resources, such as agricultural cultivation, that lead to deforestation on a wider scale." Barbier et al. (1995), p. 412.
- Argument applied to:
  - Brazil, Indonesia, Cameroon and 'major tropical countries' (Amelung and Diehl, 1992; Barbier et al., 1995).
  - Thailand (Cropper et al., 1999).

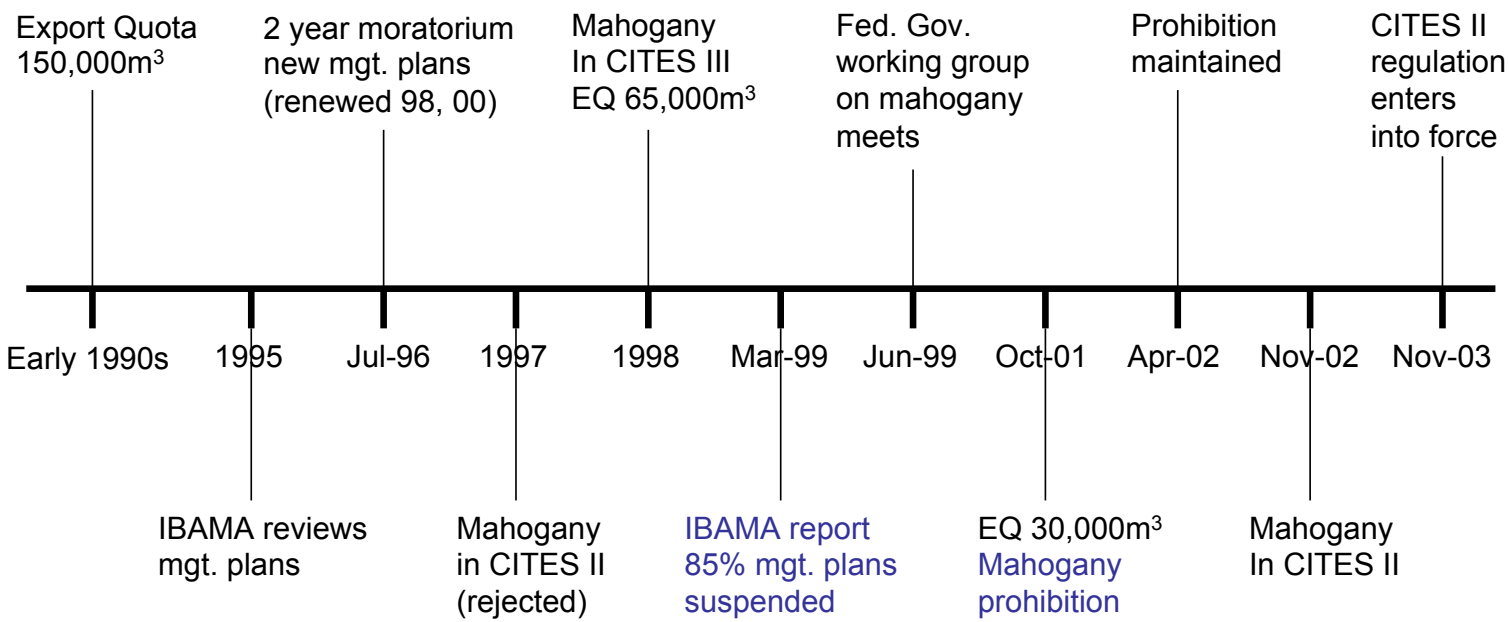
Mahogany and Deforestation in the Brazilian Amazon

"Moreover, mahogany logging indirectly contributes to regional deforestation. Logging companies have opened up some 3000 km of logging roads in southern Pará and mahogany logging has been documented in each of the region's 15 Indian Reserves. After logging, there is a growing trend to convert forests to cattle pasture, in part perhaps, because the prospects for future mahogany harvests do not appear to be good." (Verissimo et al., 1995, p. 60).

Big Leaf Mahogany

- Highly valued timber in high end markets.
- Endangered species?
- Secondary deforestation.

Timeline for Brazilian Mahogany Regulation



Mahogany Exports and Regulation

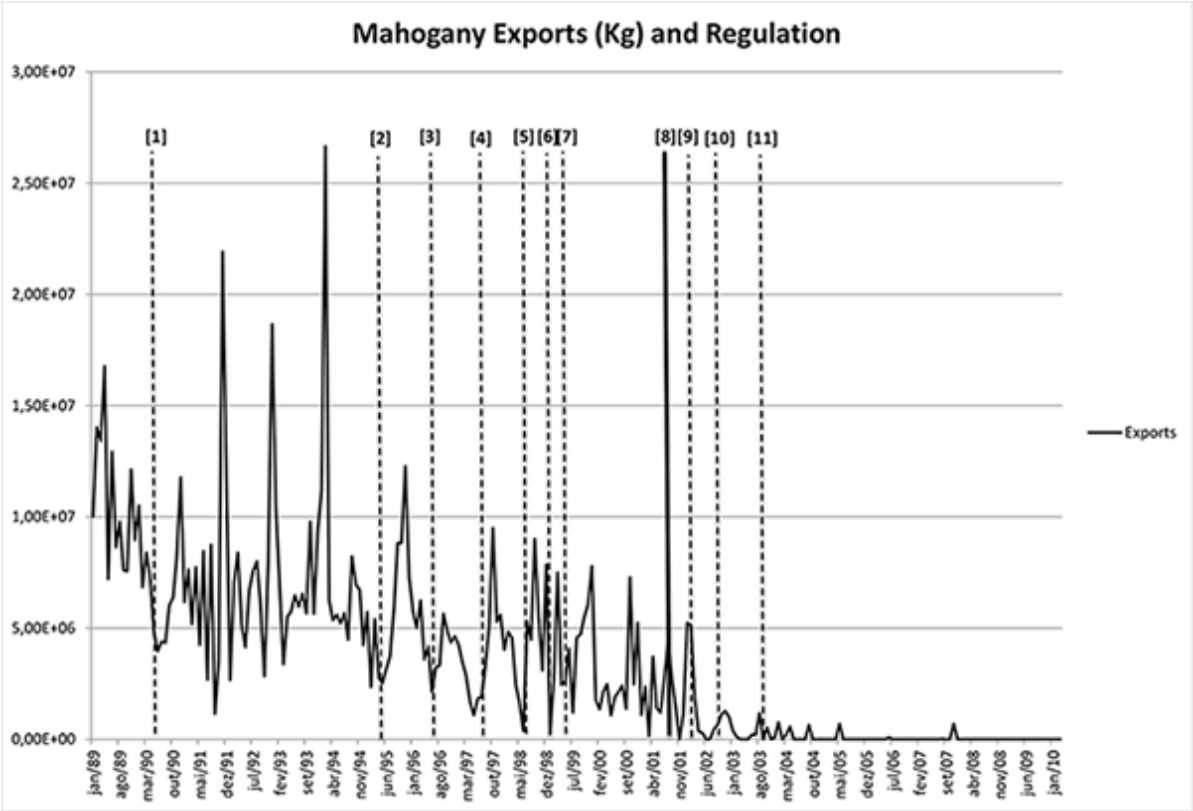


Figure 1: Total Brazilian mahogany exports (Kg) and domestic regulation of the mahogany market.

