The Use of Violence in Illegal Markets: Evidence from Mahogany Trade in the Brazilian Amazon

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Online Appendix

A.1 Municipalities in the Area of Natural Occurrence of Mahogany in Brazil

Figure A.1.1 below identifies the areas of natural occurrence of mahogany in the Brazilian Amazon, according to Lentini et al. (2003).

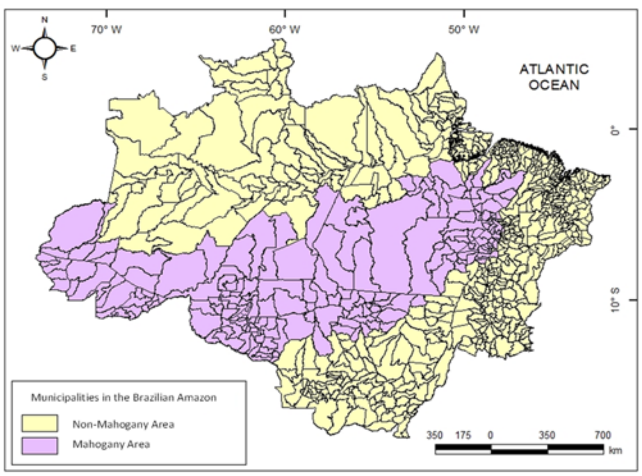

FIGURE A.1.1. AREA OF NATURAL OCCURRENCE OF MAHOGANY

Notes: Constructed by the authors from the Map Provided by Lentini et al. (2003).

A.2 Construction of Export Series

Between January 1989 and December 1995, the Brazilian government used the Brazilian Merchandise Nomenclature (NBM) to code products internationally traded. In January 1996, Brazil started adopting

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the Mercosur Merchandise Nomenclature (NCM) also used by Argentina, Paraguay and Uruguay. Since most merchandise codes were either consolidated or expanded in the new classification system, MDIC then compiled a list to convert NBM into NCM codes. We used this list to construct our series.

International trade data were reported using both systems in 1996 and we used monthly data for this year to check for possible discrepancies associated with the two classification systems. The case of mahogany exports was straightforward (4407.24.10 in the NCM system corresponds to 4407.23.0102 and 4407.23.0201 in the NBM system) with no discrepancies in 1996. As for other tropical species, exports according to the NCM system (4407.29.90) do not match the summation of the corresponding NBM codes in 1996 (4407.21.0100, 4407.21.0200, 4407.21.9900, 4407.22.0100, 4407.22.0200, 4407.22.9900, 4407.23.0199 and 4407.23.0299). Exports of other tropical species in 1996 according to the NCM system were nil for all Brazilian states, whereas they were positive for parts of the year according to the NBM system. The states that had positive exports were Amazonas, Mato Grosso and Pará, all of them in the Amazon region and with parts of their territory overlapping the area where big leaf mahogany naturally occurs. Their joint exports totaled 1,595,578 Kg in 1996, corresponding to about 2.4% of the annual average for these states between 1989 and 2007. Visual inspection of the data suggests structural breaks in the exports of other tropical species starting in 1999. Since we build our series using the summation of NBM codes prior to 1997, we err on the safe side and make the test for structural breaks more stringent.

We used the same approach to build the series for cedar, ipe and virola-balsa. Cedar's codes are 4407.29.10 from 1996 through 2007 (NCM) and 4407.99.0199, 4407.99.0201 and 4407.99.0399 from 1989 through 1996 (NBM). By using 1996 as a validation year, we build the series using only code 4407.99.0201 for the earlier period. Ipe's codes are 4407.29.20 (NCM), and 4407.99.0199, 4407.99.0208 and 4407.99.0303 (NBM). We use only the last two NBM codes to build our ipe series. Virola-balsa's codes are 4407.24.90 (NCM) and 4407.23.0199, 4407.23.0299, 4407.99.0102, 4407.99.0205, 4407.99.0301 and 4407.99.0399 (NBM). We ignore NBM codes 4407.24.90 and 4407.99.0399 in the construction of our virola-balsa series.

A.3 Illegal Mahogany Trade after Prohibition

In this Appendix, we provide evidence that exports of mahogany continued after prohibition through misclassification of mahogany exports as exports of "other tropical timber species." First, we follow the methodology developed by Bai and Perron (1998) and test for endogenous structural breaks in the series of exports of "other tropical timber species." We then check whether the breaks identified by the model match the timing of introduction of restrictions to the mahogany market. Following, we discuss data on imports of Brazilian hardwood into the US, which help illustrate how "other tropical timber species" assumed a role similar to that previously played by mahogany in the overall US imports of hardwood. The discussion in this Appendix is related to a growing body of literature on detection of illegal activities, exemplified by Fisman and Wei (2004), Fisman et al. (2009), and Della Vigna and La Ferrara (2010). Since we are interested in the initial growth of this illegal mahogany market, we focus on the period of increasing exports of "other tropical timber species," therefore looking at data between 1989 and 2007.

