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THE CAUSES AND CONSEQUENCES OF AGRICULTURAL EXPANSION IN MATOPIBA

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The Causes and Consequences of Agricultural Expansion in Matopiba*

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Abstract

This paper examines the causes and consequences of the agricultural expansion in *Matopiba* (Brazil) over the past two decades. It documents that agricultural expansion in this region is concentrated in municipalities in the Cerrado biome. The estimates indicate that since the late 1990s agricultural output is increasing faster in municipalities in this biome when compared to municipalities outside the biome. Agricultural expansion led to increases in GDP per capita. The increase in GDP per capita is a result of direct effects on the agricultural sector as well as indirect effects on services sector. The estimates also suggest that municipalities in the biome experienced larger gains in the access to durable consumer goods such as TV and refrigerator and in basic infrastructure such as access to electric power. However, the results do not indicate differential changes in migration and human capital investments between Cerrado and *non*-Cerrado municipalities.

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1 Introduction

The *Matopiba* region became a leading producer of several important agricultural products during the past 20 years.[1] However, the causes and consequences of agricultural expansion in this region have been understudied in the literature. This contrasts with the large literature discussing the transformations that affected the large agricultural frontier located north of *Brasília* since the 1960s that have emerged in the last decades.[2] This paper aims to fill of this gap through an assessment of the causes and consequences of agricultural expansion in the *Matopiba*.

The assessment begins by using data on agricultural outcomes to document that the evolution in crop cultivation and output in the *Matopiba* region is concentrated in municipalities in the Cerrado biome. The results provide evidence that cropland and the value of agricultural production start to increase faster in Cerrado municipalities compared to the *non*-Cerrado ones after the late 1990s. The magnitude of these estimates is substantial. Cropland grew 3.6 percentage points more in the Cerrado municipalities while the value of agricultural production grew 140% more than in the *non*-Cerrado municipalities during the period 1995-2012.

The increase in the value of agricultural production is not just a result of cropland expansion. The evidence suggests that the crop mix changed in the period due to increases in the relative importance of soy cultivation and declines in the relative importance of rice cultivation. There are no significant changes in the relative importance of other products such as maize and cassava. The estimates also indicate that the expansion in cropland induced a decrease in cattle ranching in the Cerrado municipalities compared to the *non*-Cerrado ones.

The analysis then uses data on economic performance to investigate the consequences of these changes in agriculture to the overall economic performance of municipalities in the Matopiba region. The results provide evidence that agricultural expansion positively affected the economic performance of the municipalities located in the Cerrado biome. The estimates suggest that GDP per capita increased 11% more in the Cerrado municipalities than in the *non*-Cerrado ones in the period 1999-2012. This increase is a result of a relative

[1] The *Matopiba* covers some areas in the states of Maranhão, Tocantins, Piauí and Bahia. Indeed, the name of the region comes from the abbreviation of the names of these four states.

[2] See Alston, Libecap, and Schneider (1996), Jepson (2006a), Jepson (2006b) and Alston, Harris, and Mueller (2012) for descriptions of the evolution of agricultural organization in this agricultural frontier. See also Pfaff (1999), VanWey et al. (2013), Assunção and Bragança (2015) and Bragança, Assunção, and Ferraz (2015) for evidence of environmental and economic consequences of the settlement some areas of the agricultural frontier.

increase of 37% in agricultural GDP per capita and 10% in services GDP capita. There is no effect of the agricultural expansion on the manufacturing GDP.

The increase in the services GDP highlights the existence of an important spillover of the agricultural expansion to other industries. This spillover effect is due to an expansion in local demand connected to forward and backward linkages of agricultural activities. The existence of this spillover contrasts with the evidence from Hornbeck and Keskin (2012) who find no effect of agricultural expansion on other sectors in the Ogalalla aquifer in the U.S.. The lack of effects on manufacturing contrasts with Foster and Rosenzweig (2004) who found, during the Green Revolution in India, that agricultural expansion hindered manufacturing expansion. It also contrasts with the evidence in Bustos, Caprettini, and Ponticelli (2013) and Marden (2014), who estimate positive effects of agricultural growth on manufacturing growth in Brazil and China, respectively.

To understand whether the expansion in GDP per capita leads into improvements in development outcomes, the analysis uses data from the Brazilian Population Census to investigate whether access to consumer goods and basic infrastructure changed across Cerrado and *non*-Cerrado areas. The results show that the share of households with television, refrigerator, and electric power increased faster in the Cerrado municipalities than in the *non*-Cerrado ones in the period 2000-2010. However, no effect was found on the share of households with a car or on the share of households with access to water or sewage.

The census data is also used to investigate other adjustments to the agricultural expansion. No effect was on local population and on educational outcomes. The former result indicates that migration is not a relevant issue in the region and contrasts with the experience of the occupation of other parts of the Cerrado documented by Bragança, Assunção, and Ferraz (2015). The latter result indicates that the agricultural expansion neither crowds-in educational investments as in Foster and Rosenzweig (1996) nor crowds-out these investments as in Soares, Kruger, and Berthelon (2012).

These results provide novel evidence of the causes and consequences of agricultural expansion in the *Matopiba* region. Previous studies as Miranda, Magalhães, and de Carvalho (2014) have focused in mapping the agricultural expansion in the region and have not examined its causes and consequences. The paper documents that agro-climatic characteristics are a major determinant of the location of agricultural expansion in the region. It also provides evidence that expansion of mechanized and large-scale agriculture leads to improvements in economic performance through direct and indirect effects. However, it is important to note that the experience of the *Matopiba* differs from the experience of

previous agricultural frontiers due to the absence of effects on migration and educational investments.

The remainder of this paper is organized in five sections. Section 2 presents a brief description of the *Matopiba* region. Section 3 presents the datasets used in the empirical analysis. Section 4 documents the expansion of agriculture in the Cerrado areas in the *Matopiba* region. Section 5 documents the impact of agricultural expansion on several economic outcomes. Section 6 presents some brief conclusions of the paper.

2 Background

The name *Matopiba* refers to the initial letters of states of Maranhão, Tocantins, Piauí and Bahia. Some areas in these states experienced substantial agricultural development over the past couple of decades. The region is responsible for almost 10% of national crop production, being an important driver of the expansion in soy and maize production (Miranda, Magalhães, and de Carvalho, 2014).

