Import processing zones, tools for regional integration? The case of the free trade zone of Manaus (Brazil)

NJIKE, ARNOLD

Université Paris Dauphine

17 December 2019

Import Processing zones : Tools for regional economic integration ? The case of the Free Trade Zone of Manaus (Brazil)

Arnold NJIKE

arnold.njike-oya@dauphine.eu

Université Paris Dauphine, PSL Research University, LEDA, DIAL,75016 Paris, France

December 15, 2019

Abstract: Characterised by low-quality transport infrastructures and located quite far from the country economic centre, the Amazonian region in Brazil was almost wholly disconnected from the rest of the country for several decades. In conjunction with other factors, this motivated the creation of a Free Trade Zone in the region by Brazilian authorities to foster economic linkages with the country's other states. We examine in this article whether this challenging goal of connecting an isolated region marked by low-quality transport infrastructures to a distant economic centre has been accomplished and if the Free Trade Zone (FTZ) has played a role in the process. Using a gravity model to assess each Brazilian state trade performance and level of trade costs, we found that the two entities representing the state of Amazonas (Manaus where the Free Trade Zone is implanted and the rest of Amazonas) were among the most effective intra-national exporters in Brazil in 2008 despite facing the highest level of trade costs in the country. These apparently counter-intuitive findings indicate a potentially significant role of the FTZ in this process of integration.

Keywords: stochastic frontier analysis, regional integration, trade costs, Import processing zones

JEL classification code : F150

1 Introduction

The world economy as of today is characterised by the prominence of international trade flows that have increased considerably in the last 30 years. As attested by the extensive literature on this subject pioneered by Tinbergen (1962), the pattern of bilateral trade flows depends on the economic size of the two trading partners. However, it is subjected to substantial and varied impediments, ranging from man-made restrictions to geographical barriers. Limao and Venables (2001) insisted on the role of infrastructures and "landlockedness", showing that a representative landlocked country will trade approximately 60 % less than a median coastal economy. They also showed that the poor performance of African countries in their intra-national or international exports could be explained solely by the bad quality of their infrastructures.

The Amazonian region in Brazil is subjected to these strong impediments. Located quite far from the economic centre of the country and not very well served by the low-quality Brazilian transport network, this region has experienced a lot of difficulties, especially with the rubber production decline at the beginning of the 20th century. Despite Brazilian authorities' efforts, this remote zone with low population density was almost wholly disconnected from the rest of the country, a real problem because of its size and substantial wealth in natural resources. Besides its increasingly widespread perception as an ecological reserve for humanity by the international community throughout time could have been detrimental to Brazil sovereignty in this region (Nunes, 1990). It explains the various policies implemented from the thirties until today to connect it with the rest of the country, consolidate the sovereignty of Brazil and therefore preserve this geostrategic asset.

Among these policies, the creation of the Free Trade Zone of Manaus in 1957 (ZFM) is of great importance. The official objective of this zone effectively implemented in 1967 was twofold as stated by SUFRAMA (Superintendancia de la Zona Franca de Manaus). Create an economic hub in West Amazonia and promote socioeconomic integration with the rest of Brazilian states to reduce the regional disparities and guarantee the country's national sovereignty on its whole territory. As we can imagine, these objectives are very challenging, especially socioeconomic integration which implies connecting an isolated region to a distant economic centre knowing that the transport network is far from excellent. It is therefore very interesting for at least three reasons to determine whether this goal has been accomplished and if the Free Trade Zone (FTZ) played a role in the process.

First of all, a lot of regions in the world are in this situation, that is to say with low-quality transport infrastructures and trying most of the time unsuccessfully to stimulate the level of their international and intra-regional trade integration by different means. Some authors, as well as international organisations, promote the somewhat natural solution of improving the quality of transport infrastructures to stimulate their exports. However, this solution could be quite expensive, especially in some regions where the lack of infrastructures is very pronounced. For example, Buys et al. (2006) estimated that upgrading the level of the transport network in Africa for overland trade to an acceptable level would require about $20 billion for initial upgrading and $1 billion annually for maintenance. On top of the fact that these improvements probably need a lot of time to be efficiently implemented because of coordination matters or other considerations, the amounts mentioned above are quite important and raise the question of their opportunity in comparison to the expected trade benefits only. If there is an alternative solution that could stimulate trade in the short to medium term at a reasonable cost before the implementation of these necessary improvements, it could be very interesting for the concerned countries.

Secondly, the theoretical and empirical literature on FTZs has focused on export processing zones (EPZs) which most of the time impose restrictions on domestic sales. The case of (ZFM) is quite different since local sales have been widely encouraged by tax incentives following the objectives detailed above. Thus, this FTZ has been excluded from several empirical analyses because of its alleged inward orientation.

Finally, as explained by Madani (1999) the locational choice of a Free Trade Zone is an essential factor of success. According to him, a lot of Free Trade Zones failed to accomplish their goals like the "Zone Franche d'Inga" in former Zaire or the Puerto Limon Zone on Costa Rica's Atlantic/Caribbean coast because of a poor locational choice as it is the case for the Free Trade Zone of Manaus. It is therefore very interesting to determine whether in these particular conditions the ZFM succeeded or at least contributed to the improvement of the state of Amazonas economic linkages with the rest of Brazilian states.

Yücer et al. (2014) provide preliminary insights on this matter. Questioning the existence of internal vertical specialization in the Brazilian production system, they show that the state of Amazonas is quite well connected to the rest of the country. Precisely, they show that this state presents the highest import content from other Brazilian states in its international exports, and also exports more indirectly than directly its value-added notably through other Brazilian states. As interesting as these results are, they unfortunately do not provide insights on the singular role of Manaus to explain this phenomenon, nor on the existence of a potential catalytic effect of Manaus on the Rest of Amazonas.

To solve this problem, we use a data set developed by Guilhoto (2014) that separates the state of Amazonas in two entities, Manaus and the rest of Amazonas. Instead on relying upon input-output analysis as Yücer et al. (2014), we provide answers to our questions by using a gravity model that helps us to determine the real level of trade costs faced by each state or entity in its trade relationships and also to derive different measures of trade performance. We notably calculate the intensity of intra-national trade with respect to the benchmark for international trade regarding each Brazilian entity; and derive using stochastic frontier analysis a measure of bilateral export efficiency for these states.