Exports of "Other Tropical" and Mahogany Regulation

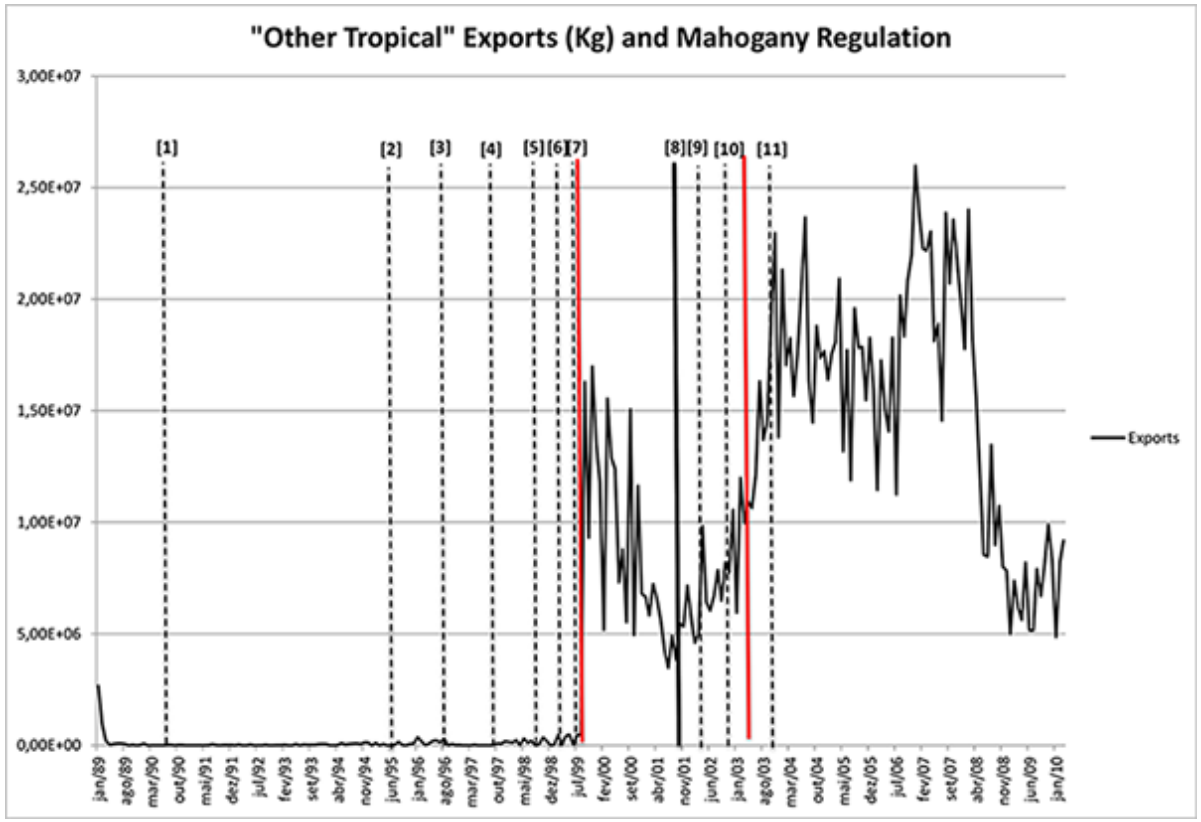
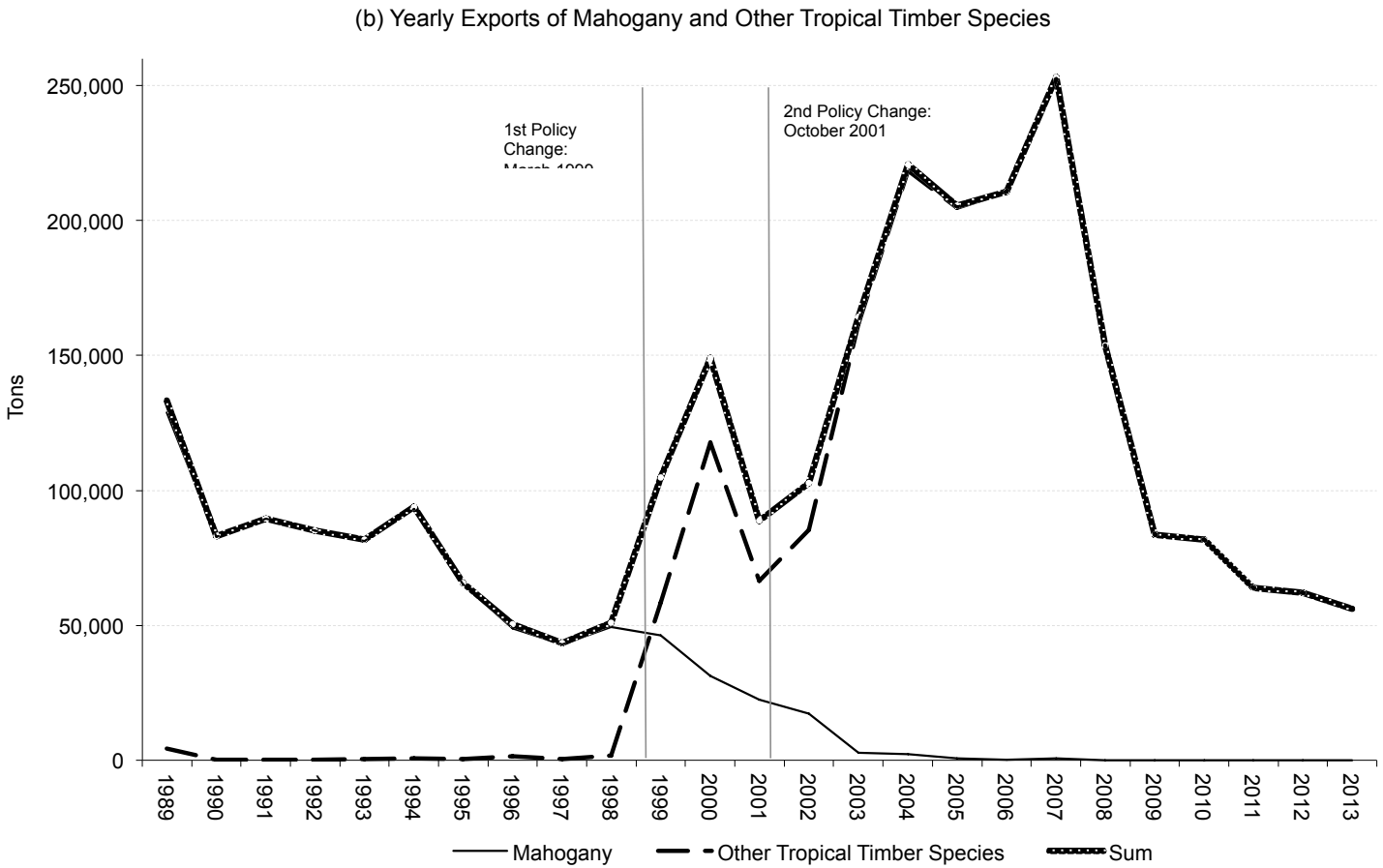


Figure 2: Total Brazilian exports of "other tropical" timber species (Kg) and domestic regulation of the mahogany market.

Combined Export Series: Mahogany + Other Tropical



Combined Export Series: Quantity

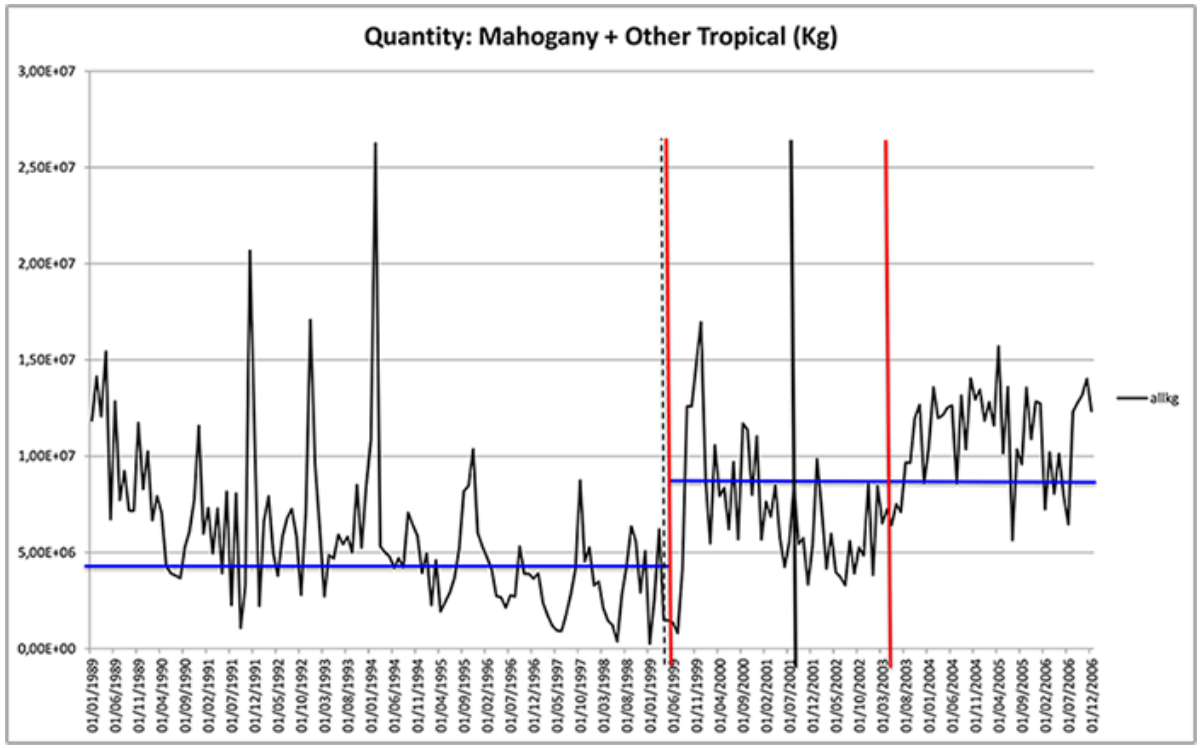


Figure 3: Quantity of exports of mahogany and other tropical species (Kg). January 1989 to December 2006.

