# Foreign Demand and Soy Exports: Evidence and Implications for Deforestation

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**Abstract**

The current paper aims to assess the credibility of demand-side policies to curb deforestation. We tackle this question focusing on the Brazilian soy sector, as conversion from forests to soy-producing areas is a major driver of deforestation. We estimate a firm-level gravity model relating soy exports to destination-specific soy demand. First, we estimate a positive elasticity of soy exports to foreign demand, which confirms the credibility of demand-side policies. Second, we document that the average response hides significant heterogeneities across exporters and across municipalities. Combining export elasticities with soy expansion possibilities, we conclude that demand-side policies could hence avoid aggregate deforestation, particularly in regions proximate to the Amazon.

**Keywords**: Agriculture, Trade, Firms, Deforestation.

**JEL Codes**: F18, Q17, Q23

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# 1 Introduction

Tackling deforestation is among the top priorities of policymakers in light of climate change issues. Existing policies include implementation of protected areas (Watson et al., 2014), blacklisting of particular municipalities (West and Fearnside, 2021), soy moratorium (Gibbs et al., 2015) among others. The common characteristic of these policies is that they are supply-side policies. Indeed, these policies target producers and intend to affect deforestation through producers' behavior. Whereas these policies can be effective (Assunção et al., 2020; Soares-Filho et al., 2023), policymakers have recently considered complementary actions. The AR6 report of the IPCC underscores the potential impact on mitigation of demand-side and material substitution measures for the agriculture, forestry, and other land use sectors. These measures could contribute to reducing emissions by 2.1 GtCO2-eq per year (IPCC, 2022). Besides, there are many international and national initiatives to implement demand-side policies to curb deforestation. For instance, the European Green Deal includes measures to favor sustainable supply chains. In France, a strategy to fight against "imported deforestation" has been set up, and actions include the relocation of plant protein production on the national territory, i.e. relying on locally available proteins instead of on imported proteins.[1] In a word, reducing the import demand of forest-risk commodities is envisaged by policymakers.

The general objective of the current paper is to assess the credibility and the potential effects of these demand-side policies. To provide some insights on this important issue, we tackle this question focusing on the soy sector. Indeed, conversion from forests to soy-producing areas (potentially indirectly through conversion into pastures first) is a major driver of deforestation (Song et al., 2021; Pendrill et al., 2019). Lowering demand for soy could thus curb land conversion and deforestation rates. Whereas soy supply is responsible for deforestation, the quantitative role of foreign demand for soy remains an open question. To answer this question, we use data covering the universe of soy exports from Brazil and estimate the elasticity of exports to soy foreign demand. Most of the soy produced in Brazil is for exports (75% in our dataset): exports and production patterns are hence very close. As a result, changes in soy production could plausibly be driven by changes in foreign demand.

Our analysis combines location and firm-specific soy export data with aggregate trade data informing on soy demand (imports) by destination. In this context, we estimate a firm-level gravity model relating firm-municipality-destination export flows to destination-specific soy demand and to standard firm-level trade determinants. Combined with demanding fixed effects, identification relies on the exogeneity of demand from abroad faced by individual soy exporters (i.e. individal firms). Indeed, as we rely on micro-level exports flows, foreign demand are plausibly exogenous from firm-specific or municipality-specific decisions. Reverse causality concerns – from individual firm soy exports to aggregate foreign destination demand are hence neutralized.

[1] https://www.deforestationimportee.ecologie.gouv.fr/en/sndi/article/sndi

To measure soy import demand by destination-year, we adjust observed import flows to account for both local and global supply shocks (using a method similar to Carreira et al. (2024)). This involves decomposing trade flows into supply shock components and then calculating the supply-corrected demand by aggregating adjusted import flows.

Our analysis delivers the following conclusions. First, we estimate an average micro-level elasticity of soy exports to foreign demand of around 0.4. On average, exporting firms increase their exports by 0.4% for a 1% increase in foreign demand. This result is robust to including a wide array of potentially omitted variables, alternative estimations, and measurement issues. This positive average elasticity confirms the credibility of demand-side policies, even though the magnitude of the effect remains small. Second, we document that the average response hides significant heterogeneities across exporters and across municipalities in Brazil. If changes in demand affect soy exports, the response varies across places and across exporting firms. In particular, our analysis highlights (i) that the largest exporters are more sensitive to soy demand shocks, (ii) that higher past deforestation patterns reduces the response, and (iii) that the number of competitors in the same municipality also dampens the impact of demand. Changes in demand, hence, mainly affect large exporters and municipalities with less competition and low soy expansion possibilities. We also document modest heterogeneity across the origin of the import demand. Third, we assess the potential benefits of the envisaged demand-side policies, taking the previous results at face value. The main metric of interest is the avoided deforestation. In our case, it measures the amount of deforestation that would have occurred to produce the avoided exports. This metric combines the avoided exports and expansion possibilities at the municipality level. In empirical terms, it combines (i) observed soy expansion possibilities with (ii) the estimated elasticities of exports to demand from the gravity model and using observed firm size, competition, and recent deforestation patterns as determinants.

The evidence on the effectiveness of demand-side policies is mixed. On the one hand, the expected effects appear to be larger in areas with high above-ground carbon biomass, suggesting that curbing demand for deforestation-prone commodities in these regions could lead to significant reductions in exports linked to deforestation. Additionally, the effects seem to be increasing over time, indicating that demand-side interventions are becoming progressively more effective in influencing export volumes and reducing deforestation. However, the effects in Cerrado —where soy production has been expanding rapidly— are highly dispersed. Besides, in areas like southern Mato Grosso and Matopiba, where significant forest cover remains, the limited response of exports to demand suggests that demand-driven policies would have a lesser impact. On the contrary, our estimates suggest that many municipalities in the Amazon have strong potential being highly affected by the envisaged policies. Our results hence highlight the potential effects of a more geographically targeted set of policies.

**Related Literature** This paper builds upon and contributes to three strands of the literature. Firstly, it adds to the growing body of research on the link between trade and deforestation. While previous studies have identified several channels through which trade openness may affect deforestation, including agricultural market prices (Berman et al., 2023), land-use value, imported agricultural input costs, and productivity (Abman and Lundberg, 2019; Pellegrina, 2022; Carreira et al., 2024), empirical evidence of the effect of trade on deforestation has been limited (Balboni et al., 2023). However, recent studies have provided new insights into this relationship. Abman and Lundberg (2019) shows that deforestation increases following regional trade agreements and that this effect is mediated by agricultural trade. Tracking the deforestation in trade flows, Pendrill et al. (2019) shows that a large part of tropical deforestation can be attributed to foreign consumer countries, especially soybean. Also, the recent microdata of the supply chains documents the involvement of transnational firms in this process (West et al., 2018). This paper builds on this literature by quantifying the heterogeneous effects of changes in foreign demand on supply and deforestation, considering geographic and firm-level characteristics. We also build on the international economics literature that considers the importance of firm heterogeneity in shaping the patterns of international trade (Melitz, 2003; Bernard et al., 2012). Here, we empirically show how the heterogeneity in firms in the soybean market affects the elasticity of supply to foreign demand and how this heterogeneity matters for the effect of demand-side policies on deforestation. Finally, this paper adds to the growing body of literature on policies to slow the rate of deforestation. Recent research has considered trade policies as instruments to encourage conservation in countries that may otherwise deforest their territories (Balboni et al., 2023). While some studies have proposed import tariffs as a means of reducing deforestation (Harstad, 2022; Domínguez-Iino, 2022) and others have examined the efficiency of bans (Busch et al., 2022; Villoria et al., 2022), the effectiveness of these policies remains controversial. This paper contributes to this literature by examining how changes in foreign demand can be transmitted heterogeneously to deforestation through firms and how these changes could translate into a decrease in deforestation. Our results on demand-side policies suggest that, although acting on foreign demands would not transmit homogeneously across the market, the adaptation of the supply to the changes in demand could indeed slow down the deforestation process in producing countries.

The rest of the article is organized as follows. The next section details the data sources and presents the context of the empirical analysis. Section 3 provides an overview of the empirical methodologies employed, in particular how we measure demand from observed import flows and the estimated equations. Section 4 describes the main results of the analysis. Section 5 presents the implications of our results for deforestation patterns. The final section concludes and discusses the results.