The expansion in agriculture in the *Matopiba* states was concentrated in the areas covered by the Cerrado biome. Technological innovations that occurred in the 1960s and 1980s enabled intensive soy cultivation in these areas (Assunção and Bragança, 2015). These innovations were connected to the development of soy varieties as well as the development of better soil management techniques (Klink and Moreira, 2002). Large scale crop cultivation becomes possible once farmers invest in liming to correct the soil and purchase tractors to cultivate it (Rezende, 2002).

Crop production started to expand in the municipalities of the *Matopiba* region in the late 1990s. The region's native pastures are being replaced with fertilizer and machine intensive crop cultivation (Lopes, 2014). This agricultural expansion is thought to have reshaped economic life in neighbouring urban centers. It is believed that these urban areas have benefited from the expansion of manufacturing and services activities with linkages to agricultural activities (Miranda, Magalhães, and de Carvalho, 2014). Agricultural expansion might also affect economic development through other channels such as migration or investments in human capital (Bragança, Assunção, and Ferraz, 2015). There is not, however, organized empirical evidence of these effects which motivates the empirical exercises in this paper.

3 Data

3.1 Data Sources

The empirical exercises from this paper use socioeconomic data from different sources. The *Pesquisa Agrícola Municipal* - a municipal assessment of agriculture in the Brazilian municipalities - provides annual information on cultivation, production and production value for the main crops cultivated in the country. We use data on land allocation and the value of crop production for the period 1995-2012 to map the evolution on agricultural outcomes in the *Matopiba* region.

The *Produto Interno Bruto Municipal* - a dataset with estimates of municipal economic performance - provides annual information on GDP from the period 1999-2012. The analysis uses measures of aggregate GDP as well as GDP in the three main industries to investigate the consequences of agricultural expansion on economic performance in the region. The *Censo Demográfico* - the Brazilian Population Census - is also used to assess the consequences of the agricultural expansion on local development. The analysis uses the census waves of 1991, 2000 and 2010 to examine the effects of agricultural expansion on access to goods, human capital investments and migration.

The empirical design tests whether these socioeconomic outcomes changed differentially in municipalities located in the Cerrado biome during the past decades. To implement this design, a biome map and a municipalities map are combined to construct a dummy variable indicating whether more than 50% of the municipal area is in the Cerrado biome. This is the main independent variable used throughout the empirical analysis.

Other geographic information is used as controls in the analysis. GIS software is used to build a dataset on the average land gradient. This measure is constructed merging the elevation maps from the Shuttle Radar Topography Mission (SRTM) with a municipalities map. A dataset on average temperature and rainfall for the period 1971-2010 is created using data from the Terrestrial Air and Temperature Database Version 3.0. In addition, information on municipal latitude and longitude is collected fro the IPEADATA website.

To account for border changes and the creation of municipalities, the paper uses the definition of minimum comparable areas from the Brazilian Institute of Applied Economic Research (IPEA). The minimum comparable areas make spatial units consistent over time. The estimates use a minimum comparable areas definition that makes spatial units consistent with the existing municipalities and borders from 1991. The sample is restricted to

municipalities with less than 200,000 inhabitants in the initial period and with information on GDP. That leaves 665 spatial units that can be compared across periods. Throughout the paper, these minimum comparable areas are referred as municipalities. Figure 1 provides a visual illustration of the sample municipalities, emphasizing the ones inside and outside the Cerrado biome.

Appendix A describes in detail the definition of all variables used in the paper.

3.2 Descriptive Statistics

Table 1 reports descriptive statistics for the main variables used in this paper. Column 1 presents the sample mean in the initial sample period while column 2 presents the sample mean in the last sample period. Column 3 presents the increase between periods.

The table indicates that there were substantial changes in agricultural and economic development throughout the period 1995-2012. Cropland grew about one-fifth in the period whereas crop output more than tripled. Cropland expansion did not induce a reduction in cattle grazing and was connected to large shifts in land use.

GDP per capita grew more than 60% in the period 1999-2012 while population increased in about 30% in the period 1991-2010. Substantial gains in access to consumer goods, basic infrastructure and human capital also occurred in the period 1991-2010. These changes highlight the important transformations in economic development observed in these four states during the period. Our empirical design tests whether these changes were different in municipalities in the Cerrado biome.

Figure 2 provides an illustration of the different changes in agricultural outcomes within and outside the biome. It depicts the evolution of land use and agricultural outcomes in Cerrado and *non*-Cerrado municipalities. The figure provides evidence that the share of cropland and the log of agricultural output per hectare grew faster inside this biome than outside of it. This evidence indicates that agricultural expansion over the past decades was indeed concentrated in the Cerrado biome as indicated in Embrapa (2015). This finding motivates the empirical exercises presented in the remainder of the paper.

4 The Determinants of Agricultural Expansion

The empirical analysis begins by documenting the causes of the agricultural expansion in the *Matopiba* region. There are several factors that can drive agricultural expansion in frontier municipalities, such as land prices, access to markets, human capital, land tenure and soil characteristics. It is therefore challenging to determine the causal effect of each of these characteristics as the presence of omitted variable bias and reverse causation suggests that OLS estimates of the determinants of agricultural expansion will be biased.

This paper uses the historical experience from the evolution of the agricultural frontier in Brazil to help map the agricultural expansion in the *Matopiba* region. This historical experience suggests that agricultural expansion in the agricultural frontier was tilted toward some geographies. This is a result of technological innovations implemented between the late 1960s and the late 1970s which enabled large scale crop cultivation in areas in the Cerrado biome (Spehar, 1994; Klink and Moreira, 2002). These innovations generated a pattern of agricultural development quite different in these areas in relation to the other frontier areas (Bragança, Assunção, and Ferraz, 2015; Assunção and Bragança, 2015).

Following the historical experience and previous literature, the paper thus examines whether the expansion of agriculture in the *Matopiba* region was concentrated in its Cerrado areas using the empirical model presented below:

$$y_{mt} = \beta_t C_m + \theta_t' \mathbf{X_m} + \alpha_m + \delta_{st} + \varepsilon_{mt} \tag{1}$$

in which y_{mt} denotes an agricultural outcome of municipality m and period t; C_m indicates whether the municipality m is in the Cerrado biome; $\mathbf{X_m}$ represents a set of geographic characteristics of municipality m and α_m and $\alpha_s t$ are municipality and state-period fixed effects.