A.3.1 Structural Break Estimation and Results

Chimeli and Boyd (2010) conducted an exercise analogous to the one proposed here using the aggregate monthly series for Brazil. We extend their analysis in two directions. First, we also perform the same tests with yearly data (which tend to be less noisy than monthly series). Second, and most important, we explicitly account for the possibility of substitution between mahogany and other types of wood and for broader movements in international timber markets.

If changes in the market for "other tropical timber species" represent just substitution away from mahogany or broader movements in the markets for timber, then they should also be reflected on changes in exports of other species traditionally explored in Brazil. Under this scenario, controlling for exports of other species when estimating the Bai and Perron (1998) model would account for these broader market changes, therefore isolating the structural breaks that are peculiar to the series of "other tropical timber species." We implement this strategy by including exports of cedar, ipe and virola-balsa as controls in the structural break estimation. Cedar and ipe are imperfect substitutes for mahogany, mainly due to their durability, and changes in their exports could reflect substitution away from mahogany following the increased restrictions to trade. Virola and balsa are less dense types of timber with very different uses from mahogany. We include virola-balsa exports to capture overall movements in the timber markets. Our structural break estimation therefore isolates the sudden changes in exports of "other tropical timber species" that are not related to substitution away from mahogany or to broader movements in international markets.

Table A.3.1 presents the estimated structural breaks for exports of "other tropical timber species." The results on the left portion of the table are based on monthly exports, while the right portion uses total annual exports. Whereas the number of observations is much larger when we use monthly information and our ability to pinpoint structural breaks improves, higher frequency data can be more volatile and mask longer run movements in the series. We therefore report our results for both series.

TABLE A.3.1: BAI AND PERRON TEST RESULTS, BREAKPOINTS IN BRAZILIAN EXPORTS OF "OTHER TROPICAL SPECIES" - 1989-2007

Monthly exports			Annual exports		
No Controls			No Controls		
Break Dates	95% Confidence Interval		Break Dates	95% Confidence Interval	
1999(8)	NA	NA	1998	NA	NA
2003(6)	2003(4)	2003(8)	2002	2001	2003
With Controls (Cedar, Ipe and Virola-Balsa)			With Controls (Cedar and Virola-Balsa)		
Break Dates	95% Confidence Interval		Break Dates	95% Confidence Interval	
1999(8)	NA	NA	1998	NA	NA
2003(6)	2003(5)	2003(9)	2002	2001	2003

Notes: Variable is export of other tropical timber species. Series cover the period from 1989 to 2007. Table reports the results of the Bai and Perron (1998) structural break test, with estimated break dates and respective confidence intervals.

Table A.3.1 presents estimated break dates (month of the year in parenthesis) followed by their corresponding confidence intervals. Since Bai and Perron's (1998) algorithm uses integers for dates, confidence intervals formed by time spans smaller than the time unit of the series are not reported and appear as NA. The top portion of the table reports estimated structural breaks in models without controls. The first structural break for our monthly series occurs in August 1999, following the suspension of 85% of all forest management plans for extraction of big leaf mahogany, and corresponds to an increase of 3,500% in exports of "other tropical timber species" in a single month.[1] When we focus on the annual series, the first structural break occurs in 1998 and reflects the increase in exports taking place in August of the following year, as described above. The second structural break occurs between 2002 and 2003. This break is consistent with the prohibition of extraction, transportation and trade of big leaf mahogany imposed by Brazilian authorities at the end of 2001. These results replicate those obtained by Chimeli and Boyd (2010) using monthly data and show that they are also present in the yearly series.

But Chimeli and Boyd (2010) do not consider the possibility that increased exports of "other tropical timber species" may reflect substitution away from mahogany and towards other species after prohibition,

1 Most of the exports of "other tropical timber species" came from the state of Pará, the largest producer of mahogany. Estimating structural breaks for exports of "other tropical timber species" from Pará only as opposed to aggregate exports as in Table A.3.1 produces identical point estimates and minor variations in the confidence intervals for the monthly series (results available upon request).

or maybe broader movements in the market for timber. In order to address this issue, we re-estimate the structural breaks controlling for exports of ipe, cedar, virola-balsa and conifers.

Ipe and cedar, as mahogany, have been historically extracted and exported from the Amazon region. Due to their durability, ipe and cedar are better imperfect substitutes for mahogany than the lower quality species that are included under the residual trade category "other tropical timber species." Therefore, variability in the exports of ipe and cedar could reflect systematic changes in the demand for substitute timber from the Amazon as a response to mahogany prohibition.

The trade category "other tropical timber species" is, in reality, meant to include species of lower quality and value. These species individually represent a small fraction of the total export volume and do not justify a separate trade category. Therefore, if no smuggling of more valuable species actually takes place under this residual category, we would expect trade patterns of "other tropical timber species" to resemble those of less valued timber. Virola, balsa and conifers are less valuable timber types that have their own trade categories (virola and balsa are combined into one category) due to their large export volumes, and can help shed light on the functioning of the market where "other tropical timber species" should belong. Virola and balsa come predominantly, but not exclusively, from the Amazon region. Their series can thus capture trade patterns for lower-valued woods from the Amazon. Conifers come predominantly, but not exclusively, from southern Brazil. Their series is less directly related to trade of Amazon species, but we include it in our set of controls to capture overall trade patterns for lower-value woods from Brazil.