Combined Export Series: Implicit Prices

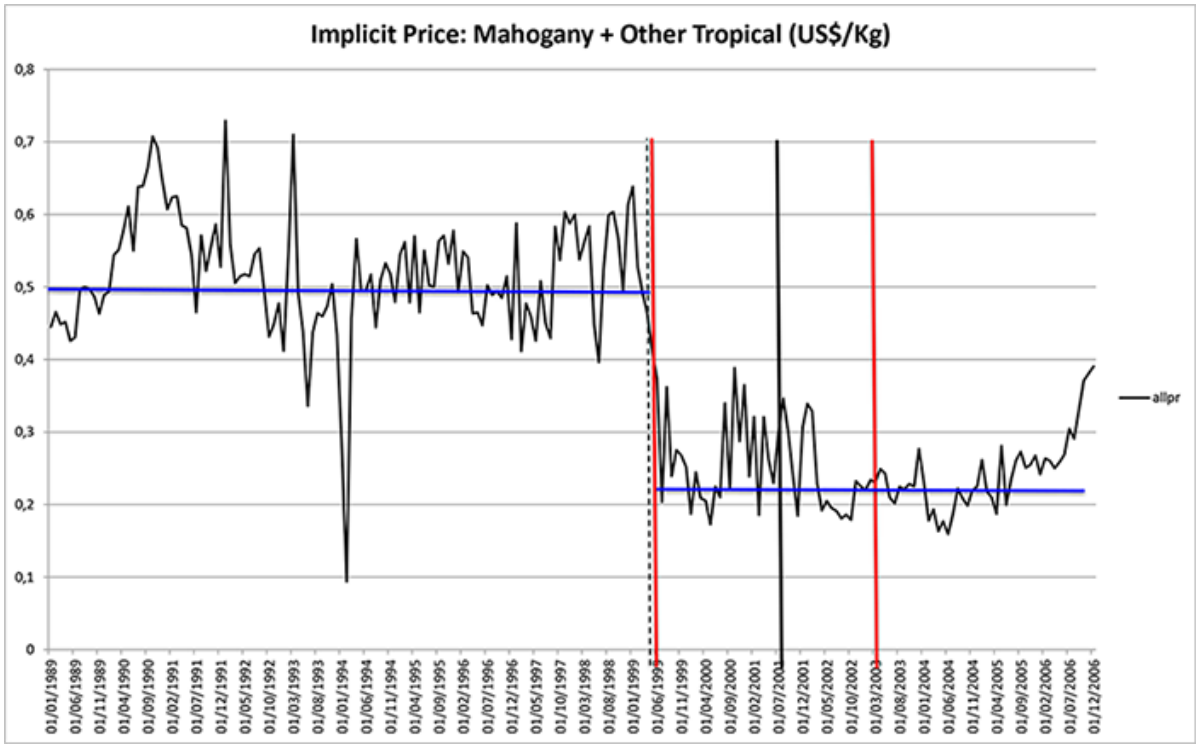


Figure 4: Implicit price of exports of mahogany and other tropical species (Kg). January 1989 to December 2006.

Quantities and Prices: A Conceptual Framework

- Idea: Regulatory environment with high monitoring costs and private monitoring (Glaeser and Shleifer, 2001; Acemoglu and Jackson, 2015).
  - Quantity regulation: firm 1 has an operating license, firm 2 does not.
  - Private enforcement: firm 1 spends m to catch firm 2?s illegal activity with probability $\theta(m)$, with $\theta'(m) > 0$.
  - If firm 2 is caught, its output is apprehended and destroyed, and it is left with its production costs.
  - Constant and identical marginal cost of production: c.
  - Legal market: private monitoring.
  - Illegal market: firms play standard Cournot.

Quantities and Prices: A Conceptual Framework

- Demand:

$$p = a - b(q_1 + q_2)$$

- Firms:

$$\max_{m,q_1} E[\pi_1] = [a - bq_1 - (1 - \theta(m))bq_2]\, q_1 - cq_1 - m$$

$$\max_{q_2} E[\pi_2] = (1 - \theta(m))[a - bq_1 - bq_2]q_2 - cq_2$$

Quantities and Prices: A Conceptual Framework

- F.O.C:

$$q_1 = \frac{a(1+\theta(m)) - c}{b(3+\theta(m))}$$

$$q_2 = \frac{a(1-\theta(m)) - c(1+\theta(m))}{b(1-\theta(m))(3+\theta(m))}$$

$$\theta'(m) = \frac{1}{bq_1q_2}$$

Quantities and Prices: A Conceptual Framework

- Regulated vs Illegal Market:

$$p^R - p^I = \frac{2\theta(m)(2a+c)}{3(3+\theta(m))} > 0$$

$$Q^R - Q^I = -\frac{\theta(m)(2a+c)}{3b(3+\theta(m))} < 0$$

Quantities and Prices: A Conceptual Framework

- Profitable to operate legally if ilegal market exists?
  - $\theta(m)$ and parameter values.

$$E[\pi_1^R] - \pi_1^I = (p^R - c)q_1^R - m - (p^I - c)q_1^I > 0$$

$$E[\pi_1^R] - \pi_1^I = \frac{\theta(m)(2a+c)(a(4\theta(m)+6) - c(\theta(m)+6))}{9b(\theta(m)+3)^2} - m > 0$$

Mahogany Prohibition: Protecting the Rainforest?

Hypothesis:

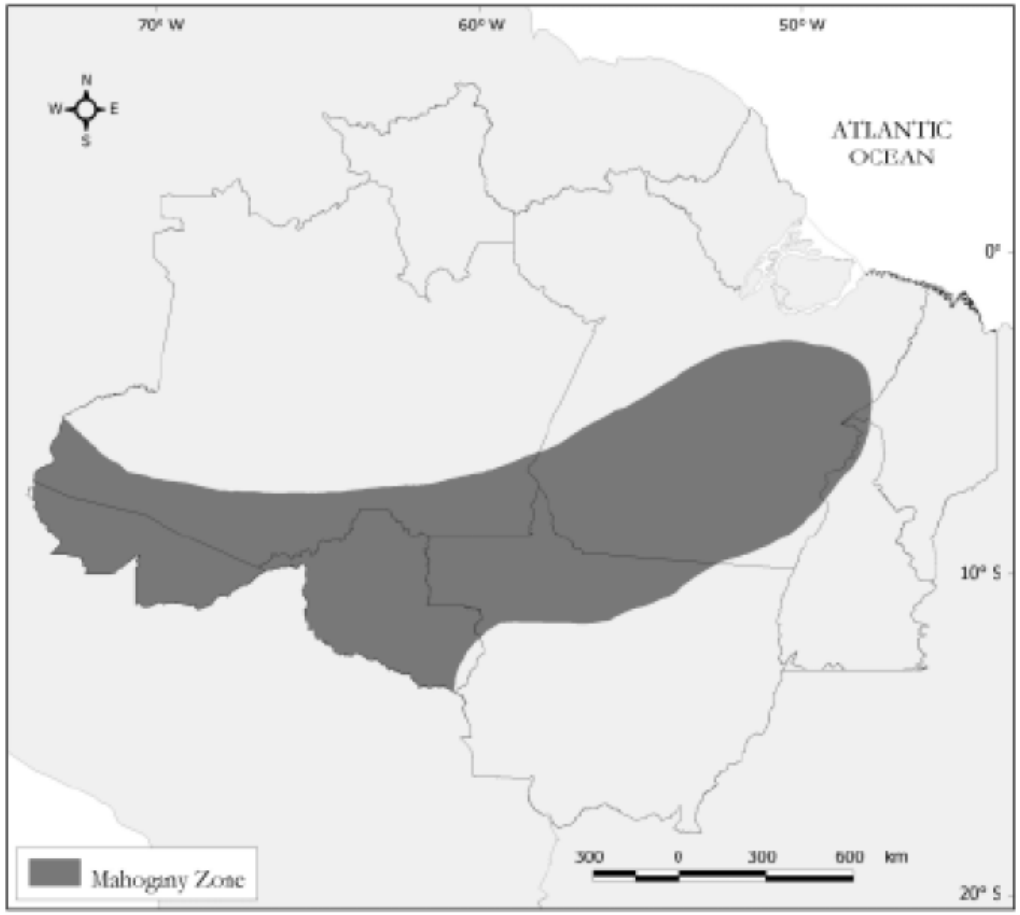
If exports of "other tropical species" indeed correspond to exports of mahogany, and mahogany exports lead to large scale deforestation, then the mahogany market prohibition must have led to increased deforestation in areas where the species naturally occurs.