Our results suggest that Manaus and the Rest of Amazonas present the highest level of trade costs among Brazilian states, but despite this, are among the most efficient intra-national exporters in Brazil. Their trade performance scores are indeed among the highest of the set of Brazilian states. It is therefore plausible that the Free Trade Zone of Manaus is the missing link to explain this situation. This idea is not devoid of sense since we found evidence using stochastic frontier analysis that a high percentage of manufactured value-added in comparison to total value-added has a positive effect on export efficiency. The fact that Manaus presents the highest manufactured value-added as a percentage of GDP in Brazil (a value-added principally attributable to the firms of the FTZ) supports this idea.

The main contribution of this paper is, therefore, to rigorously show that Manaus and the Rest of Amazonas are among the most efficient intra-national exporters in Brazil, this suggesting that a good set of tax incentives can offset the disadvantages associated with remoteness and high transport costs, and substantially stimulate a given country exports. It also enriches the conclusions of Yücer et al. (2014) by providing insights on the singular role of the Free Trade Zone of Manaus to explain this phenomenon.

The remainder of this paper is organised as follows. Section 2 presents the ZFM and its system of tax incentives before going to its economic results. In section 3, we slightly modify the Anderson and Van Wincoop structural gravity model to suit our problem and present different estimations methods with an emphasis put upon stochastic frontier analysis. Section 4 and 5 are devoted to the results and section 6 to some concluding remarks.

2 The Free Trade Zone of Manaus, specificities and economic results

The concept of Free Trade Zone may have different meanings and refer to different situations depending on the objectives and policies established by the government that builds them. They can nevertheless be defined broadly as geographical areas within the borders of a country where regulation is more business-friendly than in the rest of the national territory according to Farole and Akinci (2011). These rules concern especially the investment climate, customs duties and taxes or international trade.

In most cases, FTZs around the world are export-oriented. The Free Trade Zone of Manaus however does not seem to abide by this trend since the stylized facts show a concentration of its sales in the Brazilian market. The fact that contrarily to most EPZs across the world which have restricted access to the internal markets of their host countries, the one of Manaus is also set to stimulate trade relationships with the other Brazilian states by mean of a wide range of incentives could be an explanation. This is a fundamental distinction, which led Johansson and Nilsson (1997) to brand it an "Import Processing Zone".

Precisely, the incentives granted to ZFM can be divided into two main categories: federal incentives, and state level incentives. The first are the most important in value and have to do with custom duties and legal entities income tax, but also some Brazilian specific taxes as the tax on industrial products or some social contributions. For example, in 2008, these incentives reached $R 14 billion, approximately 16% of the total amount of tax incentives provided by the Brazilian government to the entire country according to the finance department. It represented nearly one-third of Manaus GDP in 2008 which was R$ 38 billion (IBGE).

State level incentives are weaker but significant enough to be mentioned. The main incentive is a tax called ICMS (Imposto sobre circulação de mercadorias e prestação de serviços), a value-added tax perceived by each state and which is the primary source of tax revenues for many of them. In 2008, the state of Amazonas renounced to R$ 3 billion of ICMS revenues but collected R$ 4.6 billion, about 70 % of the state budget revenue. It is R$ 500 million more than the ICMS collected by the state of Para whose GDP was R$ 58 billion at the same time, and which do not provide the same level of ICMS incentives to its firms. The tax incentives effect on the state revenue therefore appears to be more than compensated by its effect on firms' activity in Amazonas.

With all these tax incentives, the results of the FTZ are noteworthy, particularly regarding foreign direct investment, production or employment. We can see it in figure 1 which presents the evolution of some economic indicators of the industrial pole of Manaus, 2000 being the year of reference. It shows a strong progression of FDI, with a six-fold increase from $ 1021 million in 2000 to $ 6688 million in 2010. Besides, even if this figure is not shown in the chart, they represented 60% of total investment (TDI) in the industrial pole of Manaus in this period, a clear indicator of the attractiveness of the FTZ for

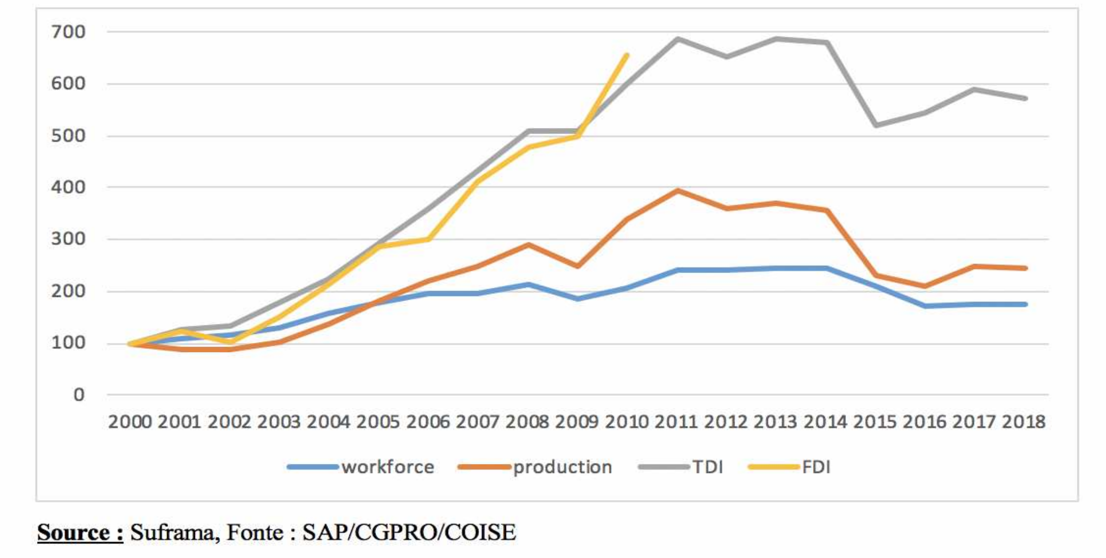


Figure 1: Evolution of some economic indicators of the industrial pole of Manaus (PIM) (Base 100 in 2000)