# 2 Data and context

## 2.1 Data

We use data covering the universe of soy exports, soy production, and foreign demand from 2004 to 2017.

**Firm-level soy exports** To identify soy export flows, we rely on the TRASE database (Godar, 2018). This database is constructed from customs records and maps trade flows (in physical quantities and port of export FOB values) from source cities to destination markets and the agribusiness firms intermediating the transactions. The unit of observation in our analysis is at the exporter group $\times$ municipality (of production) $\times$ final destination country $\times$ year level.

Indeed, exporters (mainly multinational firms) mainly buy soy from individual or collective producers (farmers, cooperatives) which are located in different municipalities. TRASE hence identifies the origin municipality where the soy is cultivated.[2]

**Firms characteristics** The TRASE database allows us to identify exporters' characteristics. Namely, we can quantify total firm exports, the number of destinations each firm serves, as well as the number of source municipalities. Moreover, TRASE enables us to measure various aggregates informing on the market structure and which may be driving forces behind the main elasticity. We compute by municipality, the number of exporters (sourcing from this specific municipality, eventually serving a specific destination), the average exports of these firms, their ranking within the hierarchy and other aggregates. Besides, the dataset also allows to identify the so-called top-4 firms (ADM, Bunge, Cargill, and Louis Dreyfus) (Clapp, 2015).

**Aggregate foreign soy import flows** We use international trade data to identify soy demand in importing countries (see next section), based on the BACI database.[3] We select the bilateral trade flows of the six-digit Harmonized System (HS) products associated with soybeans, including not only HS6 120100 (Soya beans; whether or not broken) but also other related products such as HS6 120810 (Flours and meals: of soya beans), HS6 150710 (Vegetable oils: soya-bean oil and its fractions, crude, whether or not degummed, not chemically modified), and HS6 150790 (Vegetable oils: soya-bean oil and its fractions, other than crude, whether or not refined, but not chemically modified).

**Municipality characteristics** We also collected some municipality-specific time-varying variables, which can be determinants of firm-specific and aggregate trade. Among others, we use data on municipality GDP, population from the Brazilian National Institute of Geography and Statistics (IBGE) and

[2] TRASE also identifies the main exporting port (where soy is shipped) but we do not use this information in this research.

[3] BACI is an international trade database stemming from the harmonization of the COMTRADE database, in which the trade flows reported by exporting and importing countries sometimes differ (Gaulier and Zignago, 2010).

distance to the main port (Victoria et al., 2021).

**Deforestation Patterns** To measure deforestation, we rely on the MapBiomas database (Souza et al., 2020), aggregated at the municipality-year level[4]. Because most of the soy expansion takes place in the Cerrado (an ecosystem of tropical savanna not fully included in the FAO forest definition), we extend the analysis beyond deforestation and consider more broadly the effects of the changes in demand on the changes in the class "forest formation". This ecosystem, with low legal protection compared to the Brazilian Amazon, is currently experiencing high conversion rates (five times as high as deforestation rates in the Amazon before the Soy Moratorium) in which soy plays a direct and significant role (Rausch et al., 2019).

## 2.2 Stylized facts

**Fact 1: Increasing soy trade flows.**

Figure 1 underscores a consistent pattern of growth in international trade flows for soy, illustrating how the world demand for soybean increased dramatically during the sample period. Soy exports worldwide tripled during 2005-2015, in line with an increasing global import demand. In this context, Brazil is a major exporter of soybeans: around 40% of total soy exports are from Brazil origin. Brazilian soy exports follow the same increasing trend.

**Fact 2: China and the EU are the top destinations.**

Figure 2 informs on the main destination of Brazilian soy, from TRASE dataset. Figure 2-a shows the time series of exports to all destinations, to China and to the EU in our sample period. It highlights the increasing dominance of China as the primary destination for Brazilian soy exports, surpassing the EU, which historically was a significant destination. The total growth in soy exports is largely driven by China's demand. This strong upward trend aligns with China's growing demand for soy, mainly driven by its livestock and feed industries. Figure 2-b provides the average share of each destination in the sample. The distribution of exports is skewed across destinations. China is the main importing country of soybeans, and the EU is second[5].

**Fact 3: The heterogeneous geography of soybeans exports in Brazil**

Figure 3 highlights the geographic heterogeneity across space in the exports of soybeans. Figure 3-a plots the total exports of soybeans in our sample period in the different municipalities; the darker areas representing the largest exporting municipalities. There is wide heterogeneity across municipalities and

[4] MapBiomas was chosen as the main data source because of its complete coverage and detailed classification of land use and land cover in Brazil, which includes forests and natural grasslands. Unlike PRODES, which focuses solely on forest cover in the Amazon region, and the Hansen dataset, which identifies the tree cover loss and therefore does not identify forests or wider natural vegetation, MapBiomas provides a more detailed representation of land use across the country. In addition, MapBiomas is widely used in research on land use change in Brazil (e.g. Villoria et al. (2022))

[5] We aggregate all EU countries in this Figure only, for clarity and for exposition. In the estimations, we account for the demand of each EU country separately.

across biomes. The largest exporters are in the Cerrado, located primarily in the central part of Brazil. Cerrado is known for its unique biodiversity and is characterized by a mix of forests, grasslands, and savanna-like landscapes. Figure 3-b confirms the importance of Cerrado in the exports of soybeans. The Cerrado biome plays a role in driving the overall growth of Brazil's soy exports, with significant increases after 2010. The Amazon biome, while contributing to the growth, has a comparatively smaller and more gradual increase in soy exports. This graph underscores the Cerrado's dominance as a major agricultural region for soy production and the increasing role it plays in Brazil's export market.

# 3 Methods

## 3.1 Measuring demand from import flows.

We intend to measure soy import demand by destination-year. Yet, there are several reasons why using observed import flows to measure demand may be problematic. First, observed import flows represent an equilibrium measure that reflects both demand and supply forces. Second, local supply shocks in Brazil can influence global production, world prices, and, consequently, equilibrium trade flows. To address these issues, we use import data from BACI and adjust this measure to account for potential supply shocks, following a methodology similar to that of Carreira et al. (2024).

In technical terms, first, we decompose the observed soy bilateral flows from $o$ to $d$ in the following manner:

$$X_{odt}^{soy} = \eta_{ot} + \eta_{dt} + \eta_{od} + \varepsilon_{odt} \tag{1}$$

in which $\eta_{ot}$ are the estimated supply shocks. Second, we purge the observed trade flows $X_{odt}^{soy}$ from the supply shocks (estimated in $\eta_{ot}$ in eq. 1). Aggregating these purged flows by destination-year yields the supply-corrected demand for soy, Soy Demand$_{dt}$:

$$\text{Soy Demand}_{dt} = \sum_{o} (X_{odt}^{soy} - \widehat{\eta_{ot}}) \tag{2}$$

For simplicity, we denote this value as "demand", and use this measure in the benchmark estimations.

## 3.2 Average elasticity

Our main estimation strategy of the micro-level elasticity is based on regressions of soybean exports per firm – municipality - destination on the soybean demand from a destination country. We choose this level of analysis to estimate the reaction of a firm sourcing from a municipality to a demand shock from a destination country. This level of analyses neutralizes the obvious reverse causality issue (from exports to foreign demand). It is indeed very hard to argue that firm-level exports from a municipality affect foreign aggregate import demand. At the individual firm level, foreign import demands are hence plausibly exogenous from firm-specific exports flows and production decisions. In formal terms, the regressions follow equation:

$$\text{Exports}_{fmdt} = \lambda_{fmd} + \lambda_{fmt} + \alpha\text{Soy Demand}_{dt} + \beta\text{Controls}_{dt} + \varepsilon_{fmdt} \quad (3)$$

where $\text{Exports}_{fmdt}$ is the value of the soy exports of firm $f$ from municipality $m$ to destination country $d$ in year $t$. We do not consider the EU as a group (as in Figure 2) but rely on each country's demand.

$\text{Controls}_{dt}$ is a vector of time-varying destination-specific trade determinants such as destination observables: foreign GDP and population, both to measure market size. We include a small set of control variables, to avoid over-fitting and bad controls problems. Besides, given the demanding fixed effects structure, most of the variance should be controlled.