Empirical Strategy

- Diff-in-Diff: forested area in mahogany vs. non-mahogany municipalities
- Dependent variables:
  - Deforestation/area (2000 – 2013) (problems – data before 2001)
  - Forest/area (2000 – 2013) (problems – data before 2001)
  - Bovine density (1974 – 2013)
- Treatment variables:
  - Mahogany prohibition
  - Areas where mahogany naturally occurs

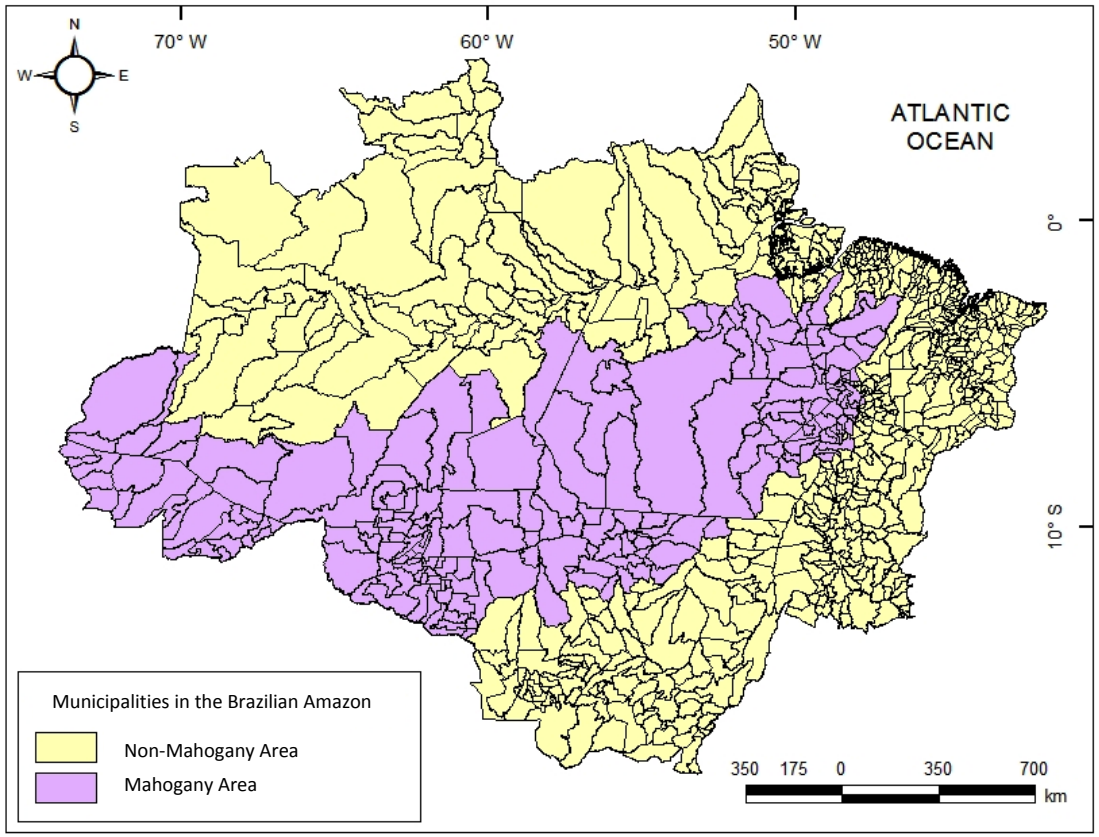
Combined Export Series: Implicit Prices

Area of Natural Occurrence of Mahogany in Brazil, from Lentini et al (2004)



Combined Export Series: Implicit Prices

Figure A1: Municipalities in the Area of Natural Occurrence of Mahogany in Brazil (built from the map provided in Lentini et al., 2003).



Empirical Strategy

- Controls:
  - Year effect
  - Year effect x State effect
  - Municipal variables at 1995 level x Year
    - ★ Bovine density
    - ★ Planted area (several temporary and permanent crops)
    - ★ Log GDP per capita
    - ★ % GDP in agriculture
    - ★ Political deaths
    - ★ Deaths by other causes

Empirical Strategy

- Robusteness Checks:
  - Placebo treatment (parallel trends)
  - Municipality-specific linear trends (differential trends in municipalities)
  - Unweighted regressions
  - Driscoll-Kraay spatially robust standard errors
  - Other outcome variables
    - ★ Equine, chicken and swine density
    - ★ Planted area (several temporary and permanent crops)

Results: Diff-in-Diff Deforestation Flow

Table 1 - Mahogany Prohibition and Deforestation Flow, 2001-2013, Differences in Differences, Results for States with Natural Ocurrence of Mahogany and for the State of Pará.

	Municipalities in states with mahogany occurrence					Municipalities in Pará			
				Triple Difference					
				State percentage in exports before 1999	Suspected state exports after 1999		Treatment interacted with linear trends		Treatment interacted with linear trends
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatament 2002	0.0489***	0.0126*	0.00403***	0.00469*	-1.46e-06	0.0221*	0.0222*	0.00350*	0.00270
	[0.0143]	[0.00678]	[0.00135]	[0.00273]	[1.06e-05]	[0.0115]	[0.0114]	[0.00201]	[0.00270]
Treatament 2002 x Trend							-4.00e-05		0.000265
							[0.000327]		[0.000348]
Treatament 2009	0.0461***	0.00811	0.000804*	0.00193*	-6.39e-05*	0.0189	0.0199	0.00112	0.00196*
	[0.0156]	[0.00712]	[0.000459]	[0.00101]	[3.75e-05]	[0.0121]	[0.0121]	[0.000792]	[0.00109]
Treatament 2009 x Trend							-0.000463***		-0.000426*
							[0.000153]		[0.000215]
Constant	-0.00975*	-0.000512	0.00115***	0.00110***	0.00137***	-0.00402	-0.00378	0.00163***	0.00189***
	[0.00528]	[0.00228]	[0.000360]	[0.000322]	[0.000322]	[0.00444]	[0.00443]	[0.000518]	[0.000538]
State FE x Year FE		X	X	X	X				
Baseline Charac. x Year FE			X	X	X			X	X
Year FE	X	X	X	X	X	X	X	X	X
Number of Observations	7,696	7,696	6,864	7,436	7,436	1,664	1,664	1,352	1,352
R^2	0.219	0.384	0.977	0.976	0.976	0.333	0.333	0.961	0.961

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is the flow of deforestation as a percentage of municipal area. All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2)-(5) control for state fixed effects interacted with year fixed effects. Columns (3), (4), (5) , (8) and (9) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area planted with temporary and permanent crops, bovine, equine, swine and chicken density, deforested area (annual flow and stock) and stock of forest as a percentage of the municipal area, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Diff-in-Diff Deforestation Stock

Table 2 - Mahogany Prohibition and Deforestation Stock, 2000-2013, Differences in Differences, Results for States with Natural Ocurrence of Mahogany and for the State of Pará.

	Municipalities in states with mahogany occurrence					Municipalities in Pará			
				Triple Difference					
				State percentage in exports before 1999	Suspected state exports after 1999		Treatment interacted with linear trends		Treatment interacted with linear trends
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatament 2002	-0.00593	0.0236***	0.0177***	0.0169	5.91e-05*	0.0157	-0.00126	0.0131	0.00188
	[0.0168]	[0.00788]	[0.00648]	[0.0125]	[3.36e-05]	[0.0112]	[0.00752]	[0.00898]	[0.00345]
Treatament 2002 x Trend							0.00566***		0.00379*
							[0.00161]		[0.00205]
Treatament 2009	0.0120	0.0457***	0.0308***	0.0389*	0.000662***	0.0408**	0.0361**	0.0311*	0.0277*
	[0.0196]	[0.0115]	[0.0102]	[0.0213]	[0.000244]	[0.0174]	[0.0165]	[0.0164]	[0.0152]
Treatament 2009 x Trend							0.00236***		0.00191*
							[0.000565]		[0.000992]
Constant	0.351***	0.343***	0.349***	0.348***	0.348***	0.389***	0.388***	0.427***	0.425***
	[0.00752]	[0.00377]	[0.00264]	[0.00148]	[0.00126]	[0.00749]	[0.00727]	[0.00569]	[0.00646]
State FE x Year FE		X	X	X	X				
Baseline Charac. x Year FE			X	X	X			X	X
Year FE	X	X	X	X	X	X	X	X	X
Number of Observations	8,288	8,288	7,392	8,008	8,008	1,792	1,792	1,456	1,456
R^2	0.984	0.989	0.998	0.998	0.998	0.993	0.993	0.997	0.997

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is the stock of deforestation as a percentage of municipal area. All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2)-(5) control for state fixed effects interacted with year fixed effects. Columns (3), (4), (5) , (8) and (9) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area planted with temporary and permanent crops, bovine, equine, swine and chicken density, deforested area (annual flow and stock) and stock of forest as a percentage of the municipal area, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Diff-in-Diff Forest Cover

Table 3 - Mahogany Prohibition and Forest Cover, 2000-2013, Differences in Differences, Results for States with Natural Ocurrence of Mahogany and for the State of Pará.