The coefficients of interest in Equation 1 are the different β_t. These coefficients represent the differential change in agricultural outcomes across municipalities located within and outside the Cerrado biome that share similar geographic characteristics. The geographic characteristics included are cubic functions of land gradient, latitude, longitude, rainfall, and temperature.

The model in equation 1 is estimated using agricultural data for the period 1995 to 2012. The main outcomes are total cropland (as a share of the municipal area) and the log of the

value of crop production (per municipal hectare). The analysis also uses the share of cropland cultivated with different agricultural products as outcomes to determine whether agricultural expansion was connected to changes in the crop mix. Coefficients are pooled in two-year periods to improve precision and facilitate the visualization of the results. All estimates are weighted using the total municipal area. Standard errors are clustered at the municipality-level to provide confidence intervals robust to the existence of serial correlation (Bertrand, Duflo, and Mullainathan, 2004).

Figure 3 presents a graphical illustration of the results. Panel (A) reports the results using cropland as the dependent variable, whereas Panel (B) reports the results using the log of the value of crop production as the dependent variable. The figure provides evidence that these variables were evolving similarly across municipalities within and outside the Cerrado biome in the beginning of the sample period. Nevertheless, agriculture starts expanding faster in municipalities in the Cerrado biome after some periods. The magnitude increases across periods, suggesting that differences between Cerrado and *non*-Cerrado municipalities are still increasing.

Table 2 presents the numerical results of the coefficients plotted in Figure 2. Column 1 reports the results for total cropland whereas column 2 depicts the results for the log of the value of crop production. The magnitude of the coefficients suggests that the share of cropland expanded 3.6 percentage points more in the Cerrado municipalities than in the *non*-Cerrado ones in the period 1995-2012, whereas the value of agricultural production increased 140% more.

An important aspect of understanding the previous estimates is whether the expansion in cropland is associated with changes in crop mix. In other words, was the increase in crop output the result of cropland expansion or the result of cropland expansion and changes in the structure of agriculture? To investigate this issue, equation 1 was reestimated using the share of cropland cultivated with different agricultural products as the dependent variables.

Figure 4 presents a graphical depiction of these results. Panel (A) provides evidence that the relative importance of soy cultivation increased in the Cerrado municipalities in the 2000s. Panel (B) indicates that the relative importance of maize production did not change in the period. Panel (C) points out that the relative importance of rice cultivation decreased in the Cerrado municipalities in the 2000s. Panel (D) points out similar results for cassava. However, the coefficients are not significant for most periods.

Table 3 presents the numerical results of the estimates from the previous figure. The mag-

nitude of the change in crop mix is substantial. Column 1 suggests that the share of cropland cultivated with soy grew 18 percentage points more in Cerrado municipalities while column 3 suggests that the share of cropland cultivated with rice fell almost 12 percentage points in these municipalities. These results support the idea that changes in crop mix accompanied the expansion in cropland. This table also provides evidence that the expansion in cropland had little effect on cattle ranching. Column 5 provides evidence that there is no significant differential change in the number of cattle per municipal area for all but one sample period. This result suggests that declines in cattle ranching do not offset the expansion in crop output.

5 The Consequences of Agricultural Expansion

The previous results indicate that agricultural expansion in the *Matopiba* region over the past decade was concentrated in the Cerrado biome. This evidence suggests that comparing the evolution of economic performance and socioeconomic indicators across Cerrado and *non*-Cerrado municipalities provides a useful assessment of the consequences of agricultural growth in the region. This empirical strategy enables us to circumvent the empirical issues that arise from regressing economic performance on agricultural output to the extent that there are no other changes in the economic environment that occur at the same period in municipalities within and outside this biome.

5.1 Economic Performance

The consequences of agricultural expansion in the *Matopiba* region on economic performance are examined using data for local GDP for the period 1999-2012. The empirical specification is the same one from Equation 1 but using a different time period for estimation and weighting the estimates using initial population.

Figure 5 provides a graphical illustration of the results. Panel (A) provides evidence of large increases in agricultural GDP per capita in Cerrado municipalities compared to *non*-Cerrado ones during the sample period. Panel (B) indicates that the expansion in agricultural GDP per capita neither crowds-out nor crowds-in manufacturing GDP per capita, while Panel (C) indicates that it crowds-in services GDP per capita. Panel (D) provides evidence that the direct effect of agricultural expansion on agricultural GDP and its indirect effect on services GDP generated increases in total GDP per capita in the Cerrado

biome.

Table 4 provides the numerical results of the estimates presented in Figure 5. Column 1 indicates that agricultural GDP increased about 37% (0.316 log points) more in Cerrado municipalities compared to *non*-Cerrado ones over the period 1999-2012. This impact increases through time with the difference between municipalities within and outside the biome increasing six-fold from 2001-2002 to 2011-2012.

Columns 2 and 3 provide evidence of the spillover effects esteeming of the agricultural expansion on other economic sectors. Point estimates are positive in both columns and indicate a differential increase of about 10% in the municipalities in the biome in relation to municipalities outside the biome over the period both in manufacturing and services GDP during the period 1999-2012. These differences are not significant for manufacturing GDP (column 2) but are significant for services GDP (column 3). These findings can be interpreted as evidence that agricultural expansion increases local demand either through backward or forward linkages. Sorting out these interpretations consists in an important agenda for future research.

Column 4 provides evidence that the total GDP per capita increased faster in Cerrado municipalities than *non*-Cerrado ones over the period 1999-2012. The difference increases over the period, reaching 11% (0.107 log points) at the end of the sample period.

5.2 Consumption and Infrastructure

An important question is whether improvements in economic performance induced improvements in overall quality of life across the *Matopiba* region. To investigate this issue, the analysis uses data from the Population Census for the years 1991, 2000 and 2010 to investigate whether access to durable goods and housing infrastructure changed differentially in the Cerrado municipalities in compared to the *non*-Cerrado ones. The estimates are obtained using the following empirical model:

$$y_{mt} = \beta_{2000} C_m + \beta_{2010} C_m + \theta_t' \mathbf{X_m} + \alpha_m + \delta_{st} + \varepsilon_{mt} \tag{2}$$

Equation 2 is similar to equation 1 which is used in the previous analysis. The main difference is that there are only two coefficients of interest (β_{2000} and β_{2010}) in the equation above. These coefficients investigate whether - conditional on the covariates $\mathbf{X_m}$ - the

outcomes were changing differentially in municipalities located within and outside the Cerrado biome.