The bottom half of Table A.3.1 presents the estimated structural breaks including exports of these other types of wood as controls. When analyzing the annual (but not monthly) series, we drop the variable for ipe from our set of controls, since the minimum time interval between two structural breaks in Bai and Perron (1998) has to be greater than the number of regressors in the model. This means that, with annual data, the inclusion of three controls plus a constant would force the structural breaks to be at least five years apart. The results with controls are virtually identical to those without controls.[2] So the regime changes detected in Table A.3.1 are not related to exports of substitutes of mahogany or of other lower quality timber that should behave similarly to "other tropical timber species." This evidence, together with the coincidence in the timing of the regime changes and the restrictions to mahogany trade, suggest that the major increase in exports of "other tropical timber species" indeed reflects mahogany exports.

2 If we ignore the problem alluded to above and estimate the model with annual series using our entire set of controls (three controls for the different types of timber plus the intercept), we artificially estimate the first break in 1997, five years before the second break in 2002. However, visual inspection of the series for "other tropical timber species" suggests that no unusual changes took place in 1997. Substituting ipe for cedar in the estimation of structural breaks for the annual series produces results analogous to those presented in the table, with one structural break in 1998 and another in 2003, and no estimated confidence intervals in either case.

To sum up, exports of "other tropical timber species" experienced discrete increases – significant both statistically and in terms of magnitude – soon after the main restrictions to mahogany trade were implemented. At those points in time, no other type of wood traditionally exported from Brazil displayed a similar export pattern. Together, this evidence indicates that an active illegal mahogany market appeared in the Brazilian Amazon starting in the end of 1990s.

A.3.2 Other Data on International Trade of Timber

Another way to try to detect the functioning of this illegal market would be to follow Fisman and Wei (2004 and 2009) and Ferrantino et al. (2012) and look at data on imports of Brazilian timber from other countries. If imports in the US and Europe continued to be classified as mahogany, even as Brazilian exports were replaced by "other tropical timber species," there would be further support to our main hypothesis. This important branch of the literature on illegal international trade focuses on discrepancies in trade statistics reported by exporting and importing countries. If no illegal trade takes place between countries A and B, quantities of a good exported from country A to country B, as reported by A, should be identical to quantities imported by country B from country A as reported by B. By analyzing systematic discrepancies between the data reported by trade partners and by examining tax and tariff structures that might give an incentive to misclassify a traded good in a given country, these studies attempt to unveil the magnitude and characteristics of illegal international trade.

Here, we discuss US import data. We observe a reduction in US imports of Brazilian mahogany concomitant with the reduction in official exports from Brazil, so the type of phenomenon noticed by Fisman and Wei (2004) is not happening. But we do observe an increase in US imports of a residual category equivalent to "other tropical timber species." In addition, the prominent role played by Brazilian mahogany before prohibition among all US imports of tropical timber is assumed, after prohibition, by "other tropical timber species." This pattern, though indirectly, supports the idea that imports of this category in the US represented disguised mahogany.

One possibility to implement this type of analysis would be to follow the literature and use data from the World Bank's World Integrated Trade Solution (WITS) database, which is derived from the United Nations' COMTRADE database. These use the Harmonized System (HS) at the 6 digit level. Unfortunately, however, the HS-6 level of aggregation prevents us from focusing exclusively on mahogany. Trade code 440723 refers to "Baboen, Mahogany, Imbuia and Balsa Wood". Furthermore, there is no clear equivalent to "other tropical timber species" among the available trade codes. In any case, the trade numbers for code 440723 for Brazil and two of its main importers of mahogany – US and UK – suggest reduced quantities until trade progressively declined to insignificant levels. Although consistent trade gaps exist throughout the period, with imports slightly larger than exports in most cases, suggesting some misreporting, there is no direct evidence of smuggling after mahogany prohibition.

So we explore alternative datasets on the international trade of timber involving Brazil and the US to further investigate the hypothesis that mahogany is smuggled out of Brazil as "other tropical timber species." Data for US imports of timber can be obtained from the US Department of Agriculture, Foreign Agricultural Service through their website (http://www.fas.usda.gov/gats/). The trade codes for the Brazilian NCM-8 and US HS-10 are similar, but not identical (in addition to the obvious two-digit level discrepancy). Furthermore, US data are reported in cubic meters, whereas Brazilian data are reported in kilograms. This difference in measurement may raise comparability problems for trade categories that include more than one species with different wood densities, such as "other tropical timber species". We should therefore use caution when comparing these two series.

Both the US import and the Brazilian export series for mahogany depict a very similar pattern, with declining trends converging to zero after restrictions started being imposed.[3] As for other tropical species, trade is virtually zero for several years and subsequently increases to significantly larger levels, except that the US data show a much smoother increase in imports than the Brazilian export series suggests.[4] It is therefore difficult to obtain deeper lessons from these datasets, other than that mahogany exports went from large levels to zero whereas the opposite happened to other tropical species, as could already be seen from the Brazilian export data alone. So the phenomenon identified by Fisman and Wei (2004) is not taking place here.