	Municipalities in states with mahogany occurrence					Municipalities in Pará			
				Triple Difference					
				State percentage in exports before 1999	Suspected state exports after 1999		Treatment interacted with linear trends		Treatment interacted with linear trends
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatament 2002	-0.00931	-0.0515***	-0.0161**	-0.0410***	6.82e-05	-0.0637***	0.0114	-0.0165	-0.0131**
	[0.0187]	[0.00955]	[0.00743]	[0.0154]	[6.16e-05]	[0.0128]	[0.00698]	[0.0113]	[0.00603]
Treatament 2002 x Trend							-0.0250***		-0.00111
							[0.00432]		[0.00258]
Treatament 2009	-0.0713**	-0.146***	-0.00961	-0.0978**	-0.000584	-0.226***	-0.221***	-0.0110	-0.0144
	[0.0327]	[0.0303]	[0.0176]	[0.0386]	[0.000464]	[0.0427]	[0.0418]	[0.0228]	[0.0215]
Treatament 2009 x Trend							-0.00248***		0.00174
							[0.000559]		[0.00188]
Constant	0.375***	0.397***	0.366***	0.356***	0.352***	0.452***	0.453***	0.422***	0.420***
	[0.0189]	[0.0151]	[0.00692]	[0.00543]	[0.00490]	[0.0276]	[0.0269]	[0.00888]	[0.00995]
State FE x Year FE		X	X	X	X				
Baseline Charac. x Year FE			X	X	X			X	X
Year FE	X	X	X	X	X	X	X	X	X
Number of Observations	8,288	8,288	7,392	8,008	8,008	1,792	1,792	1,456	1,456
R^2	0.955	0.966	0.988	0.989	0.988	0.939	0.942	0.990	0.990

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is the forest cover as a percentage of municipal area. All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2)-(5) control for state fixed effects interacted with year fixed effects. Columns (3), (4), (5) , (8) and (9) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area planted with temporary and permanent crops, bovine, equine, swine and chicken density, deforested area (annual flow and stock) and stock of forest as a percentage of the municipal area, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Bovine Density

Table 4 - Mahogany Prohibition and Bovine Density, 1995-2013, Differences in Differences, Results for States with Natural Ocurrence of Mahogany and for the State of Pará.

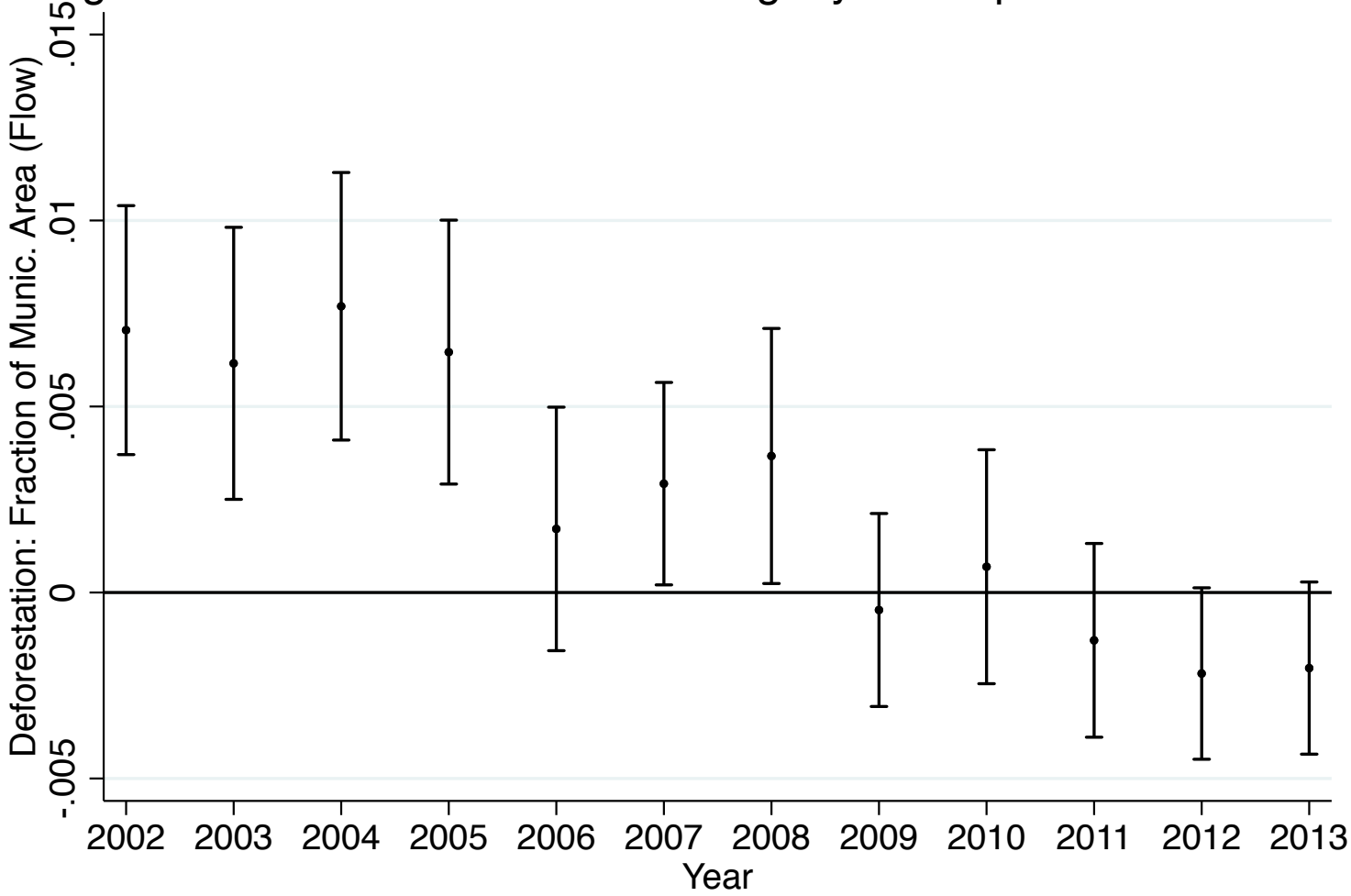
	Municipalities in states with mahogany occurrence						Municipalities in Pará		
					Triple Difference				
				Treatment interacted with linear trends	State percentage in exports before 1999	Suspected state exports after 1999			Treatment interacted with linear trends
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment 1999	6.135***	2.495**	4.031**	1.944*	6.133*	-0.00106	1.773	3.169	0.929
	[1.217]	[1.055]	[1.719]	[1.107]	[3.653]	[0.0268]	[1.596]	[2.538]	[1.570]
Treatament 1999 x Trend				0.551					0.843
				[0.674]					[0.965]
Treatament 2002	18.28***	11.58***	10.71***	9.282***	17.85***	0.0660***	14.50***	14.19***	11.75***
	[2.278]	[2.152]	[2.574]	[1.917]	[5.638]	[0.0182]	[3.003]	[3.776]	[2.756]
Treatament 2002 x Trend				0.418**					0.500**
				[0.167]					[0.244]
Constant	18.19***	18.19***	19.15***	18.19***	18.28***	18.28***	10.92***	13.31***	10.92***
	[1.115]	[1.089]	[0.872]	[1.089]	[0.859]	[0.872]	[1.132]	[1.241]	[1.132]
State FE x Year FE		X	X	X	X	X			
Baseline Charac. x Year FE			X		X	X		X	
Year FE	X	X	X	X	X	X	X	X	X
Number of Observations	11,932	11,932	10,716	11,932	11,552	11,552	2,432	1,976	2,432
R^2	0.916	0.926	0.945	0.926	0.944	0.944	0.896	0.929	0.897

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is bovine density in the municipality (number of heads/area in Km2). All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001 and after 2002 interacted with mahogany occurrence area. Columns (2) through (6) control for state fixed effects interacted with year fixed effects. Columns (3), (5) , (6) and (8) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area plantada with temporary and permanent crops, bovine, equine, swine and chicken density, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Deforestation Flow Dynamics

$$y_{it} - y_{it_0} = \delta + \beta \times M_i + \Gamma Z_{it'} + \epsilon_{it}$$