These coefficients have different interpretations in this empirical design. On the one hand, the coefficient β_{2000} is useful to test the identification assumption from equation 2. This identification assumption states that outcomes would have changed in a similar fashion in the absence of differential agricultural development in the Cerrado municipalities. This implies that β_{2000} should be zero since agriculture started to expand in the Cerrado in the 2000s. On the other hand, the coefficient β_{2010} investigates whether differential agricultural expansion induced differential increases in access to goods in municipalites within the biome in comparison to municipalities outside it.

The model presented above is estimated for six different outcomes: share of households with a television, share of household with a fridge, share of households with a car, share of households with electricity, share of households with tapped water and share of household with adequate sewage. The former three outcomes represent access to durable consumer goods while the latter three outcomes represent access to infrastructure. The estimation uses the same covariates $\mathbf{X_m}$ included in the previous estimates, weights observations using the initial population and cluster standard errors clustered at the municipal-level.

Table 5 reports the estimates for the six outcomes described above. Changes in the outcomes were similar in Cerrado and *non*-Cerrado municipalities over the period 1991-2000 which is consistent with the identification assumption. But access to television, refrigerator and electricity grow differentially in Cerrado in comparison to *non*-Cerrado municipalities over the period 2000-2010. No differential change was found in the share of households with cars, tapped water and adequate sewage.

The share of households with a television increases 5.2 percentage points faster in municipalities within the biome in relation to municipalities outside it. The effect is 4.3 percentage points for the share of households with a refrigerator and 7.3 percentage points for the share of households with electricity. The mean of these three variables was, respectively, 0.53, 0.46 and 0.69 in 2000. Hence, the estimates indicate an increase in these outcomes close to 10% for all three variables.

It is also possible to use the coefficients to calculate the percentage of the expansion in access to goods observed in the sample period which was due to agricultural expansion. This provides an alternative method to calculate the magnitude of the estimates. In the period 2000-2010, agricultural expansion accounts for 17% of the expansion in access to

television, 12% of the expansion in access to fridge and 31% of the expansion in access to electricity.

To interpret these magnitudes it also is useful to compare them with the effect on agricultural expansion. This provides a "Wald" estimator of the effect of agricultural expansion on access to goods. The ratio between the Cerrado's effect on access to goods and this effect on crop output provides elasticities of agricultural expansion on these variables. The previous results indicate that crop output more than doubled in Cerrado municipalities in comparison to *non*-Cerrado ones over the period 2000-2010. Using this estimate, we calculate elasticities of .090 for access to television, .086 for access to refrigerator and .097 for access to electricity.

5.3 Population and Human Capital

The previous estimates focused on the consequences of agricultural expansion on economic indicators. Other margins of adjustment to agricultural expansion are investigated in this subsection. The focus on the adjustments in terms of migration and human capital investments since there is evidence that changes in agricultural expansion affected these variables in other settings. There is considerable literature that provides evidence that agricultural expansion induces in-migration while declines induce out-migration in the U.S. both in the short and the long term (Lange, Olmstead, and Rhode, 2009; Hornbeck, 2012; Feng, Oppenheimer, and Schlenker, 2012). There is also evidence that changes in agriculture affect human capital investments. Agricultural expansion can increase the demand for labor and induce children to drop-out of school as emphasized by Soares, Kruger, and Berthelon (2012). However, agricultural expansion can also induce human capital investments when it is connected to changes in agricultural production towards more skill-intensive technologies as documented by Foster and Rosenzweig (1996) for India and Bragança, Assunção, and Ferraz (2015) in Brazil.

Table 6 presents the estimates of the effects of agricultural expansion on population and human capital. The data and the empirical model are the same described in the previous subsection. Column 1 presents the estimates using the log of population as the dependent variable. Columns 2 and 3 report estimates splitting between rural and urban population. Column 4 depicts the results on school attendance while Column 5 shows the results for the share of adults with 8 years or more of schooling.

The results indicate no effects in these margins. Neither population nor human capital

investments seem to be affected by the expansion in agriculture in the *Matopiba* region. These results contrast with evidence on the agricultural adjustments to agricultural expansion in Central Brazil during the 1970s and 1980s (Bragança, Assunção, and Ferraz, 2015).

6 Conclusion

Large-scale and mechanized agriculture grew fast in the states of Maranhão, Tocantins, Piauí, and Bahia (*Matopiba*) over the past two decades. This paper examines the causes and consequences of this agricultural expansion. It documents that agricultural expansion in this region is concentrated in municipalities in the Cerrado biome. The results show that the share of cropland expanded 3.6 percentage points more while the value of agricultural production increased 140% more in the Cerrado municipalities than in the *non*-Cerrado ones in the period 1995-2012. The estimates also indicate a substantial shift in land allocation from rice and cassava to soy.

The paper also documents the impact of the expansion in agricultural activities on economic development. The results indicate that agricultural expansion led to a 10% increase in GDP per capita due to direct effects on the agricultural sector and indirect effects on the services sector. Agricultural GDP per capita increased about 37% (0.316 log points) more while services GDP per capita increased about 10% (0.094 log points) more in Cerrado municipalities compared to *non*-Cerrado ones over the period 1999-2012. Cerrado municipalities also experienced larger gains in access to durable consumer goods such as TV and refrigerator and to basic infrastructure such as electricity. Nevertheless, these municipalities did not experience differential changes in migration and human capital investments.

The results presented in this paper indicate that agronomic characteristics are essential to determine the areas where expansion of large-scale and export-oriented occurs in the Brazilian interior. While the timing of the expansion seems to be connected to a range of institutional and economic factors, its location seems to be strongly influenced by the prevalence of Cerrado soils. This finding suggests that the technological changes that enabled large-scale agriculture in these soils continue to exert an important influence on the geographic variation in agricultural expansion in Brazil.[3]

[3]Bragança, Assunção, and Ferraz (2015) and Assunção and Bragança (2015) discuss and evaluate the technological changes that enabled large-scale agriculture in the Cerrado biome.

The evidence presented in this paper also indicates that export-oriented agriculture generates sizeable economic benefits. The increase in the cultivation of modern crops more than compensates the decrease in cultivation of traditional crops and leads to a overall expansion of agricultural GDP. This expansion neither crowds-out expansion in other industries as some theories predict (e.g.: see Foster and Rosenzweig (2004)) not generates benefits just to a small groups of farmers as some observers fear.