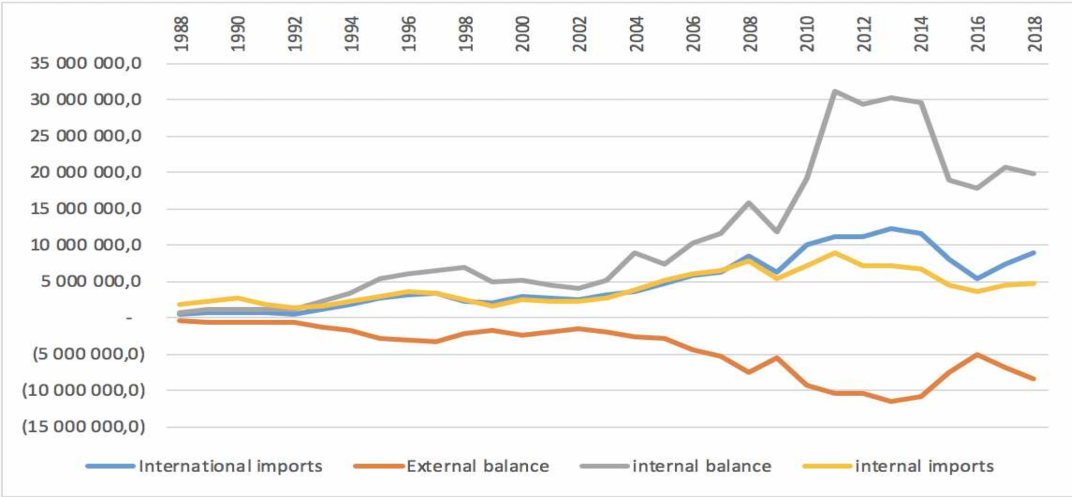
international firms.

After 2010, the data on FDI are not reported any more by SUFRAMA, but as we can see, total investment remained approximately the same until 2014 before a steep decline related to a political turmoil in the country. Just as foreign direct investments, the industrial pole of Manaus (PIM) production increased steeply in the early 2000s after a brief decline a few years before. It has thus quadrupled between 2000 and 2011 from $ 10 billion to $ 41 billion, what has also been felt on employment. These figures are quite exceptional and reflect the success of PIM.

They are however tarnished by the political instability and economic crisis experimented by Brazil from 2014 to 2016. In fact, the Brazilian GDP decreased by 3.54 % and 3.3 % respectively for 2015 and 2016 and increased only by 0.5 % in 2014. Our figures show that this crisis severely affected investment, production and employment in PIM with a 35 % decrease of production in US $ between 2014 and 2015 and a 25% decrease of total investment.[1] It has also been felt on PIM exports to the rest of the country with a 40 % decrease of the internal balance surplus as shown in figure 2.

The figure presents PIM's internal and external trade balance for the period 1988/2018 in thousands dollar and shows that the increase in production since 2000 or earlier did not result in a proportional increase of PIM external exports. Even if they grew, they remained well below exports to the rest of Brazil which sharply soared as illustrated in

[1] The decline is however less pronounced in the Brazilian currency than in dollar as we could expect.



Source : Suframa, Fonte : SAP/CGPRO/COISE

Figure 2: PIM's internal and external trade balance ($ US 1000))

the chart. It is shown in particular that the foreign trade deficit and international imports were almost of the same scale, which suggests weak international exports.

Despite the recent disappointing results related to the political instability in Brazil, these stylized facts suggest that Manaus, a municipality which represents 80% of Amazonas GDP is an outstanding performer in term of intra-national exports with the help of PIM, at least relative to international exports. However, without a comparison with other Brazilian states, it is quite difficult to determine whether the goal of socioeconomic integration with the rest of the country has been satisfactorily achieved for the state of Amazonas. To clarify this matter, a gravity model can be used to assess each Brazilian state export performance.

3 Model specification

The gravity model has been widely used in the economic literature to explain bilateral trade relationships and has become the standard workhorse for doing so because of its empirical success. It has many uses that range from counterfactual simulation analysis to the assessment of countries' trade performance. It is for this latter use that we decided to work with this model. We want to assess each Brazilian state trade performance, Manaus and the Rest of Amazonas being considered as states, in order to decide whether these two entities export performance is similar to other Brazilian states and good enough to achieve socio-economic integration with the rest of the country.

Measuring trade performance has generally been done by deriving measures of trade potentials from the difference between predicted trade flows (that is to say by the empirical model) for each bilateral relationship, and flows that actually occurred. This kind of measures can be helpful to determine for example whether Amazonas exports are in line with those of other Brazilian states. However, this method has driven some criticism from Egger (2002), regarding the inappropriateness of in-sample projections of trade potentials. He argued that a well-specified model should not present systematic differences between observed and in-sample predicted trade flows. De Benedictis and Vicarelli (2005) took Egger's remark a step further noting that out-of-sample predictions also are not immune to the eventuality of misspecification of the estimated model since the potential bias in the coefficients is also transmitted to the out-of-sample predicted flows. In other words, the trade potentials predicted for countries that were not in the sample originally used to obtain the parameters of the model will also be affected by the bias inherent to these parameters. To avoid these considerations, we use a different strategy than the calculation of trade potentials to obtain our measures of trade performance. Doing so requires a slight modification of Anderson and Van Wincoop (2003) structural gravity model.

3.1 The structural gravity Model

Despite the empirical success of the gravity model to explain bilateral trade, it has been criticized for a long time because of its lack of theoretical underpinnings. Many attempts have been made to address this problem beginning with Anderson (1979) or Bergstrand (1989) although the complexity of their models impeded their use as an everyday toolkit for trade economists. An essential contribution of Anderson and Van Wincoop (2003) simplified the expressions derived in the previous works, therefore allowing the thus theoretically founded gravity model to be used with more ease as a workhorse for trade economists. One of this work core added values is the demonstration of the relative trade costs importance in the explanation of bilateral trade. This is based on the idea that for a given bilateral barrier between two regions, say A and B for example, a rise of trade barriers with all other trading partners for A decreases the relative trade cost for B and thus increase trade between them. This justifies the integration of what they called multilateral resistance indexes (MR) in the gravity model and thus prevents the gold medal mistake mentioned by Baldwin and Taglioni (2006), generally observed in previous works on the estimation of this equation.