Our specification also includes a set of fixed effects. The main results are obtained using firm-municipality-destination fixed effects ($\lambda_{fmd}$) and firm-municipality-year fixed effects ($\lambda_{fmt}$). The former set of fixed effects absorbs variance across individuals. Coefficients are thus identified from variation across years for a given individual (i.e. an exporter-source municipality-destination country group). These fixed effects absorb the effect of many time-invariant determinants of trade, such as the distance with destination country (as all exporters are located in Brazil) and the pre-existence of a relationship between a firm and a destination country. It also absorbs trade determinants that do not vary in our sample period, such as the existence of a regional trade agreement between Brazil and a destination (as Brazil did not sign any new agreement between 2004 and 2017 with soy exports destinations).

Firm-municipality-year fixed effects control for time-varying heterogeneity across cities (such as GDP per capita, the share of agriculture in local GDP, ...) as well as across firms (such as total firm exports, number of destinations, number of sources, etc.). This set of fixed effects also controls for aggregate and local supply shocks: both local, country-wide or international supply shocks (a technology shock for instance) are absorbed in this measure. It also excludes the potential non-random selection of sourcing cities at the firm level: estimations are performed within a given firm network of sourcing and destination at the firm level. All the adjustments must therefore take place within a given network. Crucially, the firm-municipality-year fixed effects also control for changes in both the international and local prices of soy. As a result, we focus on the residual effect of demand, after accounting for price changes. These fixed effects finally control for the so-called outward multilateral resistance terms in gravity frameworks as they absorb the exporter-year dynamics (whether it is at the national or firm levels).

Our coefficient of interest is $\alpha$, which we expect to be positive as exports and demand should go in the same direction. All explanatory variables are in logs, except dummy variables. This $\alpha$ coefficient hence captures the average elasticity of exports to demand. Beyond significance, the value of $\alpha$ informs the credibility of demand-side policies. Indeed, these policies would have any effect only if $\alpha$ is large enough. Regarding inference, $\varepsilon_{fmdt}$ is a random error term. We allow errors to be correlated within groups of destination-year and cluster the standard errors at this level (which is also the level of the demand shocks).

We estimate equation (1) using a PPML estimator, as standard practice regarding trade flows (Santos Silva and Tenreyro, 2006), including zero-trade flows[6]. We check the sensitivity of results when using alternative estimators (OLS) and specifications.

### 3.3 Differential effects

After estimating the average export elasticity of firms sourcing from a municipality to a demand shock from a destination country, we investigate the heterogeneous response across firms, municipalities, and destinations. We estimate some interaction models of the following general form:

$$
\begin{aligned}
\text{Exports}_{fmdt} &= \alpha \text{Soy Demand}_{dt} + \beta \text{Controls}_{dt} + \delta_1(\text{Soy Demand}_{dt} \times \text{Controls}_{ft}) \\
&+ \delta_2(\text{Soy Demand}_{dt} \times \text{Controls}_{mt}) + \delta_3(\text{Soy Demand}_{dt} \times \text{Controls}_{dt}) \\
&+ \mathbf{FE} + \varepsilon_{fmdt}
\end{aligned} \tag{4}
$$

where the set of $\delta$ captures the differential effects of the same soy demand shock across firms, municipalities, and destinations. Regarding interpretation, conditional on a positive $\alpha$ in the previous estimations, a positive $\delta$ means that the same demand shock generates increased exports for firms, municipalities, and destinations with bigger controls.

First, to identify which exporters capture the changes in demand, we condition the impact of the demand shocks on observables at the firm level ($\text{Controls}_{ft}$). Variables include the lagged total exports, lagged total number of destinations, and lagged the number of sourcing municipalities per firm. Overall, these variables intend to capture exporter size. This dimension of heterogeneity is supposed to capture a large part of the variance in the reaction across firms. Many recent papers argue that firms react differently to foreign demand shocks depending on their size (Bernard et al., 2012; Bricongne et al., 2022; Chowdhry and Felbermayr, 2023), in line with theoretical arguments (Melitz and Ottaviano, 2008; Edmond et al., 2015).

Second, to determine *where* the additional demand is satisfied from, we focus on the interaction between demand shock and municipalities' characteristics ($\text{Controls}_{mt}$). These characteristics include the GDP of the sourcing municipalities, their population, the number of top-4 competitors in the municipality (see previous discussions), as well as its past deforestation levels. In line with economic geography arguments (Desmet and Henderson, 2015; Redding and Turner, 2015), these variables are supposed to capture differences across cities and inform on the differential pattern of soy exports across municipalities (Garrett et al., 2013).

[6] Estimated coefficients can be considered as elasticities, even though they enter in level in the left-hand side of equation.

Finally, to explore whether the response is shaped by destination characteristics, we interact soy demand with controls at the destination-year level ($\text{Controls}_{dt}$). These controls include country dummies (as for China or the EU) and destination time-varying characteristics, such as GDP, to investigate whether foreign market size shapes the elasticity.

In formal terms, we employ a wide array of fixed effects (denoted FE) to isolate the relevant identifying variation and control for many unobserved shocks. For instance, when investigating the variation across firms, we use (at least) a municipality-destination-year fixed effect to account for observables and unobservables at this level, thereby focusing exclusively on the remaining variation across firms. Note also that the whole set of fixed effects also absorbs most of the unconditional effects of variables of interest. For instance, the unconditional effect of firm size on soy exports is captured in the firm(-municipality)-year fixed effect. Importantly, we include a destination-year fixed effect: this absorbs the unconditional effect of the demand shock (acting as if all firms faced the same demand shock) but the interaction between demand and observable remains identifiable. Moreover, as some specifications include a set of destination-year fixed effects, they control for the inward multilateral resistance terms.

# 4 Results

## 4.1 Effect of foreign demand on soy exports

Benchmark results are displayed in Table 1. Column 1 includes firm-municipality-destination and year fixed effects, whereas columns 2 and others consider a more demanding fixed effects structure, including a firm x municipality x year fixed effect absorbing the major trade determinants at both the firm and the aggregate levels, and implying a change in sample.

The results in columns 1 and 2 point towards a 0.4 average elasticity. The larger the soy demand in a destination, the larger the export flow. Using this 0.4 elasticity, a 10% increase in foreign soy demand increases soy exports (in value) by 4% on average. One standard deviation of soy demand (2.32) is related to a 1% increase in exports in our sample. This value is the average effect of changes in demand across firms and municipalities. The positive elasticity is independent of the set of fixed effects included in the estimation and of the subsequent change in samples (excluding singletons in the fixed effect dimensions). Comparing columns 1 and 2 in particular excludes that the main effect is solely driven by composition effects. Regarding control variables, GDP has a positive impact on soy exports, in line with the gravity literature (Head and Mayer, 2014). We however find no significant and robust pattern regarding the impact of population – capturing the market size – on soy exports.

Table 1 further decomposes the average elasticity of soy exports to demand into an intensive (col. 3) and an extensive (col.4) margin of trade. Indeed, the baseline sample includes both zero trade flows and strictly positive flows. As for the intensive margin, we estimate equation (1) on the sample of positive trade flows. As for the extensive margin, we regress a dummy equal to 1 if the trade flow is positive, and we use a linear probability model (denoted LPM in table). We estimate that soy demands affect soy exports through both trade margins. In quantitative terms, both trade margins are at play: it implies that soy demand changes affect soy exports not only through the level of exports, conditional on presence, but also through changes in the presence of an exporter, i.e. entry and exit of the export market.

## 4.2 Differential effects across firms, municipalities, and destinations

Turning to heterogeneity, we now document the differential effect of the demand shocks across firms, across municipalities, and depending on previous deforestation patterns.

### 4.2.1 Heterogeneity across firms

Using variation across firms, holding municipality-destination-year observables constant (thanks to the fixed effects, reducing sample size however), Table 2 finds robust differential effects of increased demand across exporters. We differentiate firms along four measures of size: lagged total exports (col.1), lagged number of foreign destinations (col.2), lagged number of sourcing municipalities (col.3), and "being a top-4 firm" dummy (col.4). All those measures are documented to be proxies for firm size (Melitz and Redding, 2014; Bernard et al., 2012). We find that all interactions between soy demand and lagged firm size proxies are positive. When foreign demand increases, larger exporters capture most of this additional demand. In particular, the large differential impact of the top-4 dummy suggests that these top firms capture almost all the additional demand. One additional result is that the firm size premia on exports is not driven by the firm's access to storage and crushing facilities (col.5) as the differential effect of firm size is not affected by this augmented set of interacted controls. Overall, this exporter size premium over demand variations is in line with recent evidence on the topic, relying on heterogeneous elasticities across firms (Bricongne et al., 2022; Chowdhry and Felbermayr, 2023; Melitz and Ottaviano, 2008).