Understanding the technological, institutional and cultural factors that shape the impact of agricultural expansion on economic development is an important avenue for future research. However, this paper suggests that expansion in large-scale and mechanized agriculture has the potential to increase economic development al least in some contexts.

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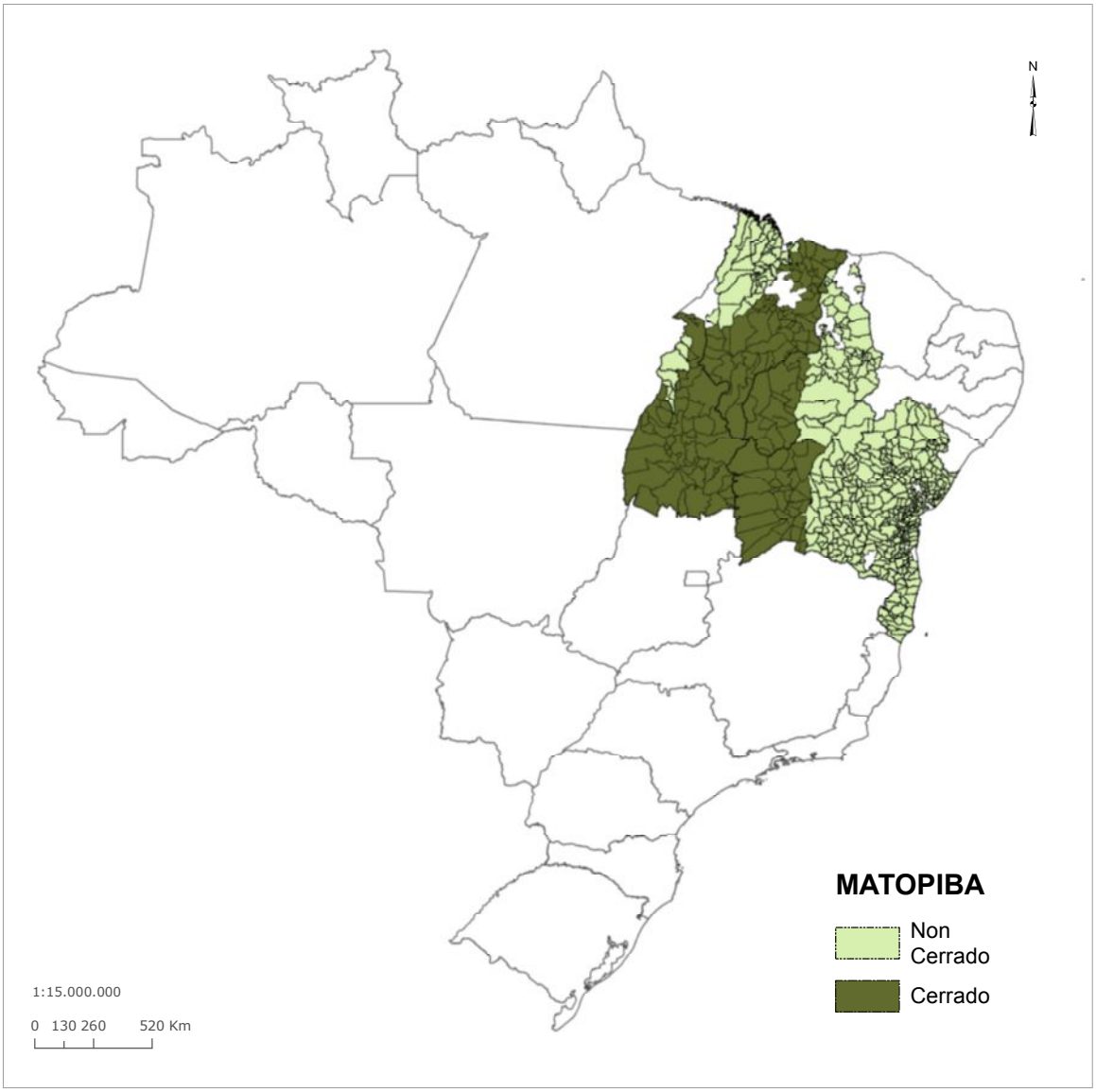