Anderson and Van Wincoop's model has the following form:

$$X_{ij} = \frac{Y_i Y_j}{Y_w} \left(\frac{T_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \quad (1)$$

With $P_j^{1-\sigma} = \sum_i \frac{Y_i}{Y_w} \frac{T_{ij}^{1-\sigma}}{\Pi_i^{1-\sigma}}$ (2)

And $\Pi_i^{1-\sigma} = \sum_j \frac{Y_j}{Y_w} \frac{T_{ij}^{1-\sigma}}{P_j^{1-\sigma}}$ (3)

And where Y_w is the world GDP, Y_i and Y_j respectively the GDP's and expenditures of countries i and j and T_{ij} the trade costs factor between the two countries. $1 - \sigma < 1$ is the trade costs elasticity, and Π_i and P_j represent the exporter and importer outward and inward multilateral resistance terms respectively. This model stems from a problem of maximisation under constraints. To address our specific question, we derive a similar kind of model. Specifically, we have the following utility function:

$$\left(\sum_i \beta_{ij}^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

subject to the budget constraint:

$$\sum_i p_{ij} c_{ij} = Y_j \tag{5}$$

Where c_{ij} is the consumption of region i goods by region j, p_{ij} the price of region i goods for region j consumers and $\beta_{ij} = \alpha_i \gamma_{ij}$ a positive distribution parameter. Contrarily to AVW, we assume that this parameter is composed of an idiosyncratic component α_i and a bilateral component γ_{ij} instead of being solely specific to i. This assumption of bilateral preferences is also made by authors as Combes et al. (2005) or Costinot and Rodríguez-Clare (2014). However, as in the original AVW article, $p_{ij} = p_i t_{ij}$ where p_i is the exporter's supply price net of trade costs and t_{ij} the trade cost factor between i and j. The nominal value of exports from i to j is therefore $x_{ij} = p_{ij} c_{ij}$ and the total income of region i which stems from the market clearing condition is $Y_i = \sum_j p_{ij} c_{ij}$. A simple maximisation of the utility function under the budget constraint yields:

$$x_{ij} = \frac{(\beta_{ij} p_i t_{ij})^{1-\sigma} Y_j}{P_j^{1-\sigma}} \tag{6}$$

With $P_j^{1-\sigma} = \sum_i (\beta_{ij} p_i t_{ij})^{1-\sigma}$ (7)

The market clearing condition implies that:

$$Y_i = \sum_j \frac{(\beta_{ij} p_i t_{ij})^{1-\sigma} Y_j}{P_j^{1-\sigma}} \tag{8}$$

As AVW, we solve for the scaled price $\alpha_i p_i$. It follows that:

$$(\alpha_i p_i)^{1-\sigma} = \frac{Y_i}{\sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j}\right)^{1-\sigma} Y_j} \tag{9}$$

$$= \frac{Y_i}{Y_w \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j}\right)^{1-\sigma} \frac{Y_j}{Y_w}}$$

$$= \frac{Y_i}{Y_w \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j}\right)^{1-\sigma} \theta_j}$$

with $\theta_j = \frac{Y_j}{Y_w}$ and $Y_w = \sum_j Y_j$ the world income.

By defining $${\Pi_i}^{1-\sigma} = \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j}\right)^{1-\sigma} \theta_j \tag{10}$$

We get: $(\alpha_i p_i)^{1-\sigma} = \frac{\theta_i}{{\Pi_i}^{1-\sigma}}$ and thus,

$$P_j^{1-\sigma} = \sum_i \left(\frac{\gamma_{ij} t_{ij}}{\Pi_i}\right)^{1-\sigma} \theta_i \tag{11}$$

Finally, we obtain:

$$x_{ij} = \frac{Y_i \, Y_j}{Y_w} \left(\frac{\gamma_{ij} t_{ij}}{\Pi_i \, P_j}\right)^{1-\sigma} \tag{12}$$

which is the Anderson and Van Wincoop's structural gravity equation scaled by the parameter ${\gamma_{ij}}^{1-\sigma}$. This parameter plays a prominent role in our model as it represents a bilateral preference that region j has on region i goods, or said differently region i's effectiveness in selling its goods to region j. Its range is [0,1[such that the more region j appreciates region i goods, the closer is ${\gamma_{ij}}^{1-\sigma}$ to 1 and inversely.

3.2 Empirical strategy

Given its nonlinear nature, many authors estimate a log-linear version of this equation. It gives:

$$\ln X_{ij} = \ a_0 + a_1 \ln Y_i + a_2 \ln Y_j + (1-\sigma)\ \ln T_{ij} - (1-\sigma) \ln \Pi_i - (1-\sigma) \ln P_J + (1-\sigma)\ \ln \gamma_{ij} + v_{ij} \qquad (13)$$

Where a_0 is the constant, and v_{ij} the error term. Regarding trade costs, they are usually approximated by different types of variables. The equation is often as follows:

$$T_{ij} = d_{ij}^{\delta_1}.exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_6 smctry_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij}) \qquad (14)$$

With d_{ij} representing the bilateral distance, and $cont_{ij}$, $lang_{ij}$, $ccol_{ij}$, col_{ij}, $smctry_{ij}$, wto_{ij}, RTA_{ij} representing dummies respectively for the presence of a common border, a common official language, a common colonizer, if the territory is or has been one of its partner colonies in the past, for the country's trade with itself, if the trading partners are members of WTO, and finally if there is a trade agreement between the two partners.

δ_6 is thus a parameter that quantifies the average intensity of internal trade with regards to international trade for the regions of the set, or in other words, the border effect. In equation 14, this parameter is the same for all the regions, but we could render it region specific. As suggested by Combes et al. (2005), it should have a positive value because the informational transaction cost is lower inside a country than between two countries, or because consumers have systematic preferences for local goods. It means that we could have model our bilateral preference parameter γ_{ij} as a function of the border effect. As it is not the case, γ_{ij} is therefore region i's efficacy in selling its goods to region j conditionally on not being member of the same country. This distinction between country and region is critical because as we will make clear in the data section, our database embed inter-state Brazilian trade flows and international trade flows.

Regarding the multilateral trade resistance terms, they are generally not directly observable. Many authors used remoteness indexes as proxies for them, but because of their discordance with theory, exporter and importer fixed-effects are more advisable (Head and Mayer, 2014). When using cross-sectional data, the latter option makes impossible the integration of other idiosyncratic variables such as GDP because of perfect collinearity. We can therefore only estimate parameters from dyadic variables.

Since Silva and Tenreyro (2006) raised concerns regarding the consistency of parameters obtained by estimating log-linearized trade equations via ordinary least squared, the Poisson Pseudo maximum likelihood estimator is more and more used. It allows the model to be estimated in level, therefore, dealing better with zero trade flows in trade data. The model estimated becomes :

$$X_{ij} = exp(\ a_0 + a_1 \ln Y_i + a_2 \ln Y_j + 1 - \sigma \ \ln T_{ij} - (1-\sigma) \ln \Pi_i - (1-\sigma) \ln P_J + (1-\sigma) \ \ln \gamma_{ij}) + n_{ij} \tag{15}$$

with X_{ij} representing exports in value from country i to country j, the other variables remaining unchanged.