In an attempt to obtain further insight into the US-Brazil trade of mahogany, we explore a more aggregate data set that might nevertheless contain some useful information. We can retrieve an aggregate series for US imports of "hardwood lumber" from Brazil (mahogany is a hardwood, in contrast to conifers, for example, that are classified as softwood). The data are aggregated at a level that prevents clear inferences about smuggling of mahogany. Still, if mahogany was an important component of the US timber imports from Brazil, then the Brazilian data for mahogany exports to the US should be correlated with the US imports of Brazilian hardwood when the mahogany market was legal. Furthermore, if

3 The trade codes for mahogany in the US HS-10 nomenclature are 4407.21.0000, 4407230025, 4407230030, 4407.24.00.25, 4407.24.00.26, and 4407.24.00.30. The trade code for mahogany in the Mercosur common nomenclature (NCM – Brazilian series) is 4407.24.10.

4 The trade codes for "other tropical" in the US HS-10 nomenclature are 4407.29.00.90, 4407.29.00.91, and 4407.29.00.95. The trade code for "other tropical timber species" in the Mercosur common nomenclature (NCM – Brazilian series) is 4407.29.90.

smuggling of mahogany as "other tropical timber species" indeed occurred, we would expect the Brazilian data on exports of "other tropical timber species" to the US to be correlated with the US imports of hardwood from Brazil after prohibition, but not before. In that case, we could conjecture that "other tropical timber species" would have assumed the role previously played by mahogany in the overall US imports of Brazilian hardwood. The correlation coefficients between US hardwood imports from Brazil, Brazilian mahogany and "other tropical timber species" exports to the US, as well as the corresponding p-values, appear in Table A.3.2.

TABLE A.3.2: US IMPORTS VS BRAZILIAN EXPORTS – VARIOUS PERIODS

	Corr(HW,OT)	Corr(HW,MH)	N
01/89 - 07/99	0.0271 [0.7623]	0.1658 [0.0625]	127
08/99 - 12/07	0.3037 [0.002]	0.0183 [0.8559]	101
11/01 - 12/07	0.3563 [0.0018]	-0.1975 [0.0917]	74

Notes: p-values in brackets.

For the period before the first estimated structural break (before 85% of the mahogany extraction licenses were cancelled, or January 1989 to July 1999), US imports of Brazilian hardwood were not significantly correlated with Brazilian exports of "other tropical timber species" to the US. This suggests that, before intervention in the mahogany market, the market for other tropical species was quite different from that for hardwood, where mahogany belongs. Furthermore, US imports of hardwood were significantly correlated with Brazilian exports of mahogany at the 7% level and with a correlation coefficient of 0.17. This pattern is reversed in the post-intervention periods (August 1999 to December 2007 and November 2001 to December 2007). The correlation between US hardwood imports and Brazilian exports of other tropical species jumps to 0.35 and becomes significant at the 1% level after the formal prohibition of the Brazilian mahogany market (November 2001). During that same period, the correlation between US hardwood imports and Brazilian mahogany exports was negative, reflecting the fact that mahogany exports were declining and started happening only in some isolated cases (mahogany apprehended by the government and impounded cargoes that were subsequently authorized), eventually dropping to zero. Even if indirectly, the correlations presented in Table A.3.2 support the hypothesis that mahogany was smuggled as "other tropical timber species" from Brazil to the US after prohibition.

Finally, the United Nations Environment Program CITES trade database provides information on trade volumes for species listed in one of its appendices. This is the case for mahogany from Brazil. However, since these data are based on official statistics and do not cover species that are not threatened and could serve as a facade for illegal trade of an endangered species, we cannot learn much from the CITES data.

A.4 Tables with Additional Difference-in-Differences Results

Tables A.4.1 and A.4.2 present the difference-in-differences results mentioned but not presented in the main text of the paper. The first of these tables shows results with unweighted regressions and Driscoll and Kraay (1998) standard errors, while the second reproduces the main results of the paper when we use minimum comparable areas instead of municipality as unit of analysis.

TABLE A.4.1: ILLEGALITY OF MAHOGANY TRADE AND HOMICIDES, MUNICIPALITIES IN PARÁ, 1995-2013, UNWEIGHTED REGRESSIONS AND STANDARD ERRORS ROBUST TO SPATIAL CORRELATION (DRISCOLL-KRAAY)

	Unweighted	Standard Errors Robust to Spatial Correlation
Vars	1	2
treat 1999	8.158***	12.68***
	[2.162]	[2.031]
treat 2002	19.16***	22.59***
	[3.281]	[1.392]
treat 2009	17.32***	16.49***
	[3.852]	[4.374]
Observations	2,432	2,432
R-squared	0.654	0.833

Notes: Robust standard-errors in brackets (clustering at municipality) in column 1; Driscoll-Kray standard-errors in brackets in column 2; *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is the homicide rate (per 100,000 inhabitants). All regressions include a constant, municipality and year dummies, and control for interactions of year dummies with baseline (1995) values of the following municipality characteristics: % of area planted, mortality by heart and circulatory diseases, neoplasms, infectious diseases, traffic accidents, suicides, child mortality, assassinations related to land conflicts (rate), per capita gdp (ln), and fraction of gdp in agriculture (the latter two measured in 1996). Columns 1 and 2 control for state specific time dummies. Columns 2 and 4 are weighted by population. Treatment variables are dummies=1 between 1999-2001 and after 2002 interacted with dummy of mahogany occurring area.