Figure 5: Deforestation Flow - Mahogany Municipalities in Pará



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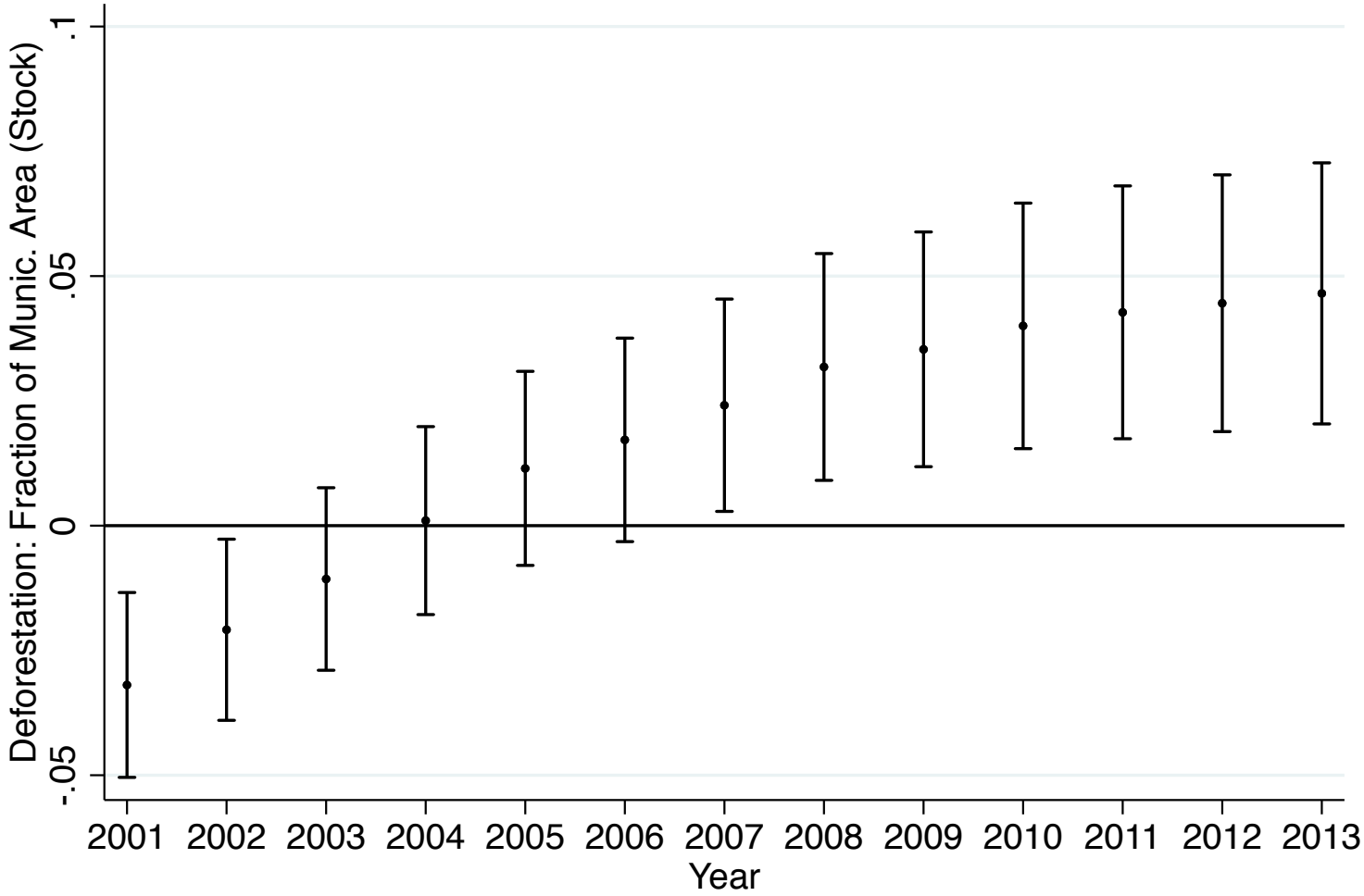
Results: Deforestation Stock Dynamics

$$y_{it} - y_{it_0} = \delta + \beta \times M_i + \Gamma Z_{it'} + \epsilon_{it}$$

Figure 6: Deforestation Stock - Mahogany Municipalities in Pará



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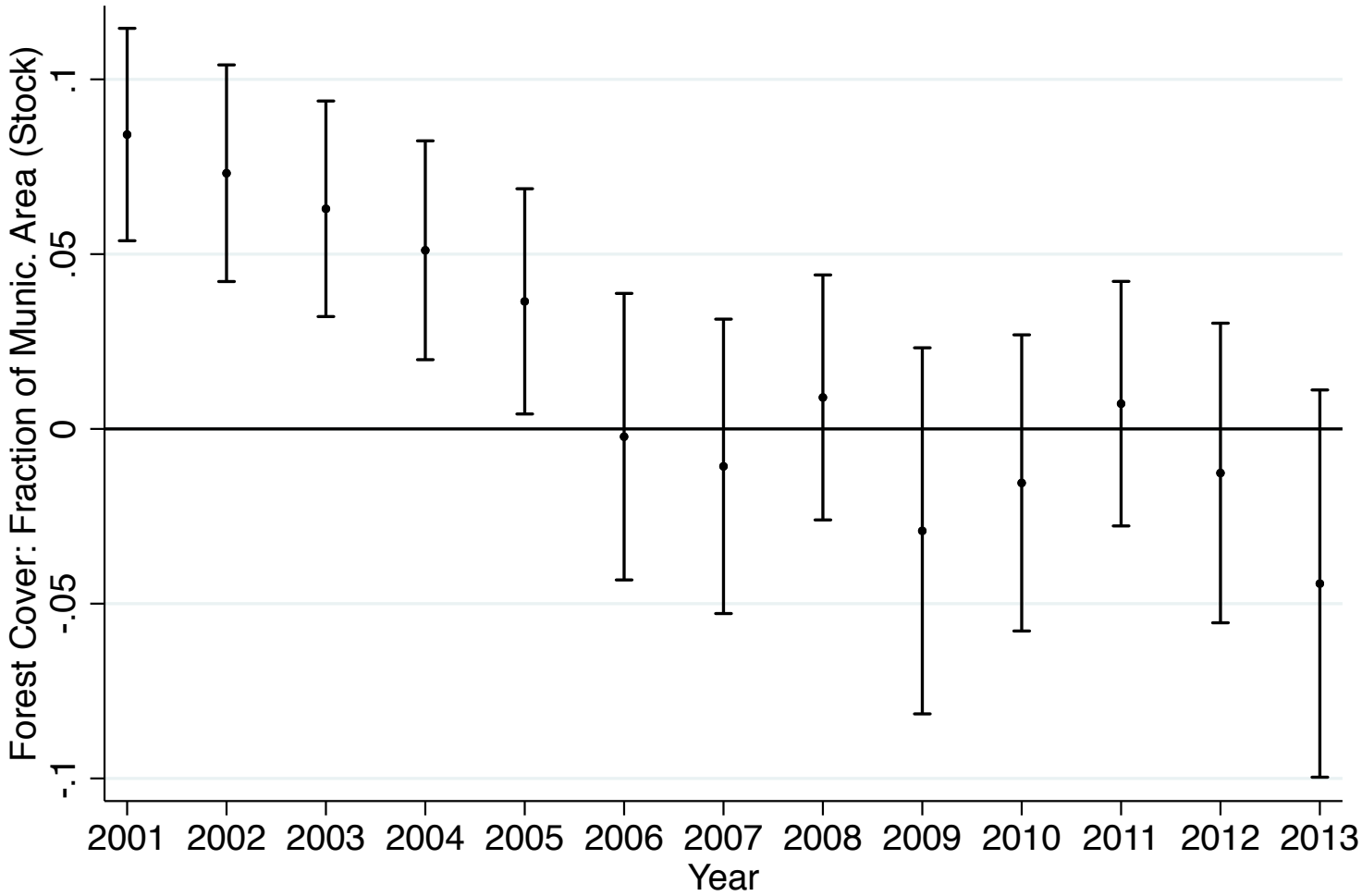
Results: Forest Cover Dynamics

$$y_{it} - y_{it_0} = \delta + \beta \times M_i + \Gamma Z_{it'} + \epsilon_{it}$$