Fally (2015) goes further by advocating that there is only one estimator of the pseudo maximum likelihood (PML) category, namely the Poisson pseudo maximum likelihood which is fully consistent with structural gravity when fixed effects are included in the estimation. This is because its first order conditions automatically satisfy the equilibrium constraints imposed to derive the multilateral resistance (MR) terms in equations (10) and (11). Accordingly, these terms can be obtained from the fixed effects estimates after some manipulations. More formally, it can be shown that for a model formulated as following:

$$X_{\text{ij}} = exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + \ b_j) \tag{16}$$

Where $\ln \gamma_{ij}^{1-\sigma}$ is the bilateral preference parameter as in equation (12), the equilibrium conditions $Y_i = \sum_j X_{ij}$ and $Y_j = \sum_i X_{ij}$ can be rewritten as:

$$Y_i = \sum_j exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + \ b_j) \tag{17}$$

$$Y_j = \sum_i exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + \ b_j) \tag{18}$$

$\Rightarrow \sum_j T_{ij}^{1-\sigma} \gamma_{ij}^{1-\sigma} Y_0 \ exp(b_j) = Y_0 Y_i \ exp(-a_i)$

$\Rightarrow \sum_i T_{ij}^{1-\sigma} \gamma_{ij}^{1-\sigma} Y_0^{-1} \ exp(a_i) = Y_0^{-1} Y_j \ exp(-b_j)$

We define:

$$\Pi_i^{1-\sigma} = Y_0 Y_i \ exp(-a_i) \tag{19}$$

$$P_j^{1-\sigma} = \frac{Y_j}{Y_0} \ exp(-b_j) \tag{20}$$

where b_j and a_i are respectively estimates of the importer and exporter fixed effects, and

Y_0 the income of the reference country. By incorporating them into equations (17) and (18), we find the expressions of $\Pi_i^{1-\sigma}$and $P_j^{1-\sigma}$ derived from the previous theoretical model (equations (10) and (11)). It proves that (19) and (20) are their solutions. As we may have noticed, because of the equilibrium conditions, these equations are valid only under the requirement of consistent data that is to say a data set where output equals the sum of outward trade, and expenditures equal the sum of inward trade. This requirement is generally met by inter-country input-output matrices, which unfortunately are very scarce.

But beyond that, there is a concern with our empirical model. In practice, preferences are not easily observable. When they are not explicitly controlled in the estimation, the estimated model is the traditional AVW model (equation (1), (2), (3)). In an empirical formulation, they logically represent a component of the error term. For the log-linear case, the estimated model therefore becomes:

$$\ln X_{ij} = \; a_0 + a_1 \ln Y_i + a_2 \ln Y_j + 1 - \sigma \;\; \ln T_{ij} - (1-\sigma) \ln \Pi_i + \varepsilon_{ij} \tag{21}$$

with $\varepsilon_{ij} = v_{ij} - u_{ij}$

and $u_{ij} = (\sigma - 1) \;\; \ln \gamma_{ij}$

Estimating this kind of equation is straightforward using stochastic frontier analysis.

3.3 Stochastic frontier analysis

Independently developed by Aigner et al. (1977) and Meeusen and van Den Broeck (1977) for cross-sectional data, the initial purpose of the stochastic frontier model is to estimate firms' efficiency in their production. For this, a maximum production achievable by a firm is firstly predicted by the model based on its production factors. Any gap between the actual and predicted levels of production is explained by a composite error term (ε_i) formed by a two-sided component v_i (alternatively positive or negative) and a one-sided strictly positive component u_i. The two-sided component captures outside influences beyond the control of the producer and the one-sided captures the degree of firm's inefficiency such that $\varepsilon_i = v_i$- u_i. The basic stochastic production frontier model is thus as follows:

$$C_i = f(A_i, \beta) + v_i - u_i \tag{22}$$

With C_i representing the dependent variable, $\mathrm{A_i}$ the vector of explanatory variables with β as the vector of coefficients, and v_i- u_i the components of the error term ε_i. The model can be estimated by maximum likelihood under some assumptions on the distribution of the composite error term. The literature generally assumes a half-normal distribution $N^+(0,\ \sigma_u^2)$, a truncated normal distribution in u $N^+(u,\ \sigma_u^2)$, or exponential and gamma distributions for the inefficiency term u_i because it is supposed to be strictly positive and a normal distribution for the two-sided term v_i. The estimation gives us the variance of the error term for the whole sample ($\sigma^2 = \sigma_v^2 + \sigma_u^2$), and the observation specific inefficiency is obtained by calculating the conditional expectation of u_i knowing ε_i as proposed by Jondrow et al. (1982). Assuming a half-normal distribution for u_i, these authors showed that the conditional density function of u_i knowing ε_i is f $(u_i \mid \varepsilon_i) \sim N^+\ (u_{*i},\ \sigma_*^2)$ with:

$$u_{*i} = \frac{-\varepsilon_i \sigma_u^2}{\sigma_v^2 + \sigma_u^2}\ and\ \sigma_*^2 = \frac{\sigma_v^2\ \sigma_u^2}{\sigma_v^2 + \sigma_u^2} \tag{23}$$

It implies that the conditional mean is:

$$E[u_i\,|\varepsilon_i] = u_{*i} + \frac{\sigma_* \phi(\frac{u_{*i}}{\sigma_*})}{\Phi(\frac{u_{*i}}{\sigma_*})} \tag{24}$$

where $\phi(.)$ and Φ are respectively the normal probability density function and the normal cumulative distribution function. Using the same method, Battese and Coelli (1988) derived an observation specific conditional efficiency term which ranges between 0 and 1, the most efficient observations being naturally close to 1. We have:

$$E[exp(-u_i)\,|\varepsilon_i] = exp(-u_{*i} + \frac{1}{2}\sigma_*^2)\frac{\Phi(\frac{u_{*i}}{\sigma_*} - \sigma_*)}{\Phi(\frac{u_{*i}}{\sigma_*})} \tag{25}$$

These results are founded on the assumption of a half-normal distribution for u_i, but we could have used different distributions. Kumbhakar and Lovell (2003) showed besides that regardless of the distribution chosen for u_i, the results remain consistent as long as we are only interested in a ranking of the most efficient observations. However, there is less flexibility regarding heteroskedasticity. According to the previous authors, ignoring the two-sided error term heteroskedasticity only biases the constant, but it is better not to ignore the inefficiency term heteroskedasticity to avoid biased parameter estimates. To address this, Caudill et al. (1995) proposed to estimate a model where the variance of u_i, σ_u^2 is a function of covariates. We thus get $u_i \sim N^+(0,\ Z_i\alpha)$. It allows the inefficiency term to be heteroskedastic and also highlights the variables Z_i that are its determinants.