A.5 Propensity Score and Synthetic Control Results

Remaining empirical concerns in our difference-in-differences strategy would have to be associated with some notion of inadequacy of the control groups used as counterfactuals. To address these potential concerns, in this Appendix we apply propensity score and synthetic control strategies.

TABLE A.4.2: ILLEGALITY OF MAHOGANY TRADE AND HOMICIDES, 1995-2013, DIFFERENCE-IN-DIFFERENCE RESULTS FOR PARÁ AND OTHER STATES SEPARATELY, MINIMUM COMPARABLE AREAS

	Panel A: Para and Other Mahogany Occurring States Separately						
	Minimum Comparable Areas in Pará			Minimum Comparable Areas in States with Mahogany Occurrence Excluding Pará			
			Treat.'s interacted with linear trends				Treat.'s interacted with linear trends
Vars	1	2	3	4	5	6	7
treat 1999	11.92***	11.85***	8.593**	1.113	2.238	1.979	-2.477
	[4.076]	[2.717]	[3.760]	[2.609]	[2.007]	[1.393]	[1.791]
treat 1999 × trend			3.332*				4.715**
			[1.734]				[2.297]
treat 2002	21.19***	22.01***	19.84***	1.646	8.353**	7.254**	8.987***
	[5.542]	[5.907]	[4.765]	[3.500]	[3.679]	[3.020]	[3.212]
treat 2002 × trend			0.449				-0.212
			[0.847]				[0.462]
treat 2009	14.08**	23.10***	22.68***	-8.105**	3.215	4.304**	3.520
	[6.305]	[6.152]	[8.066]	[3.896]	[2.884]	[1.902]	[3.746]
treat 2009 × trend			-4.300***				-0.153
			[1.344]				[0.778]
state f.e. × year f.e.					X	X	X
baseline charact. × year f.e		X				X	
Observations	1,786	1,634	1,786	6,517	6,517	6,517	6,517
R-squared	0.761	0.888	0.765	0.723	0.776	0.814	0.777

	Panel B: Minimum Comparable Areas in Pará, Robustness and Characterization of Homicides						
	Testing for Parallel Trends		Males				
	Double-Diff	Municipality Linear Trend	all ages	ages 15-39	ages 15-39, single	ages 15-39, death outside home	ages 15-39, homicide by firearm
Vars	1	2	3	4	5	6	7
treat 1999	12.26**	13.48***	21.36***	35.66***	21.57***	31.38***	24.81***
	[5.679]	[3.718]	[5.044]	[9.885]	[7.659]	[8.568]	[6.700]
treat 2002	21.53***	24.97***	35.39***	62.75***	48.00***	58.32***	36.60**
	[6.205]	[4.663]	[10.13]	[18.96]	[16.72]	[17.54]	[15.84]
treat 2009	14.42**	20.53***	20.81	24.60	20.44	21.15	-3.381
	[6.672]	[5.816]	[13.00]	[24.92]	[22.64]	[24.63]	[26.33]
placebo	0.680						
	[4.240]						
municipality specific trend		X					
Observations	1,786	1,786	1,692	1,692	1,692	1,692	1,692
R-squared	0.761	0.833	0.784	0.765	0.766	0.767	0.723

Notes: Robust standard-errors in brackets (clustering at municipality); *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is the homicide rate (per 100,000 inhabitants). All regressions include a constant, municipality and year dummies, and are weighted by population. Treatment variables are dummies=1 between 1999-2001, between 2002 and 2008, and after 2008 interacted with dummy of mahogany occurring area. Columns 5 to 7 control for state specific time dummies. Columns 2 and 6 in Panel A and column 2 in Panel B control for interactions of year dummies with baseline (1995) values of the following municipality characteristics: % of area planted, mortality by heart and circulatory diseases, neoplasms, infectious diseases, traffic accidents, suicides, child mortality, assassinations related to land conflicts (rate), per capita gdp (ln), and fraction of gdp in agriculture (the latter two measured in 1996). This table reproduces the main specification from Tables 3, 4, and 5 using minimum comparable areas instead of municipalities. Please refer to these tables for a more detailed description of remaining variables. Columns 3 to 7 in Panel B include data starting in 1996 only.

A.5.1 Propensity Score Weighting and Matching

First, using information from the pre-prohibition period, we estimate a probit of the probability of being in the mahogany area on the full set of municipality characteristics that we observe, including the homicide rate (area planted, mortality variables, homicide rate, GDP per capita, and fraction of GDP in agriculture, averaged over 1995-1998).[5] Following, once the predicted propensity score is obtained, we conduct a one-to-one nearest neighbor matching and also apply an inverse-probability weighted regression adjustment.