Figure 1: Sample Municipalities

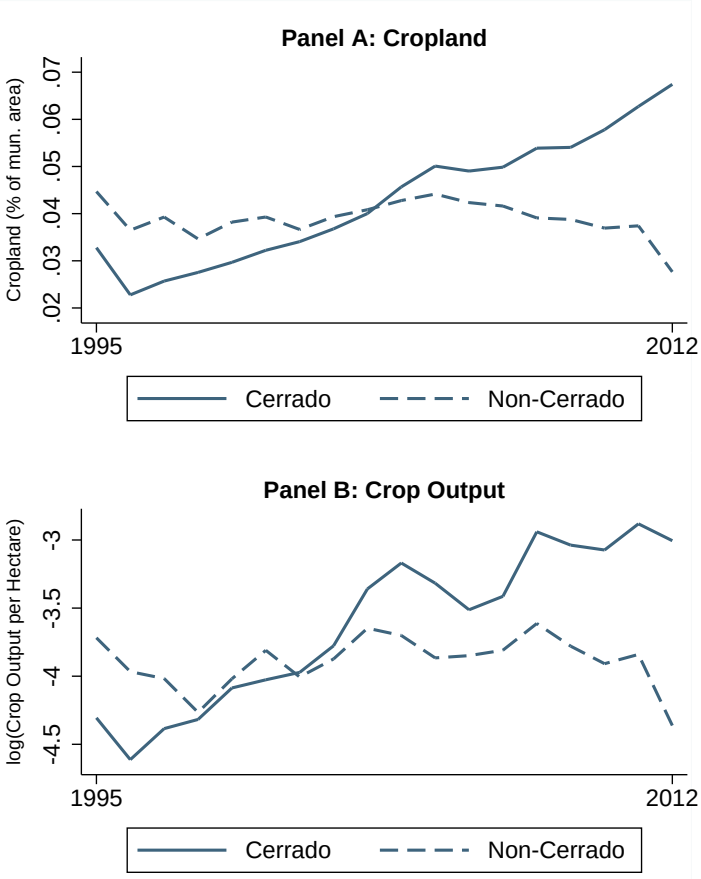

Figure 2: Evolution in Agricultural Outcomes

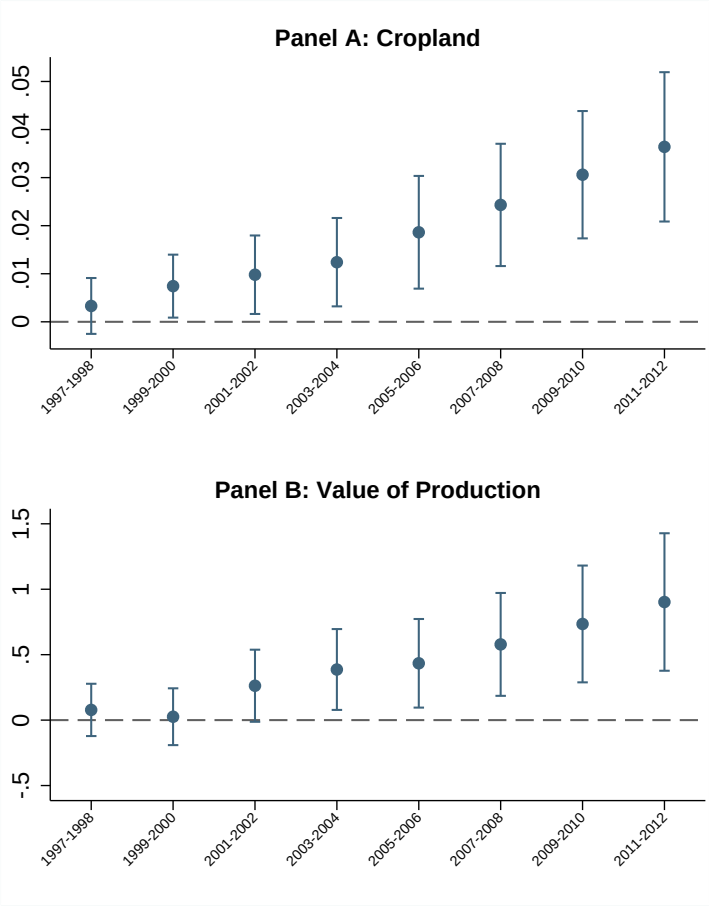

Figure 3: Effects on Agricultural Outcomes

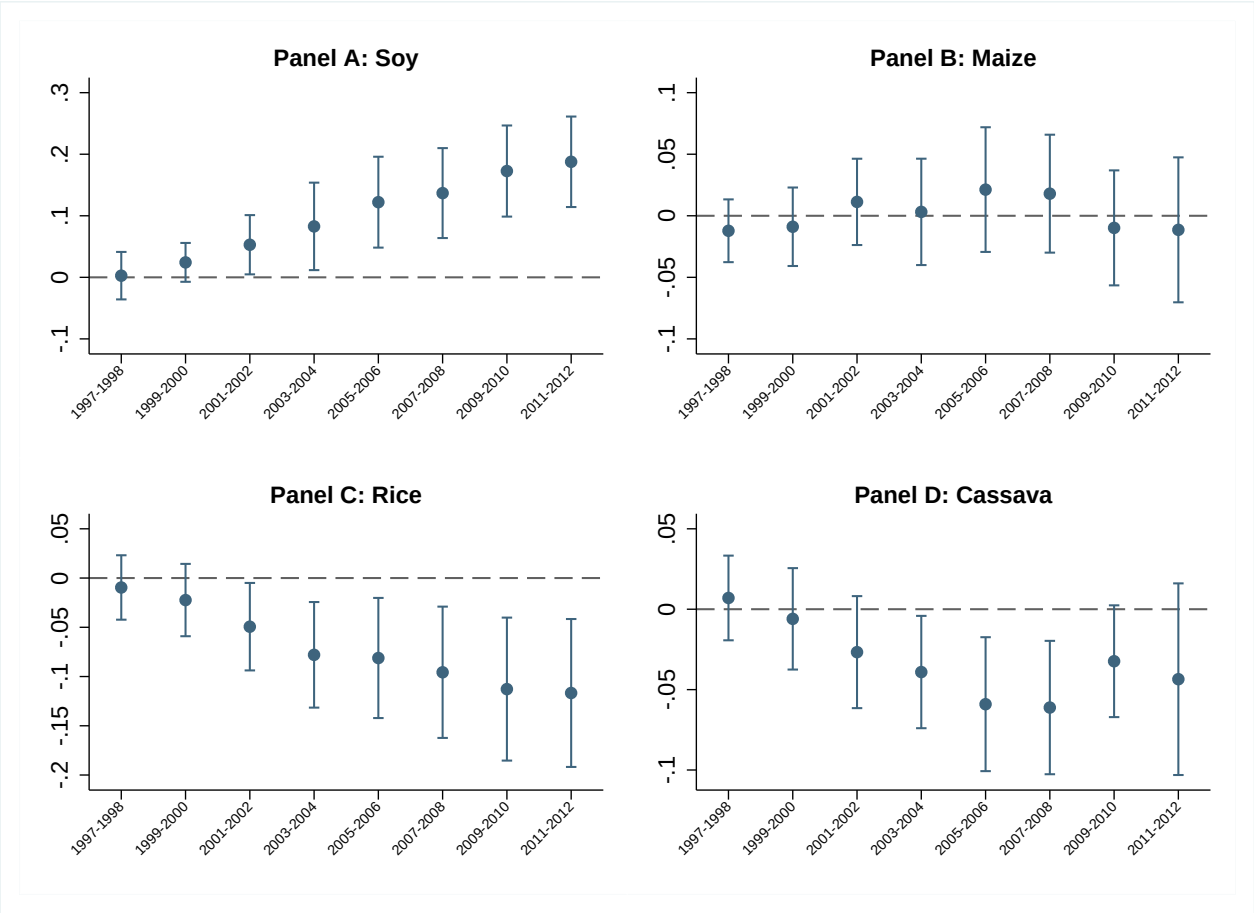

Figure 4: Effects on Agricultural Outcomes

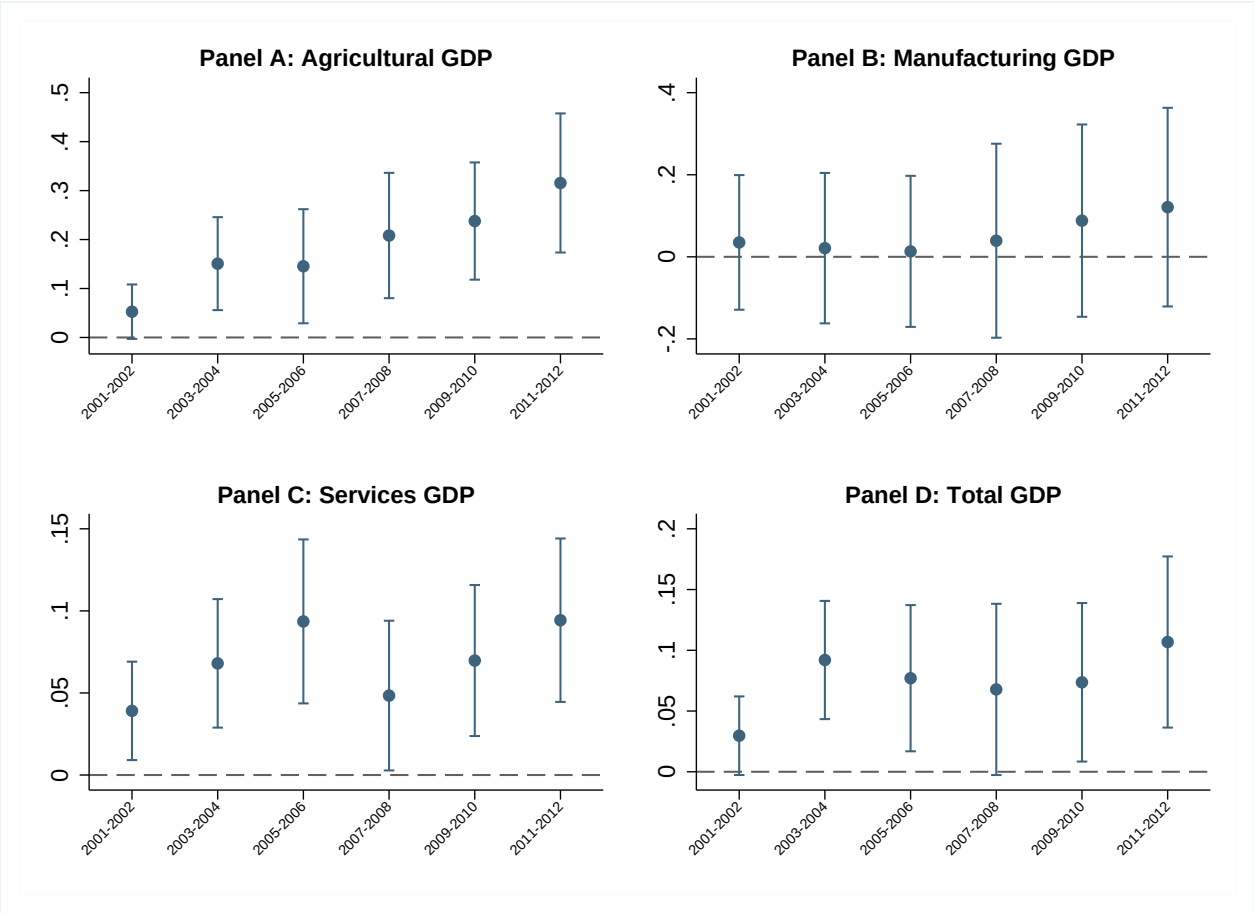

Figure 5: Effects on Economic Performance

Table 1: Descriptive Statistics

	Initial	Final	Difference
	(1)	(2)	(3)
Cropland (% of municipality area)	0.039	0.048	0.009
	[0.003]	[0.006]	[0.005]
Crop Output per hectare	0.038	0.104	0.066
	[0.003]	[0.006]	[0.005]
Soy (% of cropland)	0.078	0.194	0.116
	[0.018]	[0.023]	[0.017]
Number of Cattle (per hectare)	0.146	0.185	0.039
	[0.008]	[0.011]	[0.006]
GDP per capita	4.779	7.774	2.995
	[0.578]	[0.430]	[0.316]
Population	42.077	54.30	12.22
	[3.002]	[4.128]	[1.627]
Share with TV	0.308	0.854	0.545
	[0.011]	[0.004]	[0.008]
Share with Refrigerator	0.276	0.783	0.507
	[0.011]	[0.005]	[0.007]
Share with Electricity	0.551	0.937	0.387
	0.013	0.003	0.011
School Enrollment (15-17)	0.485	0.831	0.346
	[0.007]	[0.002]	[0.007]
Share with 8+ Years of Schooling	0.128	0.364	0.236
	[0.005]	[0.007]	[0.003]

Notes: Standard deviations are reported in brackets. Observations are computed using data from all 665 municipalities in the Matopiba region. Agricultural outcomes are weighted by municipality area while socioeconomic outcomes are weighted by population.