### 4.2.2 Heterogeneity across municipalities

Next, changes in foreign demand have a different impact across soy-producing municipalities. Table 3 controls for firm-destination-year fixed effects and the identifying variation is hence across cities. Results support strong and robust differential effects of an increase in demand across soy-producing municipalities. Conclusions are threefold.

First, we estimate that, conditional on the soy demand change, the impact is larger in cities with smaller GDP per capita (measured in 2004 to avoid endogeneity) (col. 1). The larger the GDP in 2004, the lower the elasticity to soy demand changes. This effect is almost offset by population: large municipalities capture and absorb more the demand shock. These effects may partly be driven by cities closer to ports (col. 2). Distance to ports could capture within-Brazil trade costs such that the pro-trade effect of increased foreign demand could favor places with lower relative trade costs within the country.[7]

Second, competition between exporters drives a large part of the differential effect. We measure municipality-specific competition by counting the number of top-4 firms serving the same destination-year from the same municipality. We estimate that, conditional on soy demand changes, the larger effects are observed in municipalities with a low number of top-4 firms that are present in the previous year (col.3). This competition channel appears to be quantitatively an important driver of the differential effect across municipalities, as other determinants are estimated insignificant in column 3 onward. The export response hence seems to be driven much more by competition than by local economic conditions. This is in line with anecdotal evidence on the importance of these top firms (in an oligopoly setup, with a fringe of small firms) and of their strategic interactions. Firms sourcing from municipalities with fewer competitors yield higher elasticities.

Third, recent deforestation patterns also shape the potential export response. Proximity to the deforestation frontier shapes the exports response to demand. Indeed, we find that the elasticity of exports to demand is larger in places with lower recent deforestation. Most of the action seems to be at play in places with lower recent deforestation patterns. Indeed, low levels of recent deforestation are correlated to potentially large deforestation in the past and thus a path-dependence pattern. Overall, smaller GDP, fewer competitors in the municipality, and lower recent deforestation patterns enhance the impact of demand changes on soy exports.

#### 4.2.3 Heterogeneity across destinations

Finally, the origin of the demand shock seems to play a role in the pattern of exports. Table 4 displays models including an interaction term between soy demand and dummies characterizing the origin country. On average, firms do not particularly react to demand originating from China (compared to other countries altogether, in col. 1), but seem to under-react when the shock comes from the EU (col. 2). More generally, destination GDP per capita (as a market size proxy) shapes the elasticity. The larger the GDP, the lower the elasticity.

### 4.3 Robustness checks

Conclusions are robust to many robustness checks detailed in this subsection.

**Soy Demands measures.** Our results are robust to the use of alternatives measures of foreign demand. First, we checked the sensitivity of our results to the estimation strategy when identifying the demand component from imports flows. We also substracted the bilateral time-constant component of

[7] Recall that distance with the final destination of the good is absorbed in the destination fixed effect.

trade flows, on top of the origin-year component in the following way:

$$\text{Soy Demand}_{dt} = \sum_{o} (X_{odt}^{soy} - \widehat{\eta_{ot}} - \widehat{\eta_{od}}) \tag{5}$$

to measure an alternative demand. Results using this measure are presented in Table A.1, and confirm the benchmark conclusions: on average, demand affects soy exports but favor the largest firms, with a minor role for (economic) geography. Besides, results do not differ from the benchmark estimates, which is not surprising as the $\widehat{\eta_{od}}$ term is already controlled for using fixed effects in the estimations.

Second, Tables A.2 and A.3 show results when using the observed import flows as a measure of demand ($\text{Soy Demand}_{dt} = \sum_{o} (X_{odt}^{soy})$) in which $X_{odt}^{soy}$ are soy values or soy quantities (in tonnes), respectively.

**Firm-level exports measures.** We replicated the estimations using firm-level exported quantities (Table A.4 and firm-level unit values (defined as the ratio of exports value over exported quantities) ( Table A.5). The average effects occur regarding quantities, whereas firm-level unit values differentials are mainly unaffected.

**Estimator** Table A.6 shows results when estimating equation 3 with the log of exports as the dependent variable and using an OLS estimator. Focusing on the universe of positive trade flows only, Table A.6 supports that the main elasticity value is affected by the choice of the estimator and lies on average around 0.2. This is about half the value of the benchmark estimates. It is not surprising to obtain smaller point estimates as the OLS estimates capture the effect of demand on exports at the intensive margin only, whereas the benchmark PPML estimates identify the effects at both the intensive and extensive margins of trade.

**Clustering of standard errors** Inference is robust to the use of alternative standard error clustering levels: whereas benchmark results were based on destination-year clustering, inference is confirmed when municipality-year clustered errors (Table A.7) or with two-way municipality-year and destination-year clusters (Table A.8). As trade flows are partially modelled (tracing back the flows from the logistic hub to the municipality of production), Table A.9 also shows results when clustering the standard errors at the logistic hub-year level (at the intensive margin of trade only, hence reducing sample size however). Finally, Table A.10 shows results when clustering the standard errors at both the firm level and the destination level to account for potential correlation in the error term across observations within firms and within destinations.

# 5 Implications for deforestation

So far, we have examined how certain firms and municipalities heterogeneously capture demand variations. Building on this previous result, the final section of this paper derives the implications of this result for the effectiveness of demand-side policies in mitigating deforestation.

## 5.1 Background

Studies evaluating forest conservation policies typically quantify their effectiveness in terms of avoided carbon emissions or avoided deforestation, which is the gap between observed deforestation and a counterfactual value (Combes Motel et al., 2008; Delacote et al., 2016; Alix-Garcia et al., 2017). To answer our specific research question, we need to examine the extent of forest preservation achievable through policies that lower foreign demand for soy, relative to a business-as-usual scenario.

The effects of changes in foreign demand on deforestation can be decomposed into two distinct dimensions. First, the previous section provided an elasticity of exports to demand, that varies across municipalities and firms, indicating that demand reductions affect differently exports depending on location and market structure. Second, whether this change in exports will result in deforestation depends on the potential for soybean expansion into forests: how much forest would have been affected in order to produce the (avoided) exports? This factor is also highly location-specific, with some regions exhibiting significantly greater residual forest cover than others. We take both these dimensions into account in our discussion, recognizing that avoided deforestation is the combination of avoided exports on the one hand and soy expansion possibilities on the other hand.

## 5.2 Avoided Exports

To estimate avoided exports, we use previously derived regression models to predict the export response to a marginal change in foreign demand. These models are estimated at the municipality and firm levels, allowing us to capture the heterogeneous spatial and firm-specific impacts. Figure 4 displays the estimated elasticities at the municipality level. Darker regions indicate higher elasticities, suggesting a more pronounced response to demand-side interventions, while lighter regions indicate lower sensitivity to demand changes. For instance, municipalities in the eastern Amazon and southern Brazil exhibit higher elasticity, whereas Matopiba—an area experiencing rapid soy expansion—shows lower sensitivity despite being a major soy-producing region.

More generally, the spatial variation in the responsiveness of municipalities to foreign demand shocks are illustrated in Figure 5 and inform about where and when these policies might be most effective, in terms of avoided exports. Panel 5-a compares elasticities between different biomes, showing that all biomes yield the same elasticity. Responses are however more dispersed within Cerrado, than within other biomes. While reductions in foreign demand may result in slightly larger export reductions from Cerrado, the Amazonia biome might be less affected by these policies. Panel 5-b examines the variation in elasticities across municipalities with differing shares of remaining forest suitable for soy cultivation. Municipalities with a higher proportion of such forest cover exhibit slightly lower elasticities. Consequently, demand-side policies may have a more modest impact on exports in these municipalities compared to those with less suitable for soy forest cover. Panel 5-c reveals an important insight: municipalities with higher above-ground carbon biomass exhibit both higher and more volatile elasticities (data from Englund et al. (2017)). This indicates that foreign demand reductions would have a larger impact on exports from carbon-rich areas, suggesting that these regions are more vulnerable to global demand fluctuations. Demand-side policies targeting these areas could therefore have a significant impact on reducing deforestation, as agricultural expansion in these regions appears closely tied to export markets. Finally, panel 5-d plots how potential export variations to demand have evolved over time. We observe a slight increase in elasticities: over time, changes in foreign demand are having progressively larger impacts on exports. This suggests that deforestation-free supply chains may be becoming more effective, though there remains significant year-to-year variability.