Before considering the use of this method, we need to test its applicability. We hence need to check if our assumption on the error term form that is to say $\varepsilon_i = v_i$- u_i[2] with u_i a positive real number and v_i distributed symmetrically around 0 is credible. If this assumption is correct, ordinary least squares residuals should be asymmetrical and left skewed. To test this, we can use a sample-moment based statistic following Schmidt and Lin (1984)[3] and a skewness- kurtosis test of normality. If the null hypothesis of no skewness is rejected, we can hence estimate the stochastic frontier model. An alternative way is to perform a likelihood ratio test between the stochastic frontier and the OLS estimations, which amounts to testing the hypothesis that σ_u^2=0. See Kumbhakar et al. (2015).

Authors like Ravishankar and Stack (2014) or Kang and Fratianni (2006) have already used this kind of empirical model to estimate gravity equations. It is especially useful when it comes to the determination of bilateral trade potentials. Contrarily to the conventional method which estimates the benchmark level of trade achievable by a country with its trading partners and defines the trade potential as the deviation with this benchmark, the stochastic frontier model calculates the maximum level of trade achievable by a country with a given partner. The level of trade efficiency or inefficiency can consequently be determined via the deviation with this maximum and serve as an indication of trade potential. This measure is better than a simple difference between actual and predicted trade flows because the two-sided noise term, which in principle captures outside influences beyond the control of the exporter has been singled out.

4 Data and econometric results

4.1 Data

Our dataset is composed of aggregate bilateral trade flows for 222 importing countries and entities (including the different Brazilian states and 217 exporting countries and entities from three different sources, the COMTRADE database, the Brazilian external trade and development department and the 2008 Brazilian inter-regional input-output matrix estimated by Guilhoto and Sesso Filho (2010). The COMTRADE database is the main source for international trade flows but does not provide Brazilian states trade data. Besides, some countries did not report their exports for the year 2008 although their imports were recorded. It explains the difference between the number of exporters

[2]This is the form of a production-type stochastic frontier model, but there are other forms

[3]The statistic is computed like this: $\sqrt{b} = \frac{m_2}{m_3\sqrt{m_2}}$ where m_2 and m_3 are respectively the second and the third sample moments of the OLS residuals

and importers.[4] The Brazilian external trade and development department provides trade flows for each Brazilian state with their international partners but does not propose trade flows between Brazilian states. It is worth mentioning that these data include exports to Brazilian states from countries that are absent in the COMTRADE database, and also that both imports and exports are provided in their FOB value. The 2008 Brazilian inter-regional input-output matrix estimated by Guilhoto and Sesso Filho (2010) provides trade flows between Brazilian states. In this database, we have 26 Brazilian states + the state of Amazonas which is divided into two entities, Manaus and the rest of Amazonas. We restricted our samples to 2008 because of Brazilian intra-national trade data availability. 2008 flows aside, the more recent are from 1999. The sources of the other variables used in our estimations are reported in table 1. For instance, we obtained the geographic distance between each pair of countries/states by using a generator built by the Centre for Biodiversity and Conservation of the American Museum of Natural History (AMNH). The distance of a country to itself is calculated following Redding and Venables (2004): $d_{ii} = 0.33\sqrt{\frac{area}{\pi}}$. Whenever necessary, we converted Brazilian data in US dollar using the average exchange rate in 2008 1\$= 1.8346\$R.

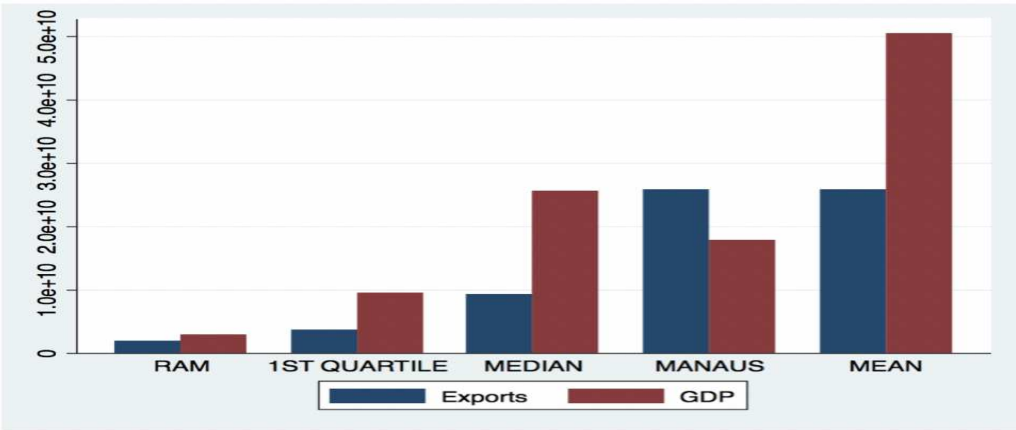
Table 1: Sources of different variables used in our estimations

Variables	Source
Exporter / importer GDP	Brazilian system of national accounts Word development indicators
Distance	Geographic distance Matrix generator (American museum of natural history)
Contiguity	Cepii/Author calculations
Common official language	Cepii/Author calculations
Colony	Cepii/Author calculations
Common colonisator	Cepii/Author calculations
Regional trade agreement	WTO RTA information system.
WTO membership	WTO website

Before going to the econometric results, it would be interesting to present some descriptive statistics. Figure 3 presents summary statistics on Brazilian states intra-national exports and GDPs, Manaus and the Rest of Amazonas being considered as states. As we can see, Manaus total exports to other Brazilian states are very close to the average of the sample, and way above the median. It is not the case for its GDP which is inferior to the mean and the median of the sample. This fact already suggests that Manaus is a good performer

[4]It should be noted that zero trade flows are not reported in this data set; we must therefore add them. To ensure that the added flows are truly null, and not just unreported, we do not consider as zero the missing flows of countries that appear as importers but not as exporters in the COMTRADE database.

in term of internal exports. However, as we can see, the value of its internal exports is superior to its GDP, which means that a share of the said internal exports comes from somewhere else. We should therefore pay attention to this if we want to determine the export performance of Manaus rigorously.



Source: SUFRAMA, Brazilian national accounts

Figure 3: Selected states total internal exports and GDP

Regarding the rest of Amazonas (RAM) the situation is entirely different as its exports are lower than its GDP and both are inferior to the first quartile. It is therefore difficult to make a preliminary conclusion regarding its trade performance in comparison to other Brazilian states. The econometric results analysis should provide more insights.