Table 2: Effects on Agricultural Outcomes

	Dependent Variable	
	Cropland (% of municipality area)	log(Crop Output per municipality hectare)
	(1)	(2)
Cerrado * (1997-1998)	0.003	0.078
	(0.003)	(0.102)
Cerrado * (1999-2000)	0.007**	0.026
	(0.003)	(0.111)
Cerrado * (2001-2002)	0.010**	0.263*
	(0.004)	(0.140)
Cerrado * (2003-2004)	0.012***	0.387**
	(0.005)	(0.157)
Cerrado * (2005-2006)	0.019***	0.434**
	(0.006)	(0.172)
Cerrado * (2007-2008)	0.024***	0.579***
	(0.006)	(0.200)
Cerrado * (2009-2010)	0.031***	0.735***
	(0.007)	(0.227)
Cerrado * (2011-2012)	0.036***	0.903***
	(0.008)	(0.268)
R-Squared	0.872	0.851
Number of Municipalities	665	664
Number of Observations	11,970	11,903

Notes: Each column reports the estimation of equation 1 from the main text. All regressions include the geographic controls described in the text as well as municipality and state*year fixed effects. Column 1 reports estimates using cropland as the dependent variable while column 2 reports estimates using the log of crop output. Details on the construction of all variables are presented in the appendix. Observations are weighted by municipal area. Standard errors clustered at the municipality level are reported in parentheses. *** p<0.01 ** p<0.05 * p<0.1