In the one-to-one matching, we look at the dependent variable both as the homicide rate averaged over the post-prohibition period and the change in homicide rate between the pre- and post-prohibition periods. Since the propensity score strategy allows only the analysis of before-after events, we choose to focus on the periods of growth in exports of other tropical timber species: (either 1999-2007, corresponding to the increased restrictions to trade, or 2002-2007, corresponding to prohibition).

In the inverse-probability weighted regression, we use as dependent variable the change in homicide rates between the post- and pre-prohibition periods, and as controls all the variables listed before (including the initial homicide rate). The inverse probability weighted regressions have the additional advantage of being doubly robust, meaning that misspecification of either the regression equation or the propensity score separately do not harm consistency (Imbens and Wooldridge, 2009). In addition, since we run this specification in differences, the propensity score is robust to selection on unobservables, as long as these unobservables are time invariant (Abadie, 2005).

Since our goal is to minimize problems of heterogeneity, we use an initial sample of treatment and pool of potential controls that already takes that into account. The evidence from Table 3 shows that the most important effect of prohibition was concentrated in Pará, which played a prominent role in the trade of mahogany. So we consider municipalities in the mahogany area within the state of Pará as our treatment group. For the pool of potential controls, we consider municipalities without mahogany, but located in states with some mahogany occurrence. This leaves us with a sample of 509 municipalities, corresponding to municipalities with mahogany in the state of Pará and municipalities without mahogany located in states with some mahogany occurrence. In all cases we estimate the average treatment effect on the treated, meaning the impact of prohibition on municipalities of Pará that were located in the mahogany area.

To implement the propensity score matching, we first average all dependent and independent variables over the pre-intervention period (1995-1998). We then estimate a probit of the probability that the municipality belongs to the mahogany area on all variables that can be observed at the municipality level: GDP per capita (natural logarithm, observed only in 1996), fraction of GDP in agriculture (also in 1996),

5 Though location in the mahogany area is obviously an intrinsic characteristic of municipalities, being therefore predetermined, this probit intends to capture characteristics of municipalities that are correlated with this geographic feature. This way, we can use the propensity score to build a control group that is, on the socioeconomic characteristics observed, as similar as possible to the municipalities in the mahogany area. Strictly, location in the mahogany area is not a random variable, so this equation is not correct in a structural sense (longitude and latitude, for example, would fully determine whether a municipality is in the mahogany area).

fraction of area planted, child mortality, heart and circulatory diseases mortality, infectious diseases mortality, neoplasms mortality, suicide rate, mortality by traffic accidents, land conflict deaths, and also homicide rate (the dependent variable before treatment).

TABLE A.5.1: PROPENSITY SCORE PROBIT ESTIMATION, MUNICIPALITIES IN MAHOGANY AREAS OF PARÁ AND MUNICIPALITIES OUTSIDE THE MAHOGANY AREA (BUT LOCATED IN STATES WITH SOME OCCURRENCE OF MAHOGANY, EXCLUDING PARÁ), AVERAGES BETWEEN 1995-1998

Vars	Dep. Var: Mahogany Area Dummy
ln_gdp_pc	0.0803
	[0.166]
% gdp agric	-0.361
	[0.471]
% area plant	-3.081
	[2.589]
child mort	0.174***
	[0.0579]
heart mort	-1.382**
	[0.582]
infecc mort	-1.236
	[0.793]
neop mort	-1.030
	[1.171]
suic	-5.805
	[4.085]
traff mort	1.151
	[0.974]
polit deaths	22.54***
	[8.004]
homicide	0.0201**
	[0.00844]
Observations	508

Notes: Robust standard-errors in brackets; *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is a dummy indicating that a municipality is located in the mahogany occurrence area. Independent variables are averages between 1995 and 1998 of gdp per capita (ln, 1996), fraction of gdp in agriculture (1996), % of area planted, mortality by heart and circulatory diseases, neoplasms, infectious diseases, traffic accidents, suicides, child mortality, assassinations related to land conflicts, and homicide rate.

For the interested reader, Tables A.5.1 and A.5.2 present the results from our propensity score estimation and for a means difference test between treatment and control for the case of the nearest neighbor matching. Table A.5.3 presents the results from our exercises using propensity score matching. We consider two alternative treatment periods (post-1999 and post-2002) and four different specifications. For purposes of comparison, the first row presents the results from a simple difference-in-difference regression, analogous to that estimated before, but using the data collapsed in the before-after periods (just two observations in time), without using the propensity score. The second row conducts a simple one-to-one nearest neighbor matching comparison, where the dependent variable is the average homicide rate in the post intervention period. The third row repeats the same exercise, except that the dependent variable is the change in average homicide rates between the post- and the pre-intervention periods. Finally, the fourth row presents results from an inverse-probability weighted regression, where the dependent variable is the change in homicide rates and the controls are the pre-intervention values of all variables included in the propensity score estimation (including the initial value of the homicide rate).