4.2 Econometric Results

In this sub-section, we present the econometric results obtained using different estimators among which ordinary least squares, Pseudo Poisson maximum likelihood, and the stochastic frontier estimator. To ease the analysis, table 2 presents the different variables used in the estimations, their definitions and expected signs.

For each estimator, we used the following empirical models:

- OLS: $\ln X_{ij} = \ a_i + b_j + (1 - \sigma) \ \ln T_{ij} + v_{ij}$
- PPML: $X_{ij} = \exp \ (a_i + b_j + (1 - \sigma) \ \ln T_{ij}) + n_{ij}$
- Stochastic frontier: $\ln X_{ij} = \ a_i + b_j + (1 - \sigma) \ \ln T_{ij} + \varepsilon_{ij}$
  - with $\varepsilon_{ij} = v_{ij}$ - u_{ij}
  - and $u_{ij} = (\sigma - 1) \ \ln \gamma_{ij}$

Where a_i and b_j represent respectively exporter and importer fixed effects.

Table 2: Variables of the estimated models and their definitions

Variable	Definition	Expected sign
ldist	Distance	Negative
contig	Dummy for sharing a common border	Positive
comlang_off	Dummy for entities with the same official language	Positive
smctry	Dummy for trade between Brazilian states	Positive
comcol	Dummy for entities sharing a common colonizer	Positive
colony	Dummy for colonial ties between two entities	Positive
RTA	Dummy for Regional trade agreements	Positive
both_wto	Dummy for trading partners both WTO members	Positive
lva_indr	Share of Manufactured goods in exporter value added	-
lva_indp	Share of Manufactured goods in importer value added	-

We also used two different specifications for the trade costs indices. The first one is similar to equation 14 where we estimate a single average parameter δ_6 for the Brazilian border effect.

- $T_{ij} = d_{ij}^{\delta_1}.exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_6 smctry_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij})$

In the second specification, we estimate 28 different parameters δ_i for each Brazilian state border effect including Manaus and the rest of Amazonas.

- $T_{ij} = d_{ij}^{\delta_1}.exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_i border_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij})$

$border_{ij}$ is, therefore, a dummy equal to one for the trade of a given Brazilian entity, Manaus, RAM or any other state with all other Brazilian entities and zero otherwise whereas $smctry_{ij}$ is a dummy equal to one whenever a Brazilian state trades with another one and zero otherwise. More precisely, with $border_{ij}$ each Brazilian entity has a dummy for its exports to other Brazilian entities and with $smctry_{ij}$ we only have one dummy for the inter-Brazilian entities trade. Also, as mentioned in the data section, we have internal trade flows only for Brazil.

Distinguishing between these two trade costs specifications has critical implications for the assessment of trade performance that will follow in the next section. The idiosyncratic parameters δ_i as they represent the intensity of internal trade in comparison to international trade for each Brazilian state are per se measures of intra-national export performance. As we analyse them in more detail in the following section, we do not show them in table 3 that presents our preliminary econometric results.

The first 3 columns present results obtained using the second specification of trade costs while the last three columns use the first specification. The PPML estimations have 41,586 observations while it is 24,564 for the others because of zero trade flows. Importer and exporter fixed effects parameters are not shown in this table to save space. As regards the stochastic frontier estimations, the variables Usigma and Vsigma represent respectively the log of the variance regarding the inefficiency component of the error term u_{ij} and the two-sided component v_{ij}. The estimations have been made on the assumption of a normal distribution for the two-sided noise term, and an exponential distribution for the inefficiency term. We also assumed homoskedasticity for the two components of the error term. We will relax this assumption in the following section.

Table 3: The determinants of Bilateral gross exports

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	PPML	OLS	Frontier	PPML	OLS	Frontier
ldist	-0.764***	-1.611***	-1.536***	-0.762***	-1.599***	-1.527***
	(0.0475)	(0.0281)	(0.0258)	(0.0474)	(0.0283)	(0.0258)
smctry				2.715***	3.593***	3.016***
				(0.222)	(0.149)	(0.137)
contig	0.300***	0.450***	0.594***	0.297***	0.434***	0.592***
	(0.0876)	(0.122)	(0.110)	(0.0872)	(0.125)	(0.112)
comlang_off	0.199**	0.766***	0.633***	0.201**	0.768***	0.638***
	(0.0786)	(0.0556)	(0.0500)	(0.0785)	(0.0557)	(0.0500)
comcol	0.341**	0.708***	0.632***	0.343**	0.702***	0.630***
	(0.162)	(0.0778)	(0.0678)	(0.162)	(0.0778)	(0.0678)
colony	0.212	1.043***	1.069***	0.213	1.047***	1.073***
	(0.138)	(0.121)	(0.102)	(0.138)	(0.121)	(0.102)
RTA	0.577***	0.733***	0.644***	0.580***	0.751***	0.655***
	(0.0832)	(0.0588)	(0.0520)	(0.0831)	(0.0590)	(0.0520)
both_wto	-0.0556	0.268	0.204	-0.0567	0.262	0.200
	(0.439)	(0.174)	(0.164)	(0.438)	(0.174)	(0.164)
Constant	19.43***	40.95***	41.09***	19.41***	40.82***	41.01***
	(0.695)	(0.359)	(0.331)	(0.694)	(0.363)	(0.331)
Usigma ($ln\sigma_u^2$)			0.948***			0.955***
			(0.0328)			(0.0325)
Vsigma ($ln\sigma_v^2$)			0.609***			0.619***
			(0.0290)			(0.0286)
Observations	41,586	24,564	24,564	41,586	24,564	24,564
R-squared	0.896	0.726		0.896	0.724	
Reporter FE	YES	YES	YES	YES	YES	YES
Partner FE	YES	YES	YES	YES	YES	YES
Border effect	YES	YES	YES	-	-	-

Cluster-robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As we can see, the distance coefficient is close to what is observed in the literature. When the PPML estimator is used, we have a coefficient around 0.75 whereas the coefficient is above unity when OLS or stochastic frontier are used. Furthermore, we see that Brazilian states trade far more with themselves than with their international partners as the parameters related to the variable "smctry" show. According to the PPML estimation in column 4, they traded approximately 15 times more "exp (2.715)" between each other than with foreign countries in 2008, a coefficient at least twice lower than that obtained by Daumal and Zignago (2010) for 1999 data. We should however mention that OLS suggest a significantly higher intra-Brazilian level of trade.