Table 3: Effects on Land Use

	Dependent Variable				
	Soy (% of cropland)	Maize (% of cropland)	Rice (% of cropland)	Cassava (% of cropland)	Cattle (per hectare)
	(1)	(2)	(3)	(4)	(5)
Cerrado * (1997-1998)	0.003	-0.012	-0.010	0.007	0.021
	(0.020)	(0.013)	(0.017)	(0.013)	(0.013)
Cerrado * (1999-2000)	0.024	-0.009	-0.022	-0.006	0.010
	(0.016)	(0.016)	(0.019)	(0.016)	(0.007)
Cerrado * (2001-2002)	0.053**	0.011	-0.049**	-0.027	0.010
	(0.025)	(0.018)	(0.023)	(0.018)	(0.011)
Cerrado * (2003-2004)	0.083**	0.003	-0.078***	-0.039**	-0.019
	(0.036)	(0.022)	(0.027)	(0.018)	(0.014)
Cerrado * (2005-2006)	0.122***	0.021	-0.081***	-0.059***	-0.035**
	(0.038)	(0.026)	(0.031)	(0.021)	(0.016)
Cerrado * (2007-2008)	0.137***	0.018	-0.096***	-0.061***	-0.025
	(0.037)	(0.024)	(0.034)	(0.021)	(0.017)
Cerrado * (2009-2010)	0.173***	-0.010	-0.113***	-0.032*	-0.023
	(0.038)	(0.024)	(0.037)	(0.018)	(0.018)
Cerrado * (2011-2012)	0.188***	-0.011	-0.117***	-0.044	-0.014
	(0.037)	(0.030)	(0.038)	(0.030)	(0.019)
R-Squared	0.900	0.828	0.925	0.841	0.915
Number of Municipalities	664	664	664	664	665
Number of Observations	11,910	11,910	11,910	11,910	11,970

Notes: Each column reports the estimation of equation 1 from the main text. All regressions include the geographic controls described in the text as well as municipality and state*year fixed effects. Columns 1 to 4 report estimates using the share of cropland cultivated with a particular product as the dependent variable. Column 5 reports estimates using the number of cattle per hectare as the dependent variable. Details on the construction of all variables are presented in the appendix. Observations are weighted by municipal area. Standard errors clustered at the municipality level are reported in parentheses. *** p<0.01 ** p<0.05 * p<0.1

Table 4: Effects on Economic Performance

	Dependent Variable: log of per capita GDP in each category			
	Agriculture	Manufacturing	Services	Total
	(1)	(2)	(3)	(4)
Cerrado * (2001-2002)	0.053*	0.035	0.039**	0.030*
	(0.028)	(0.084)	(0.015)	(0.016)
Cerrado * (2003-2004)	0.151***	0.021	0.068***	0.092***
	(0.048)	(0.093)	(0.020)	(0.025)
Cerrado * (2005-2006)	0.145**	0.013	0.094***	0.077**
	(0.059)	(0.094)	(0.025)	(0.031)
Cerrado * (2007-2008)	0.208***	0.039	0.048**	0.068*
	(0.065)	(0.120)	(0.023)	(0.036)
Cerrado * (2009-2010)	0.238***	0.088	0.070***	0.074**
	(0.061)	(0.119)	(0.023)	(0.033)
Cerrado * (2011-2012)	0.316***	0.121	0.094***	0.107***
	(0.072)	(0.123)	(0.025)	(0.036)
R-Squared	0.938	0.945	0.972	0.959
Number of Municipalities	665	665	665	665
Number of Observations	9,310	9,310	9,310	9,310

Notes: Each column reports the estimation of equation 1 from the main text. All regressions include the geographic controls described in the text as well as municipality and state*year fixed effects. Columns 1 to 3 report estimates using GDP per capita in different sectors as the dependent variable. Column 4 reports estimates using aggregate GDP per capita as the dependent variable. Details on the construction of all variables are presented in the appendix. Observations are weighted by municipal population. Standard errors clustered at the municipality level are reported in parentheses. *** p<0.01 ** p<0.05 * p<0.1

Table 5: Effects on Consumption and Infrastructure

	Dependent Variable: % of Households with Access to the Good					
	TV	Refrigerator	Car	Electricity	Water	Sewage
	(1)	(2)	(3)	(4)	(5)	(6)
Cerrado * 2000	-0.002	0.005	-0.003	0.021	-0.004	0.003
	(0.015)	(0.011)	(0.004)	(0.021)	(0.015)	(0.041)
Cerrado * 2010	0.052**	0.043*	-0.011	0.073*	-0.001	-0.002
	(0.026)	(0.023)	(0.007)	(0.039)	(0.024)	(0.030)
R-Squared	0.947	0.960	0.929	0.856	0.919	0.707
Number of Municipalities	665	665	665	665	665	665
Number of Observations	1,995	1,995	1,995	1,995	1,995	1,995

Notes: Each column reports the estimation of equation 2 from the main text. All regressions include the geographic controls described in the text as well as municipality and state*year fixed effects. Each column reports estimates using the share of households with access to a particular good as the dependent variable. Details on the construction of all variables are presented in the appendix. Observations are weighted by municipal population. Standard errors clustered at the municipality level are reported in parentheses. *** p<0.01 ** p<0.05 * p<0.1

Table 6: Effects on Population and Human Capital

	Dependent Variable				
	log (Population)	log (Rural Population)	log (Urban Population)	School Enrollment (15-17)	8+ Years of Schooling
	(1)	(2)	(3)	(4)	(5)
Cerrado * 2000	-0.018	-0.055	0.017	0.011	-0.004
	(0.030)	(0.045)	(0.060)	(0.019)	(0.007)
Cerrado * 2010	0.014	-0.014	0.061	0.011	-0.014
	(0.047)	(0.063)	(0.085)	(0.024)	(0.009)
R-Squared	0.983	0.952	0.983	0.870	0.969
Number of Municipalities	665	664	665	665	665
Number of Observations	1,995	1,991	1,995	1,995	1,995

Notes: Each column reports the estimation of equation 2 from the main text. All regressions include the geographic controls described in the text as well as municipality and state*year fixed effects. Each column reports estimates using the the dependent variable described in the top of the column. Details on the construction of all variables are presented in the appendix. Observations are weighted by municipal population. Standard errors clustered at the municipality level are reported in parentheses. *** p<0.01 ** p<0.05 * p<0.1