### 5.3 Avoided Deforestation

We now estimate avoided deforestation by combining export elasticities with the potential for soy expansion into forested areas. Indeed, the extent to which avoided exports translate into reduced deforestation can vary according to local conditions. In municipalities with limited remaining forest cover or low suitability for soybean cultivation, the potential for soy-related deforestation is inherently constrained.

Soy expansion potential is quantified as the share of remaining forest cover within each municipality, using 2023 MapBiomas data, that is also suitable for soy cultivation. To assess suitability, we rely on the GAEZ suitability maps (FAO and IIASA, 2024), also used in Heilmayr et al. (2020), which classify land into eight classes based on topographic, soil and climatic factors. In particular, we focus on the very high, high, good and medium suitability classes to identify areas where soybean cultivation is considered viable.

Figure 6 presents a spatial analysis of the potential for avoided deforestation across Brazilian municipalities, highlighting the relative contributions of export elasticity and remaining forest cover. Figure 6-left plots the hierarchy of the estimated avoided deforestation. Darker regions indicate higher potential for avoided deforestation.

Figure 6-right decomposes this index into the two components (shades of pink for exports elasticity and shades of green for soy expansion possibilities). A dark color indicates a high percentage of remaining suitable forest coupled with a high elasticity. This corresponds to areas where demand-side policies result in large avoided deforestation. This map reveals that many municipalities have a high potential

for avoided deforestation. These are mainly located in the Amazon biome. However, in certain localities, such as southern Mato Grosso or Matopiba, where forest cover remains high but export sensitivity is low, the potential for avoided deforestation is limited. In particular, municipalities with high levels of exports (Fig 3) exhibit high levels of avoided deforestation, but mainly because of the large suitable forest cover. This reinforces the importance of understanding the channels through which policymakers could affect both the land conversion process to produce soy as well as the exporter dynamics regarding this sector.

From a normative point of view, in a context where reducing deforestation is a global priority, the evidence on the effectiveness of demand-side policies is mixed. On the one hand, the expected effects appear to be larger in areas with high above-ground carbon biomass, suggesting that curbing demand for deforestation-prone commodities in these regions could lead to significant reductions in exports linked to deforestation. Additionally, the effects seem to be increasing over time, indicating that demand-side interventions are becoming progressively more effective in influencing export volumes and reducing deforestation. However, the effects in Cerrado—where soy production has been expanding rapidly— are highly dispersed, highlighting the potential effects of a more geographically targeted set of policies.

## 5.4 Limitations

Several limitations in our analysis must be acknowledged. First, the GAEZ data, based on meteorological, soil, and topographic factors, may underestimate the potential for soy cultivation in certain forest areas. It does not fully capture specific land management practices that could increase the suitability of locations for soy cultivation. Additionally, our model focuses on soy-related land use and does not account for competition with other crops or land uses, such as cattle ranching, which may also drive deforestation. Second, our model captures short-term responses to foreign demand shocks, but deforestation often occurs over a longer time horizon. The dynamics of land-use change may therefore not be fully captured in our analysis, which is based on historical data primarily characterized by growing soy demand. Instead, we capture the potential instantaneous effects of demand-side policies, leaving aside longer-run adjustments. Third, we observed a significant impact of the demand shock's origin on the results. Changes in demand have varying effects on exports depending on whether the demand originates from the EU or other countries. Therefore, policies aimed at reducing imports or curbing import growth may have different effects on exports depending on the source of the demand shock. Finally, the assumption that reduced foreign demand will have symmetrical effects as increased demand may not hold. Behavioral responses to shrinking demand could differ significantly from those observed during periods of growth.

## 6 Conclusion and Discussion

The current paper aims to assess the credibility of demand-side policies to curb deforestation. Are changes in consumer demand related to deforestation? To provide some insights on this important issue, we tackle this question focusing on the soy sector. Indeed, conversion from forests to soy-producing areas is a major driver of deforestation. We estimate a firm-level gravity model relating firm-municipality-destination export flows to destination-specific soy demand and to standard firm-level trade determinants.

Our analysis delivers the following conclusions. First, we estimate a positive average micro-level elasticity of soy exports to foreign demand, which confirms the credibility of demand-side policies. Second, we document that the average response hides significant heterogeneities across exporters and across municipalities in Brazil. Our analysis highlights (i) that the largest exporters are more sensitive to soy demand shocks, (ii) that higher past deforestation patterns reduces the response, and (iii) that the number of competitors in the same municipality also dampens the impact of demand. Third, we assess the potential benefits of the envisaged demand-side policies. In the cross-section of municipalities, export elasticities and soy expansion possibilities are positively correlated: places with high export response to demand are also places with a lot of remaining forests. Many municipalities have a high potential for avoided deforestation. These are mainly located in the Amazon region. However, in certain localities such as southern Mato Grosso or Matopiba, which still have significant forest cover, the weak response to exports suggests that the effects of a demand-driven policy would be lower. In light of these considerations, one may anticipate that demand-side policies may slow down deforestation in Brazil, particularly in regions proximate to the Amazon.

Estimating the effectiveness of demand-side policies remains challenging and warrants further investigation. The analysis carried out here does not consider general equilibrium effects, and the findings are contingent upon the assumption of symmetry between the impacts of rising and falling foreign demand. These aspects could be explored in future research projects to gain a more nuanced understanding of the dynamics surrounding demand-side policies and their implications for deforestation in tropical countries such as Brazil.

Finally, how to reduce import soy demand remains a challenging question. Increased meat and soy-based product consumption and population growth are fueling growth in soy demand worldwide and trends are not likely to reverse in the short-run. Additionally, substituting soy with local protein crops is still challenging and the search for alternatives requires attention to avoid creating additional environmental impacts.

# Tables and Figures

Figure 1: Soy trade flows, from BACI

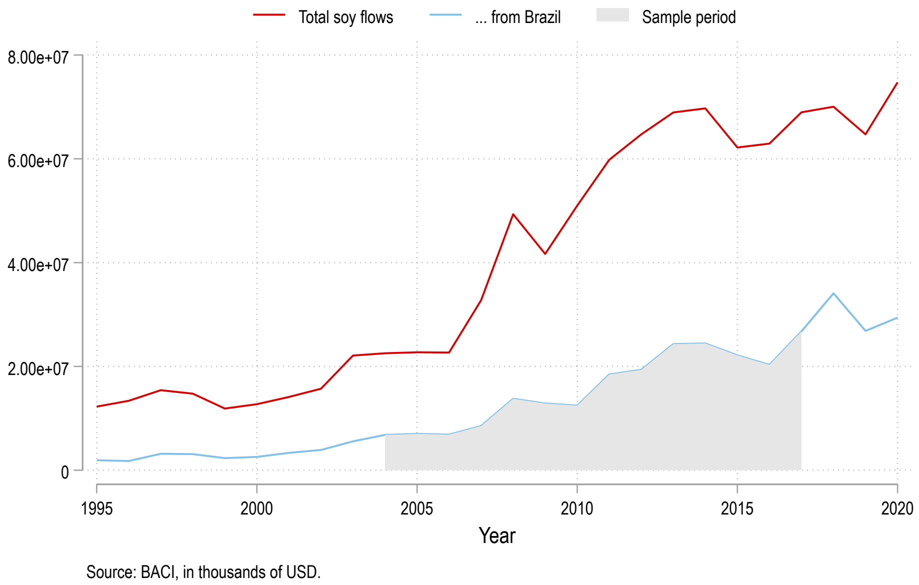
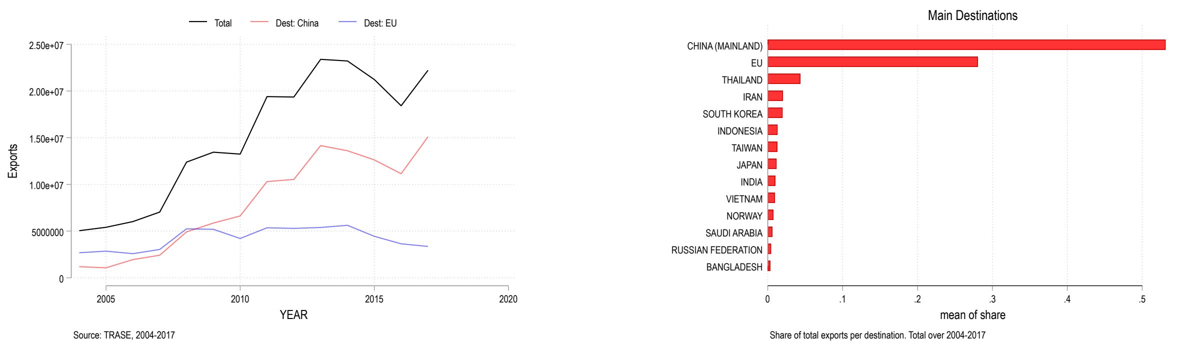