Figure 7: Forest Cover - Mahogany Municipalities in Pará



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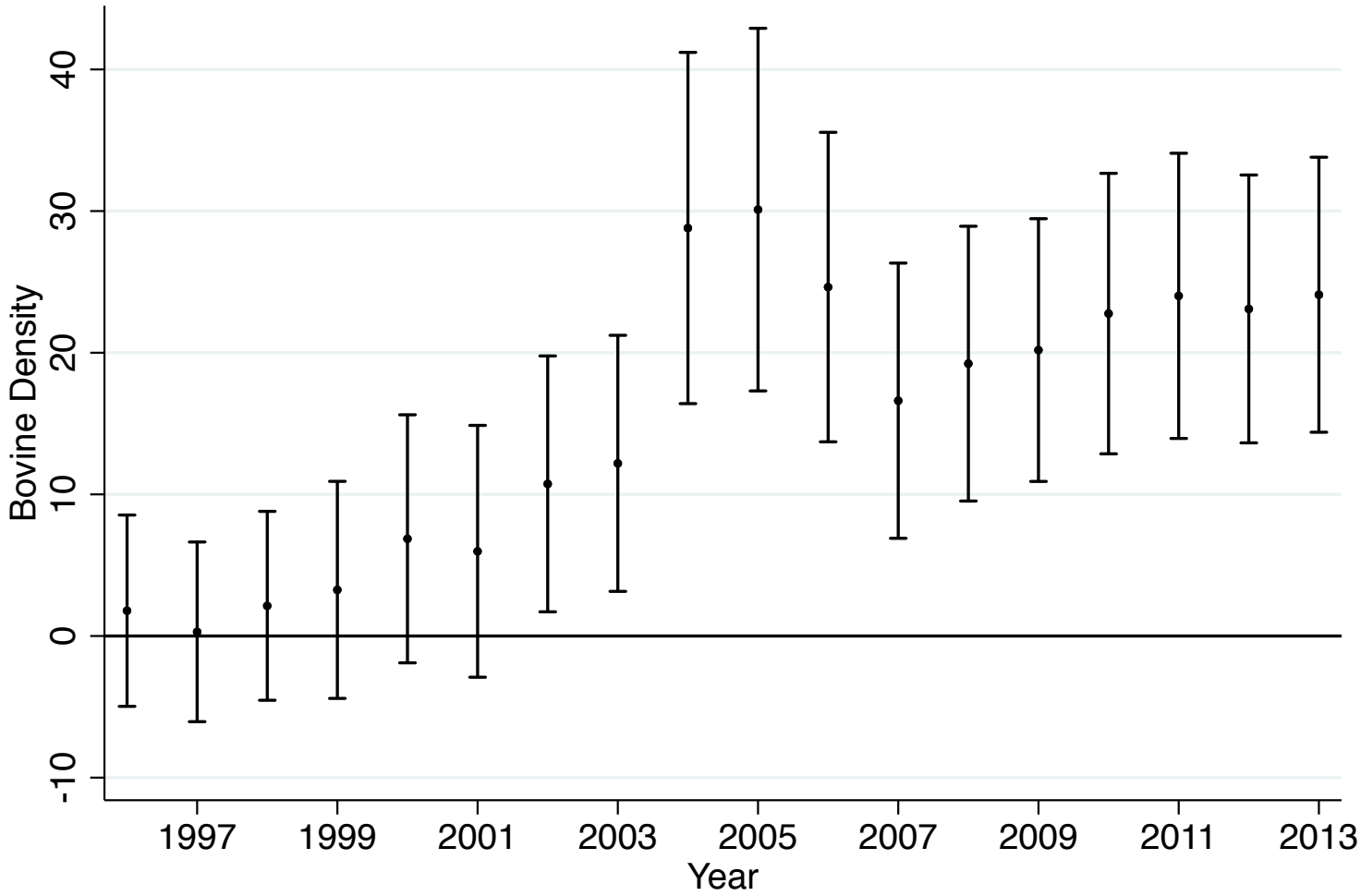
Results: Bovine Density Dynamics

$$y_{it} - y_{it_0} = \delta + \beta \times M_i + \Gamma Z_{it'} + \epsilon_{it}$$

Figure 8: Bovine Density - Mahogany Municipalities in Pará



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Conclusion

- Natural experiment: mahogany market prohibition led to larger illegal market. Private monitoring, prices and quantities.
- Hypothesis: high-value timber opens access to dense tropical forest for other economic activities that promote large-scale deforestation.
- Policy evaluation: We find evidence that deforestation **increased** in areas where mahogany naturally occurs after prohibition.
- Hypothesis testing: evidence that high-value timber indeed indirectly promotes large-scale deforestation.

Results: Bovine Density (Placebo, M. Trends)

Table 6 - Mahogany Prohibition and Bovine Density, 1995-2013, Test for Parallel Trends, Municipality-Specific Trends.

	Municipalities in mahogany states		Municipalities in mahogany states excluding Pará		Municipalities in Pará	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Treatment 1999	8.572***	3.134**	12.16***	5.077***	1.324	-0.903
	[2.107]	[1.280]	[2.823]	[1.524]	[2.163]	[2.131]
Treatment 2002	19.87***	10.15***	23.48***	11.76***	13.14***	7.097**
	[2.643]	[1.909]	[3.662]	[2.504]	[3.192]	[3.055]
Treatment 2009	21.90***	7.032***	25.64***	8.352***	15.32***	4.690
	[2.894]	[1.951]	[3.917]	[2.425]	[3.793]	[3.426]
Placebo	4.873**		7.670***		-0.899	
	[2.030]		[2.768]		[1.831]	
Constant	18.19***	18.19***	21.57***	21.57***	10.92***	10.92***
	[1.107]	[1.036]	[1.524]	[1.439]	[1.135]	[0.919]
Municipality-specific linear trend		X		X		X
Year FE	X	X	X	X	X	X
Number of Observations	11,932	11,932	9,500	9,500	2,432	2,432
R^2	0.916	0.957	0.920	0.959	0.896	0.941

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is bovine density in the municipality (number of heads/area in Km2). All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. The pre-treatment placebo is a dummy for 1997-1998 interacted with a mahogany area dummy. Columns (2), (4) and (6) include a municipal fixed effect interacted with a linear trend.

Results: Bovine Density (Unweighted, Spatial)

Table 7 - Mahogany Prohibition and Bovine Density, 1995-2013, Pará, Unweighted Regression and Standar Errors Robust to Spatial Correlation (Driscoll-Kraay).

	Unweighted	Standard errors robust to spatial correlation
Variables	(1)	(2)
Treatment 1999	2.979	1.773***
	[1.997]	[0.403]
Treatment 2002	14.77***	13.59***
	[3.256]	[2.874]
Treatment 2009	15.94***	15.77***
	[3.168]	[0.615]
Constant	15.96***	33.78***
	[1.407]	[3.256]
Year FE	X	X
Number of Observations	2,432	2,432
R^2	0.894	0.881
Number of groups		128

Notes: Robust standard errors in brackets (clustered at the municipal level) in column (1); Driscoll Kraay standard errors in bracked in column (2); Dependent variable is bovine density in the municipality (number of heads/area in Km2). All regressions include a constant, municipality fixed effects and year fixed effects. In column (2), the regression is weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area.

Results: Equine, Chicken, Swine Density

Table 8 - Mahogany Prohibition and Equine, Chicken and Swine Density, 1995-2013, Differences in Differences, Results for Pará.

	Equine			Chicken			Swine		
			Treatment interacted with linear trends			Treatment interacted with linear trends			Treatment interacted with linear trends
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment 1999	0.0434	0.0578	0.0398	-31.52	-15.89	-87.43	-2.022	-0.0463	-1.871
	[0.0373]	[0.0515]	[0.0372]	[29.86]	[27.50]	[86.59]	[1.612]	[0.428]	[1.510]
Treatament 1999 x Trend			0.00360			55.91			-0.151
			[0.0167]			[57.67]			[0.134]
Treatament 2002	0.207***	0.225***	0.154**	93.50	54.13	64.31	-0.543	0.125	-2.430
	[0.0631]	[0.0842]	[0.0601]	[122.0]	[48.67]	[94.35]	[0.610]	[0.381]	[1.924]
Treatament 2002 x Trend			0.0178**			9.728			0.629
			[0.00819]			[12.39]			[0.549]
Treat 2009	0.354***	0.213***	0.299***	100.1	92.51	101.6	1.367	0.238	0.746
	[0.0862]	[0.0801]	[0.0784]	[139.6]	[71.44]	[134.3]	[1.535]	[0.407]	[1.322]
Treatament 2009 x Trend			0.0275*			-0.781			0.311**
			[0.0143]			[5.048]			[0.128]
Constant	0.475***	0.632***	0.475***	316.3***	451.9***	316.3***	6.044***	8.368***	6.044***
	[0.0796]	[0.0262]	[0.0797]	[111.0]	[16.34]	[111.0]	[0.977]	[0.177]	[0.978]
Baseline Charac. x Year FE		X			X			X	
Year FE	X	X	X	X	X	X	X	X	X
Number of Observations	2,432	1,976	2,432	2,432	1,976	2,432	2,432	1,976	2,432
R^2	0.759	0.896	0.759	0.833	0.969	0.833	0.715	0.977	0.717

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variables are equine (columns (1) -(3)), chicken (columns (4)-(6)) and swines (columns (7)-(9)) densities in the municipality (number of heads/area in Km2). All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2), (5) and (8) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area plantada with temporary and permanent crops, bovine, equine, swine and chicken density, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Temporary Crops

Table 9 - Mahogany Prohibition and Fraction of Municipal Area Planted with Temporary Crops: Total, Rice, Beans, Cassava and Soy, 1995-2013, Differences in Differences, Results for the State of Pará.