TABLE A.5.2: MEAN-DIFFERENCES TEST FOR NEAREST NEIGHBOR MATCH ON PRE-1999 AVERAGES - MUNICIPALITIES IN MAHOGANY AREAS OF PARÁ MATCHED TO MUNICIPALITIES OUTSIDE THE MAHOGANY AREA, BUT LOCATED IN STATES WITH SOME OCCURRENCE OF MAHOGANY (EXCLUDING PARÁ)

Variable	Unmatched/Matched	Mean		Diff. Treat x Control	
		Treated	Control	t	p>|t|
ln_gdp_pc	Unmatched	0.3505	0.3506	0	1.00
	Matched	0.3505	0.3502	0	1.00
% gdp agric	Unmatched	0.4960	0.5076	-0.35	0.73
	Matched	0.4960	0.4521	0.98	0.33
% area plant	Unmatched	0.0247	0.0421	-1.79	0.07
	Matched	0.0247	0.0156	1.75	0.08
child mort	Unmatched	2.9644	2.3680	1.8	0.07
	Matched	2.9644	2.8175	0.28	0.78
heart mort	Unmatched	0.2655	0.4366	-2.85	0.01
	Matched	0.2655	0.2467	0.46	0.65
infect mort	Unmatched	0.2673	0.3055	-1.02	0.31
	Matched	0.2673	0.2191	1.27	0.21
neop mort	Unmatched	0.0878	0.1355	-2.13	0.03
	Matched	0.0878	0.0779	0.51	0.61
suic	Unmatched	0.0105	0.0184	-1.5	0.13
	Matched	0.0105	0.0091	0.35	0.73
traff mort	Unmatched	0.0829	0.0878	-0.24	0.81
	Matched	0.0829	0.0815	0.06	0.95
polit deaths	Unmatched	0.0125	0.0012	5.82	0.00
	Matched	0.0125	0.0045	1.35	0.18
homicide	Unmatched	12.3990	8.9437	1.75	0.08
	Matched	12.3990	11.6980	0.26	0.80

Notes: Variables are averages between 1995 and 1998 of gdp per capita (ln, 1996), fraction of gdp in agriculture (1996), % of area planted, mortality by heart and circulatory diseases, neoplasms, infectious diseases, traffic accidents, suicides, child mortality, assassinations related to land conflicts, and homicide rate.

All estimated treatment effects are positive and statistically significant. Though the coefficients vary a bit in magnitude across specifications and treatments, they all fall within the range of those presented in Tables 2 and 3. The average estimated impact across the propensity score specifications that consider the post-1999 treatment is 12.25, close to the simple pre-post difference-in-difference from the first row in

Table A.5.3. When considering the post-2002 treatment, the average effect across the propensity score specifications is 18.17, also similar to the simple diff-in-diff specification from the first row in Table A.5.3. As in Table 2 and 3, estimated effects for the post-2002 period are systematically larger than the analogous effects for the post-1999 period.

TABLE A.5.3: AVERAGE TREATMENT EFFECT ON THE TREATED ESTIMATED USING THE PROPENSITY SCORE - MUNICIPALITIES IN MAHOGANY AREAS OF PARÁ AND MUNICIPALITIES OUTSIDE THE MAHOGANY AREA, BUT LOCATED IN STATES WITH SOME OCCURRENCE OF MAHOGANY - OUTCOMES MEASURED AS AVERAGES AFTER 1999 OR AFTER 2002

	Treat. Group: Municip. with Mahogany in Pará Control Group: Municip. without Mahogany in States with Mahogany Occurrence	
	Post-1999/Pre-1999	Post-2002/Pre-1999
	1	2
Before-after Diff-in-Diff without Matching*	14.256*** [2.458]	18.24*** [2.890]
Nearest Neighrbor Match; Outcome: Avg Homic	13.34*** [2.774]	19.12*** [3.488]
Nearest Neighrbor Match; Outcome: Δ Avg Homic	13.96*** [2.458]	19.74*** [3.666]
Inverse-Probability Weighted Regression; Outcome: Δ Avg Homic; Controls: Pre-1999 Variables	9.456** [4.569]	15.66*** [5.242]

Notes: Propensity Score estimated from the equation presented in the Appendix Table A.5.4. Details of the methodology explained in the text. *: First line corresponds to simple regression of the before-after change in the homicide rate on the dummy for municipalities in the mahogany area, using the same initial sample from the propensity score exercise (with robust standard errors).

Overall, results from the propensity score strategies are remarkably consistent, both quantitative and qualitatively, with the results from the difference-in-difference exercises. Most importantly, the similarity of results across the various specifications indicates that heterogeneity across control and treatment groups before prohibition does not seem to be an issue. This was already suggested by our previous estimates considering different samples, and is confirmed here.

A.5.2 Synthetic Control

Though the matching strategy is able to compare municipalities that were as similar as possible in the period before intervention, it misses the specific dynamics of homicide rates before prohibition, since data have to be collapsed into pre- and post-prohibition periods. If the main concern related to comparability refers to the dynamics of the dependent variable before prohibition, something may be missed in the matching strategy. In addition, if outcomes across municipalities in the mahogany area are too correlated to be treated as independent units, the difference-in-differences strategy will not be adequate. An alternative in this case is to apply the synthetic control method for comparative case studies proposed by Abadie and Gardeazabal (2003).