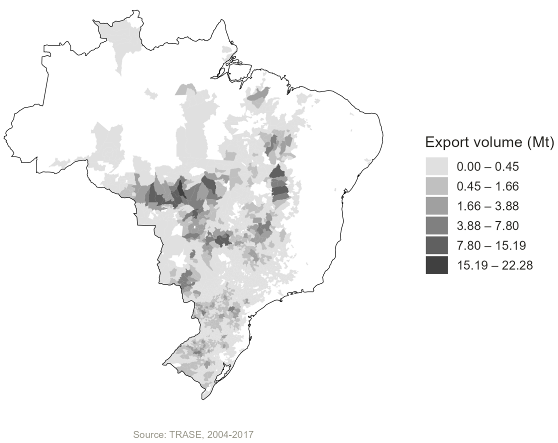

Figure 2: Brazilian Soybean Exports Destinations



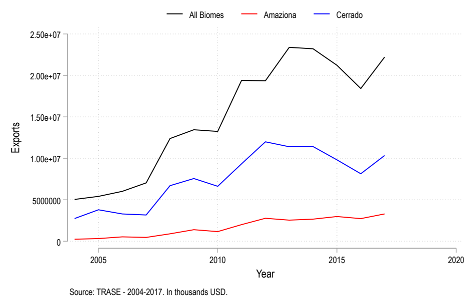

(a) Time-series of soybean exports

(b) Distribution of export destinations of soybeans

Figure 3: Geography of Soybean Exports in Brazil




(a) Map of soybean exports in Brazil




(b) Distribution of exports across biomes of origin

Figure 4: Average elasticities of exports in municipalities

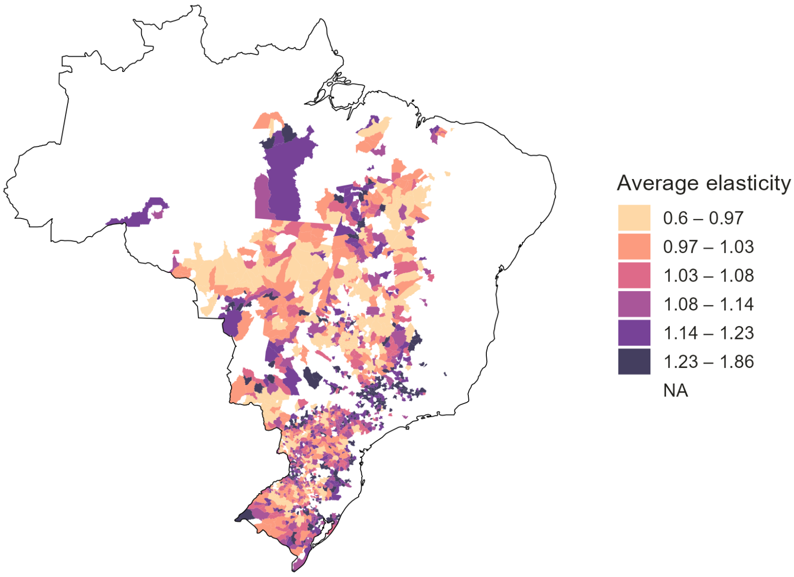
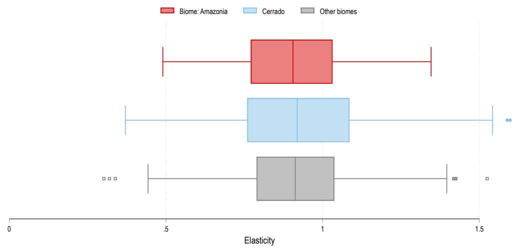
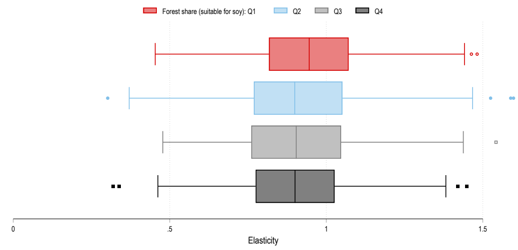


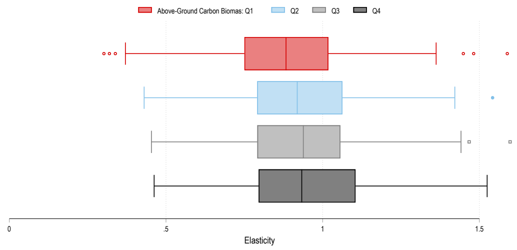
Figure 5: Heterogeneity in elasticity to exports based on biome, forest cover, carbon content, and over time.



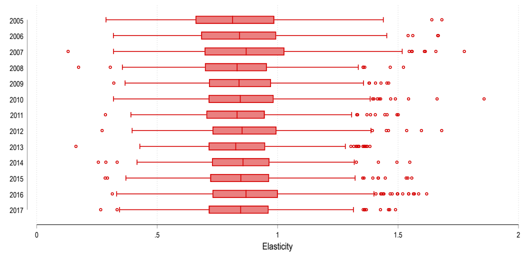

(a) Elasticity by biome




(b) Elasticity by forest cover




(c) Elasticity by carbon content (ABG)