	Total Temporary			Rice			Beans			Cassava			Soy		
			Treatment interacted with linear trend			Treatment interacted with linear trend			Treatment interacted with linear trend			Treatment interacted with linear trend			Treatment interacted with linear trend
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Treatment 1999	0.00409	0.000179	0.00543*	0.00103	0.00101	0.00185*	-0.000599	-0.00121**	-0.000621	0.00293	-0.00227*	0.00247	1.81e-05	-1.55e-05	2.29e-05
	[0.00301]	[0.00275]	[0.00323]	[0.000642]	[0.000739]	[0.000949]	[0.000524]	[0.000592]	[0.000545]	[0.00218]	[0.00127]	[0.00210]	[2.18e-05]	[1.60e-05]	[3.25e-05]
Treatament 1999 x Trend			-0.00133			-0.000827*			2.19e-05			0.000466			-4.91e-06
			[0.00127]			[0.000494]			[0.000190]			[0.000447]			[1.28e-05]
Treatament 2002	-0.00365	-0.0112***	-0.00219	-0.00176	-0.000854	-0.00166	-0.00195	-0.00189	-0.00229	0.000478	-0.00419**	0.00214	-0.000118	-0.000972*	-0.000121
	[0.00453]	[0.00412]	[0.00428]	[0.00160]	[0.00139]	[0.00178]	[0.00133]	[0.00145]	[0.00162]	[0.00270]	[0.00208]	[0.00263]	[0.000505]	[0.000518]	[0.000145]
Treatament 2002 x Trend			-0.000480			-3.37e-05			0.000110			-0.000546			6.60e-07
			[0.000511]			[0.000183]			[0.000141]			[0.000341]			[0.000125]
Treat 2009	-0.00170	-0.0104**	-0.00506	-0.00212	0.00151	-0.00186	-0.000219	-0.00126	-0.000813	-0.00137	-0.00545*	-0.00215	0.00146	-0.00141*	8.50e-05
	[0.00501]	[0.00465]	[0.00527]	[0.00182]	[0.00163]	[0.00165]	[0.000710]	[0.000860]	[0.000940]	[0.00257]	[0.00300]	[0.00312]	[0.00132]	[0.000803]	[0.000836]
Treatament 2009 x Trend			0.00162**			-0.000130			0.000291*			0.000373			0.000667*
			[0.000781]			[0.000284]			[0.000169]			[0.000404]			[0.000373]
Constant	0.0227***	0.0241***	0.0227***	0.00335***	0.00350***	0.00335***	0.00271***	0.00319***	0.00271***	0.0114***	0.0116***	0.0114***	-3.63e-05	1.39e-06	-3.00e-05
	[0.00269]	[0.00146]	[0.00269]	[0.000375]	[0.000228]	[0.000373]	[0.000498]	[0.000566]	[0.000497]	[0.00209]	[0.000760]	[0.00210]	[0.000253]	[0.000159]	[0.000250]
Baseline Charac. x Year FE		X			X			X			X			X	
Year FE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Number of Observations	2,349	1,938	2,349	2,349	1,938	2,349	2,349	1,938	2,349	2,349	1,938	2,349	2,349	1,938	2,349
R^2	0.764	0.838	0.765	0.554	0.784	0.555	0.797	0.862	0.798	0.744	0.844	0.744	0.403	0.652	0.410

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variables are the fraction of the municipal area planted with total temporary crops (columns (1)-(3)), rice (columns (4)-(6)), beans (columns (7)-(9)), cassava (columns (10), (11) and (12)) and soy (columns (13), (14) and (15)). All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2), (5), (8), (11) and (14) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area planted with temporary and permanent crops, bovine, equine, swine and chicken density, deforested area (annual flow and stock) and stock of forest as a percentage of the municipal area, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).

Results: Permanent Crops

Table 10 - Mahogany Prohibition and Fraction of the Municipality with Area Planted with Permanent Crops: Total, Banana, Cacao, and Dende, 1995-2013, Differences in Differences, Results for the State of Pará.

	Total Permanent			Banana			Cacao			Dende		
			Treatment interacted with linear trend			Treatment interacted with linear trend			Treatment interacted with linear trend			Treatment interacted with linear trend
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Treatment 1999	0.00163**	-0.00134**	0.00129*	0.000353***	0.000619***	0.000290***	0.000158	-9.01e-05	0.000146	-1.19e-05	-0.00152**	-0.000118
	[0.000742]	[0.000628]	[0.000747]	[0.000132]	[0.000191]	[9.28e-05]	[0.000190]	[0.000148]	[0.000200]	[0.000421]	[0.000664]	[0.000484]
Treatament 1999 x Trend			0.000328			6.02e-05			1.11e-05			0.000102
			[0.000225]			[7.84e-05]			[4.31e-05]			[0.000138]
Treatament 2002	0.000506	-0.00191*	-3.48e-05	0.000285	0.000464**	0.000140	0.000188	3.07e-05	6.06e-05	-0.000162	-0.00152**	-0.000319
	[0.000823]	[0.00109]	[0.000667]	[0.000179]	[0.000210]	[0.000123]	[0.000175]	[0.000237]	[0.000164]	[0.000446]	[0.000748]	[0.000425]
Treatament 2002 x Trend			0.000173			4.67e-05			4.11e-05			5.02e-05
			[0.000139]			[4.58e-05]			[3.07e-05]			[8.29e-05]
Treat 2009	0.00144	0.000259	0.00143	0.000482	0.000625*	0.000470	0.000541	0.000474	0.000452	-0.000235	-0.000449	8.15e-05
	[0.00109]	[0.00195]	[0.00103]	[0.000303]	[0.000375]	[0.000303]	[0.000356]	[0.000377]	[0.000287]	[0.000808]	[0.00173]	[0.000754]
Treatament 2009 x Trend			2.63e-06			4.68e-06			4.38e-05			-0.000160
			[0.000134]			[2.15e-05]			[4.19e-05]			[0.000128]
Constant	0.00718***	0.00710***	0.00718***	0.000592***	0.000661***	0.000591***	0.00109***	0.00117***	0.00108***	0.00207***	0.00222***	0.00207***
	[0.000684]	[0.000563]	[0.000681]	[7.84e-05]	[6.48e-05]	[7.87e-05]	[0.000138]	[6.85e-05]	[0.000138]	[0.000443]	[0.000378]	[0.000443]
Baseline Charac. x Year FE		X			X			X			X	
Year FE	X	X	X	X	X	X	X	X	X	X	X	X
Number of Observations	2,351	1,928	2,351	2,351	1,928	2,351	2,351	1,928	2,351	2,351	1,928	2,351
R^2	0.858	0.928	0.858	0.683	0.803	0.684	0.909	0.971	0.909	0.812	0.916	0.812

Notes: Robust standard errors in brackets (clustered at the municipal level), *** p<0.01, ** p<0.05, * p<0.1. Dependent variables are the fraction of the municipal area planted with total permanent crops (columns (1)-(3)), banana (columns (4)-(6)), cacao (columns (7)-(9)), and dende (columns (10), (11) and (12)). All regressions include a constant, municipality fixed effects and year fixed effects, and are weighted by municipal population. Treatment variables are dummies = 1 for the period 1999-2001, 2002-2008 and after 2009 interacted with mahogany occurrence area. Columns (2), (5), (8) and (11) control for year dummies interacted with baseline values (1995) for the following variables: homicide rate, political deaths, rate of infant deaths, rate of death by infections diseases, cardiac diseases, neoplasms, suicide and traffic accidents, area planted with temporary and permanent crops, bovine, equine, swine and chicken density, deforested area (annual flow and stock) and stock of forest as a percentage of the municipal area, ln of GDP per capita (1996) and fraction of GDP in agriculture (1996).