We apply this methodology by looking at the area of natural occurrence of mahogany in the state of Pará as a single unit and by matching the behavior of its homicide rate in the pre-prohibition period with the weighted average of the homicide rates in areas from a potential control group. This strategy has some serious limitations in our setting, but we believe the result suggests that our main conclusion is robust to the assumptions implicit in the synthetic control method. Together with the propensity score matching discussed before, our synthetic control exercise addresses the remaining concerns stemming from the difference-in-differences strategy. The similarity of results across these diverse empirical settings lends additional credibility to the analysis.

To keep this exercise as comparable as possible to the propensity score strategy from the last Appendix, we look at the evolution of average homicides within the mahogany area of the state of Pará, and create a synthetic control group from the areas without mahogany, but located in states with some mahogany occurrence (results are very similar if we use the entire country to construct the synthetic control). The results from this exercise should be seen with caution, since we have a very small number of units to generate the counterfactuals (only five states – Amazonas, Mato Grosso, Tocantins, Pará, and Maranhão –, corresponding to those that have mahogany occurrence, but that also have areas without mahogany) and few pre-intervention periods. For this reason, we refrain from making inference exercises regarding these results and see them as suggestive evidence.

The synthetic control is constructed to reproduce as closely as possible the behavior of homicide rates in the mahogany areas of Pará before 1999. The predictors we use to create the weights associated with the synthetic control are the yearly homicide rates before 1999, and all municipality variables averaged over the pre-intervention period (GDP per capita, fraction of GDP in agriculture, area planted, and all mortality variables).

The results from this exercise are presented in Figure A.5.1, plotted as time series. For comparison, we also plot the evolution of homicides in the areas of Pará without mahogany. The synthetic control closely matches the evolution of homicides in mahogany areas of Pará in the pre-treatment period. After that, the synthetic control displays a mildly upward trend. As a result, there is a gap in homicide rates between mahogany areas of Pará and the synthetic group that appears in 1999, and then widens up again in 2002.

If we compute the average difference in homicide rates between the mahogany area of Pará and the synthetic control after 1999, it amounts to 18.9. If we make the same calculation for the period after 2002, it adds up to 23.8. Both these numbers are again similar to the numbers from Table 3. Also importantly, Figure A.5.1 shows that the evolution of homicides in the synthetic control after 1999 is not very much different from the evolution of homicides in areas without mahogany in the state of Pará. Once again, the evidence validates the initial results obtained with the difference-in-difference strategy.

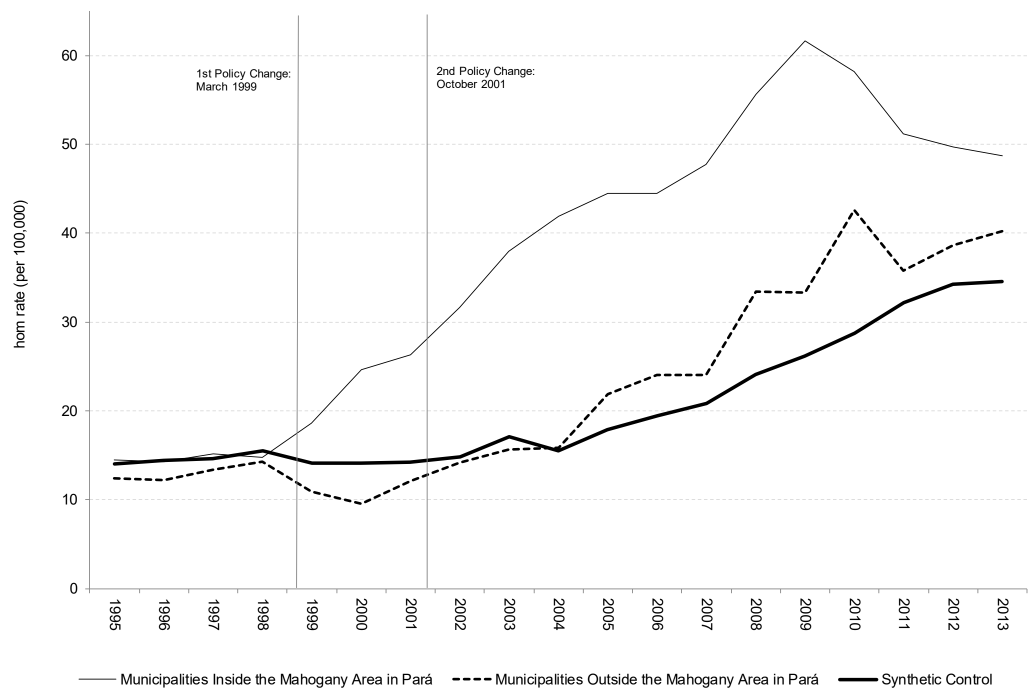

FIGURE A.5.1: HOMICIDE RATES IN THE SYNTHETIC CONTROL AND IN MUNICIPALITIES INSIDE AND OUTSIDE THE MAHOGANY AREA, 1995-2013

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