(d) Elasticity across years

Figure 6: Potential of demand-side policies to avoid deforestation

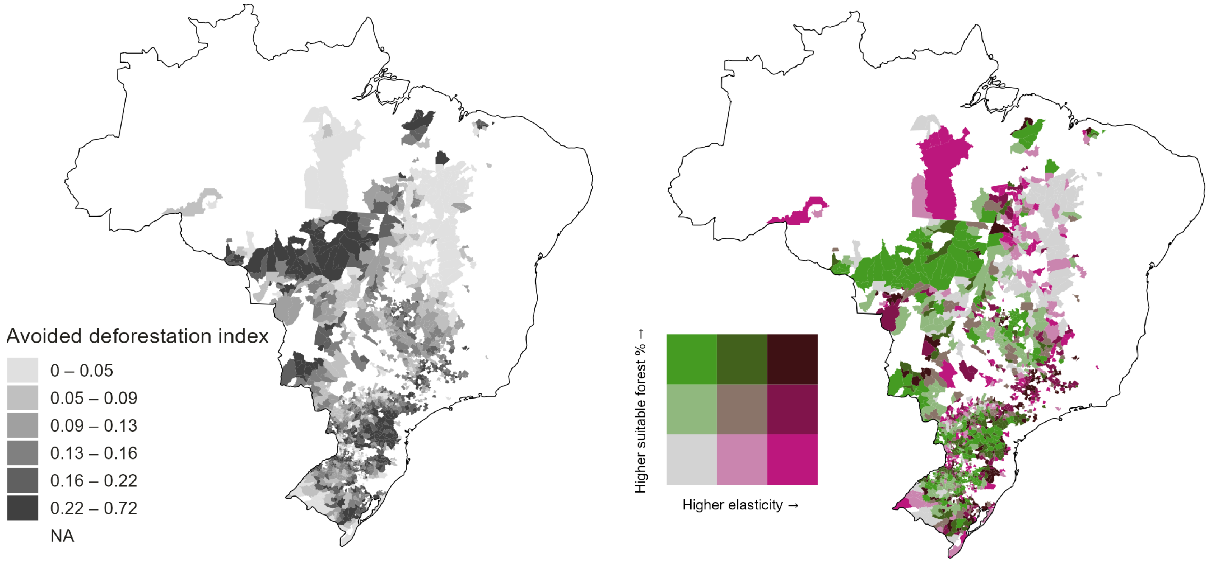


Table 1: Average Effects

| Dep. Variable: | Firm-level Exports ($X_{fmdt}$) | | | $1(X > 0)$ |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.404*** | 0.437*** | 0.243*** | 0.069*** |
| | (0.076) | (0.069) | (0.073) | (0.011) |
| Log Dest GDP p.c. | 1.514*** | 2.061*** | 1.754*** | 0.118*** |
| | (0.124) | (0.154) | (0.246) | (0.026) |
| Log. Dest. Pop. | 0.095 | 0.905 | -0.791 | 0.048 |
| | (0.729) | (0.728) | (0.706) | (0.116) |
| Observations | 200225 | 111087 | 56949 | 191364 |
| $R^2$ | | | 0.848 | 0.609 |
| Firm-Muni-Dest. FE | ✓ | ✓ | ✓ | ✓ |
| Firm-Muni-Year FE | | ✓ | ✓ | ✓ |
| Year FE | ✓ | | | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |
| Sample | Full | Full | Exports>0 | Full |
| Estimator | PPML | PPML | PPML | LPM |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 2: Heterogeneity across Firms

| | Dep. Variable: Firm-level Exports ($X_{fmdt}$) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Log Soy Demand × Log Firm Exports (t-1) | 0.055*** | | | | 0.058*** |
| | (0.009) | | | | (0.009) |
| Log Soy Demand × Log Nb Dest. (t-1) | | 0.096*** | | | |
| | | (0.023) | | | |
| Log Soy Demand × Log Nb Sources (t-1) | | | 0.052*** | | |
| | | | (0.010) | | |
| Log Soy Demand × Dtop4 | | | | 0.106*** | |
| | | | | (0.025) | |
| Log Soy Demand × Storage | | | | | -0.637*** |
| | | | | | (0.182) |
| Log Soy Demand × Crushing | | | | | -0.403*** |
| | | | | | (0.055) |
| Observations | 21769 | 21769 | 21769 | 23929 | 21769 |
| Muni-Dest.-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ |
| Firm-Muni-Year FE | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table 3: Heterogeneity across Municipalities

| | Dep. Variable: Firm-level Exports ($X_{fmdt}$) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand × Log GDP 2004 | -0.031*** | -0.018 | -0.020 | -0.004 |
| | (0.012) | (0.011) | (0.019) | (0.019) |
| Log Soy Demand × Log Population (city) (t-1) | 0.031*** | 0.019 | 0.025 | -0.000 |
| | (0.012) | (0.012) | (0.019) | (0.018) |
| Log Soy Demand × Log Distance to Port | | -0.053*** | -0.024 | 0.012 |
| | | (0.016) | (0.019) | (0.020) |
| Nb Top 4 firms (t-1) | | | 2.246*** | 2.007*** |
| | | | (0.284) | (0.297) |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.113*** | -0.098*** |
| | | | (0.019) | (0.019) |
| Log Soy Demand × Deforestation (t-1) (Mapbiomas) | | | | -0.007*** |
| | | | | (0.001) |
| Log Soy Demand × Deforestation (t-1) (Mapbiomas) | | | | -0.008*** |
| | | | | (0.002) |
| Observations | 133938 | 133938 | 46228 | 37569 |
| Firm-Dest.-Year FE | ✓ | ✓ | ✓ | ✓ |
| Muni.-Year FE | ✓ | ✓ | ✓ | ✓ |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 4: Heterogeneity across Destinations

| | Dep. Variable: Firm-level Exports ($X_{fmdt}$) | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.434*** | 0.608*** | 0.610*** | 1.582*** |
| | (0.069) | (0.095) | (0.095) | (0.452) |
| Log Dest GDP p.c. | 1.930*** | 1.765*** | 1.789*** | 3.443*** |
| | (0.229) | (0.171) | (0.237) | (0.795) |
| Log. Dest. Pop. | 0.983 | 0.345 | 0.325 | 0.433 |
| | (0.741) | (0.752) | (0.761) | (0.750) |
| Log Soy Demand × China | 0.080 | | -0.016 | 0.023 |
| | (0.149) | | (0.151) | (0.161) |
| Log Soy Demand × EU | | -0.324*** | -0.327*** | -0.170 |
| | | (0.111) | (0.110) | (0.134) |
| Log Soy Demand × Log Dest GDP p.c. | | | | -0.105** |
| | | | | (0.049) |
| Observations | 111087 | 111087 | 111087 | 111087 |
| Firm-Muni-Dest. FE | ✓ | ✓ | ✓ | ✓ |
| Firm-Muni-Year FE | ✓ | ✓ | ✓ | ✓ |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

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# Appendix (Not for Publication)

Foreign Demand and Soy Exports: Evidence and Implications for Deforestation

## A Robustness: Tables

Table A.1: Alternative measure of demand

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.436*** | | | 1.913*** |
| | (0.069) | | | (0.394) |
| Log Dest. GDP p.c. | 2.063*** | | | 4.260*** |
| | (0.154) | | | (0.638) |
| Log. Dest. Pop. | 0.906 | | | 0.646 |
| | (0.728) | | | (0.704) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.009) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.004 | |
| | | | (0.019) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.000 | |
| | | | (0.018) | |
| Log Soy Demand × Log Distance to Ports | | | 0.012 | |
| | | | (0.020) | |
| Nb Top 4 firms (t-1) | | | 2.007*** | |
| | | | (0.297) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.098*** | |
| | | | (0.019) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.001) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.008*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.147*** |
| | | | | (0.039) |
| Observations | 111087 | 21769 | 37569 | 111087 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.2: Soy Imports Values as Demand

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Imports (Value) | 0.434*** | | | 1.913*** |
| | (0.069) | | | (0.394) |
| Log Dest. GDP p.c. | 2.065*** | | | 4.264*** |
| | (0.154) | | | (0.638) |
| Log. Dest. Pop. | 0.913 | | | 0.653 |
| | (0.728) | | | (0.704) |
| Log Soy Imports (Value) × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.009) | | |
| Log Soy Imports (Value) × 2004-GDP (municipality) | | | -0.004 | |
| | | | (0.019) | |
| Log Soy Imports (Value) × Log Population (municipality) (t-1) | | | -0.000 | |
| | | | (0.018) | |
| Log Soy Imports (Value) × Log Distance to Ports | | | 0.012 | |
| | | | (0.020) | |
| Nb Top 4 firms (t-1) | | | 2.007*** | |
| | | | (0.297) | |
| Log Soy Imports (Value) × Nb Top 4 firms (t-1) | | | -0.098*** | |
| | | | (0.019) | |
| Log Soy Imports (Value) × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.001) | |
| Log Soy Imports (Value) × Deforestation (t-2) (Mapbiomas) | | | -0.008*** | |
| | | | (0.002) | |
| Log Soy Imports (Value) × Log Dest. GDP p.c. | | | | -0.147*** |
| | | | | (0.039) |
| Observations | 111089 | 21769 | 37569 | 111089 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.3: Soy Imports (Quantities) as Demand

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Imports (Q) | 0.345*** | | | 2.034*** |
| | (0.058) | | | (0.400) |
| Log Dest. GDP p.c. | 2.173*** | | | 4.872*** |
| | (0.148) | | | (0.628) |
| Log. Dest. Pop. | 1.299* | | | 0.838 |
| | (0.719) | | | (0.699) |
| Log Soy Imports (Q) × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.009) | | |
| Log Soy Imports (Q) × 2004-GDP (municipality) | | | -0.006 | |
| | | | (0.019) | |
| Log Soy Imports (Q) × Log Population (municipality) (t-1) | | | 0.001 | |
| | | | (0.017) | |
| Log Soy Imports (Q) × Log Distance to Ports | | | 0.014 | |
| | | | (0.019) | |
| Nb Top 4 firms (t-1) | | | 2.019*** | |
| | | | (0.312) | |
| Log Soy Imports (Q) × Nb Top 4 firms (t-1) | | | -0.094*** | |
| | | | (0.019) | |
| Log Soy Imports (Q) × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.001) | |
| Log Soy Imports (Q) × Deforestation (t-2) (Mapbiomas) | | | -0.007*** | |
| | | | (0.002) | |
| Log Soy Imports (Q) × Log Dest. GDP p.c. | | | | -0.166*** |
| | | | | (0.038) |
| Observations | 111089 | 21769 | 37569 | 111089 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.4: Firm-level exports in Quantities

| | Dep. Variable: Firm-level Exports Volumes Q. | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.411*** | | | 1.840*** |
| | (0.068) | | | (0.424) |
| Log Dest. GDP p.c. | 2.163*** | | | 4.234*** |
| | (0.182) | | | (0.712) |
| Log. Dest. Pop. | 0.896 | | | 0.693 |
| | (0.750) | | | (0.725) |
| Log Soy Demand × Log Firms Exports (t-1) | | 0.048*** | | |
| | | (0.009) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.006 | |
| | | | (0.019) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.004 | |
| | | | (0.018) | |
| Log Soy Demand × Log Distance to Ports | | | 0.014 | |
| | | | (0.020) | |
| Nb Top 4 firms (t-1) | | | 2.041*** | |
| | | | (0.321) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.099*** | |
| | | | (0.021) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.001) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.007*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.141*** |
| | | | | (0.042) |
| Observations | 111087 | 21769 | 37569 | 111087 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.5: Unit Values

| | Dep. Variable: Firm-level: Unit Value | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.018* | | | 0.141** |
| | (0.010) | | | (0.055) |
| Log Dest. GDP p.c. | -0.053** | | | 0.129 |
| | (0.026) | | | (0.084) |
| Log Soy Demand × Log Firm Exports (t-1) | | -0.004*** | | |
| | | (0.001) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.000 | |
| | | | (0.001) | |
| Log Soy Demand × Log Populatoon (municipality) (t-1) | | | -0.000 | |
| | | | (0.001) | |
| Log Soy Demand × Log Distance to Ports | | | -0.013*** | |
| | | | (0.003) | |
| Nb Top 4 firms (t-1) | | | 0.062 | |
| | | | (0.047) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.004 | |
| | | | (0.003) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.000 | |
| | | | (0.000) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | 0.000 | |
| | | | (0.000) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.012** |
| | | | | (0.005) |
| Observations | 56949 | 8633 | 15646 | 56949 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.6: OLS

| | Dep. Variable: log Firm-level Exports | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.243*** | | | 0.531 |
| | (0.073) | | | (0.459) |
| Log Dest. GDP p.c. | 1.754*** | | | 2.166*** |
| | (0.246) | | | (0.706) |
| Log. Dest. Pop. | -0.791 | | | -0.806 |
| | (0.706) | | | (0.712) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.049*** | | |
| | | (0.009) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | 0.024 | |
| | | | (0.018) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.025 | |
| | | | (0.018) | |
| Log Soy Demand × Log Distance to Ports | | | 0.004 | |
| | | | (0.024) | |
| Nb Top 4 firms (t-1) | | | 1.023** | |
| | | | (0.435) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.046 | |
| | | | (0.029) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.004*** | |
| | | | (0.001) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.004*** | |
| | | | (0.001) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.029 |
| | | | | (0.046) |
| Observations | 56949 | 8633 | 15646 | 56949 |
| $R^2$ | 0.848 | 0.794 | 0.727 | 0.848 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level: Destination-Year | ✓ | ✓ | ✓ | ✓ |

OLS estimations. Standard errors in parentheses.

* p<0.1, ** p<0.05, *** p<0.01

Table A.7: Alternative clustering: municipality-year

| | Dep. Variable: Firm-level Exports | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.437*** | | | 1.913*** |
| | (0.045) | | | (0.303) |
| Log Dest. GDP p.c. | 2.061*** | | | 4.258*** |
| | (0.118) | | | (0.437) |
| Log. Dest. Pop. | 0.905* | | | 0.645 |
| | (0.470) | | | (0.453) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.008) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.004 | |
| | | | (0.023) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.000 | |
| | | | (0.023) | |
| Log Soy Demand × Log Distance to Ports | | | 0.012 | |
| | | | (0.024) | |
| Nb Top 4 firms (t-1) | | | 2.007*** | |
| | | | (0.454) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.098*** | |
| | | | (0.030) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.002) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.008*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.147*** |
| | | | | (0.030) |
| Observations | 111087 | 21769 | 37569 | 111087 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level | by municipality-year | | | |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.8: Two-way clustering: municipality-year + destination-year

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.437*** | | | 1.913*** |
| | (0.073) | | | (0.435) |
| Log Dest. GDP p.c. | 2.061*** | | | 4.258*** |
| | (0.169) | | | (0.679) |
| Log. Dest. Pop. | 0.905 | | | 0.645 |
| | (0.739) | | | (0.712) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.010) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.004 | |
| | | | (0.025) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.000 | |
| | | | (0.025) | |
| Log Soy Demand × Log Distance to Ports | | | 0.012 | |
| | | | (0.026) | |
| Nb Top 4 firms (t-1) | | | 2.007*** | |
| | | | (0.402) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.098*** | |
| | | | (0.027) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.002) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.008*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.147*** |
| | | | | (0.043) |
| Observations | 111087 | 21769 | 37569 | 111087 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level | by municipality-year and destination-year | | | |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.9: Alternative clustering: by logistic hub-year

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.172*** | | | 1.048*** |
| | (0.051) | | | (0.381) |
| Log Dest. GDP p.c. | 1.877*** | | | 3.163*** |
| | (0.142) | | | (0.553) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.044*** | | |
| | | (0.008) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | 0.026 | |
| | | | (0.019) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | 0.001 | |
| | | | (0.021) | |
| Log Soy Demand × Log Distance to Ports | | | 0.076*** | |
| | | | (0.024) | |
| Nb Top 4 firms (t-1) | | | 1.359*** | |
| | | | (0.387) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.066*** | |
| | | | (0.026) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.005*** | |
| | | | (0.002) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.006*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.086** |
| | | | | (0.037) |
| Observations | 56949 | 8633 | 15646 | 56949 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level | by logistic hub - year | | | |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

Table A.10: Alternative clustering: twoway firm and destination

| | Dep. Variable: Firm-level Exports Values | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Log Soy Demand | 0.437** | | | 1.913*** |
| | (0.195) | | | (0.432) |
| Log Dest. GDP p.c. | 2.061*** | | | 4.258*** |
| | (0.291) | | | (0.361) |
| Log. Dest. Pop. | 0.905 | | | 0.645 |
| | (1.144) | | | (1.135) |
| Log Soy Demand × Log Firm Exports (t-1) | | 0.055*** | | |
| | | (0.016) | | |
| Log Soy Demand × 2004-GDP (municipality) | | | -0.004 | |
| | | | (0.043) | |
| Log Soy Demand × Log Population (municipality) (t-1) | | | -0.000 | |
| | | | (0.030) | |
| Log Soy Demand × Log Distance to Ports | | | 0.012 | |
| | | | (0.026) | |
| Nb Top 4 firms (t-1) | | | 2.007*** | |
| | | | (0.244) | |
| Log Soy Demand × Nb Top 4 firms (t-1) | | | -0.098*** | |
| | | | (0.014) | |
| Log Soy Demand × Deforestation (t-1) | | | -0.007*** | |
| | | | (0.002) | |
| Log Soy Demand × Deforestation (t-2) (Mapbiomas) | | | -0.008*** | |
| | | | (0.002) | |
| Log Soy Demand × Log Dest. GDP p.c. | | | | -0.147*** |
| | | | | (0.034) |
| Observations | 111087 | 21769 | 37569 | 111087 |
| Firm-Muni.-Year FE | ✓ | ✓ | | ✓ |
| Firm-Muni.-Dest FE | ✓ | | | ✓ |
| Firm-Dest.-Year FE | | | ✓ | |
| Muni.-Dest.-Year FE | | ✓ | | |
| Muni.-Year FE | | | ✓ | |
| Cluster Level | twoway: firm and destination | | | |

Standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01