Roughly, all the other variables in these estimations have expected signs and coefficients. As this work is not about determining their true value, we will not pay much attention to their analysis and will focus more on the stochastic frontier results presented in columns 3 and 6. It appears that the log of the inefficiency term variance is significant at the 1% level no matter the specification of trade costs,thus suggesting the existence of an inefficiency component in the error term. This idea is confirmed by a likelihood ratio test between the OLS and the stochastic frontier estimation presented in appendix 6.A which amounts to test the hypothesis that σ_u^2=0 as said in section 3.3. With the help of the results presented above, we derived different measures of trade costs and trade performance to carry out our analysis on Manaus and the rest of Amazonas level of trade integration in Brazil.

5 Manaus and the rest of Amazonas trade performance

To asses properly the trade performance of the two entities composing the state of Amazonas in our sample, we carry out an analysis that is organized in three parts. Firstly, we show that Manaus and the rest of Amazonas are among the most efficient intra-national exporters in Brazil. Then, we show that despite their intra-national export efficiency these two entities levels of trade costs are among the highest of the subset of Brazilian states. This apparently counter-intuitive result leads us to our third point which is to envisage the tax incentives provided by the Free Trade Zone of Manaus as one of the main explanations to the state of Amazonas trade performance.

To substantiate our first point, we analyse two different measures of trade performance namely the intensity of intra-national trade in comparison to international trade for each Brazilian state, and the score of export performance derived from the stochastic frontier analysis. As regards the intensity of intra-national trade in comparison to international trade or framed differently the border effect, we obtain it as said earlier with the three estimations whose results are presented in the three first columns of table 3 respectively for the PPML estimator, OLS and the stochastic frontier estimator. Table 4 displays these parameters for the 28 Brazilian entities of our sample.

Manaus and the rest of Amazonas are represented in this table respectively by "MANAUS" and "RAM". As we can see, according to all the estimators used, the rest of Amazonas is the Brazilian entity that has the highest export intensity toward other Brazilian states in comparison to the benchmark for international exports. Depending on the estimator, Manaus is either ranked sixth or third, therefore suggesting that these entities are among the most efficient intra-national exporters in Brazil.

It is worth to note that 10 of the 14 largest states in term of economic size are also among the 14 states presenting the lowest border effect coefficient, which suggest that smaller states tend to trade more with their Brazilian counterparts than with other countries in the world. However, as interesting as these results are, they present the weakness to display an aggregate intra-national trade performance for each Brazilian state and do not provide insights regarding the bilateral intra-national export efficiency. A state could therefore export a lot to two or three states and few to the other states, but this measure would still suggest that the intra-national export performance is high. To solve this problem, we rely upon stochastic frontier analysis to obtain measures that reflects more the bilateral intra-national export performance of each Brazilian state.

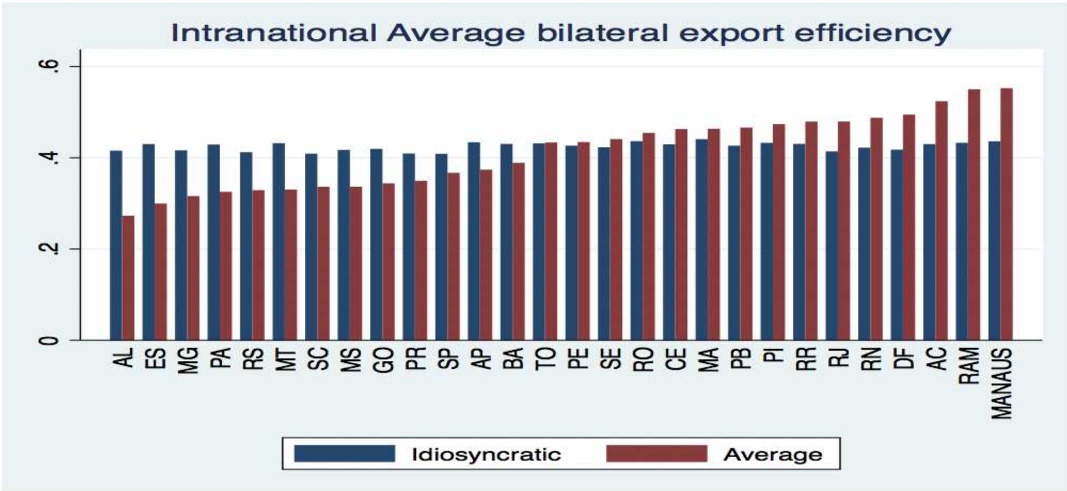
More precisely, we estimate the parameter ${\gamma_{ij}}^{1-\sigma}$ that derives from our theoretical model. As mentioned earlier, we assumed that preferences have the following form ${\beta_{ij}}^{1-\sigma} = (\alpha_i {\gamma_{ij}}^{1-\sigma})$ with two components, an idiosyncratic one "${\alpha_i}^{1-\sigma}$" that we interpreted as country i's efficacy in selling its goods to all its partners and a bilateral one ${\gamma_{ij}}^{1-\sigma}$ that we interpreted as country i's efficacy in selling its goods to country j specifically. The first component is naturally captured by the exporter fixed effects since it is idiosyncratic. Estimating the second component ${\gamma_{ij}}^{1-\sigma}$requires the use of stochastic frontier analysis as discussed in section 3.3.

From the estimations in table 3 columns 3 and 6 representing the specifications with an idiosyncratic border effect for each Brazilian state and an average one respectively, we calculated this bilateral component of trade efficiency. The results are displayed in the following figure that presents the average bilateral efficiency regarding the intra-national exports of the different Brazilian states.

As explained in section 3.3, we obtained the scores of bilateral export efficiency by using equation 26 (the conditional expectation of efficiency knowing the error term $\varepsilon_{ij)}$ after estimating the stochastic frontier model. We then calculated an average bilateral trade efficiency for each Brazilian state intra-national exports. It appears that when the specification with an idiosyncratic border effect is used (table 3 column 3), there is no significant difference in the average bilateral trade efficiency scores of Brazilian states. However, when the specification with an average border effect is used, Manaus and RAM are the most efficient intra-national exporter of the set of Brazilian states.

This result is sensical because as said earlier, the idiosyncratic border effect parameters presented in table 4 for each Brazilian state capture their aggregate intra-national trade performance. When we use a single average parameter to control for the border effect

[5]Appendix 6.B displays the list of Brazilian States.



Source: Author's estimations

Figure 4: Brazilian states intra-national export performance

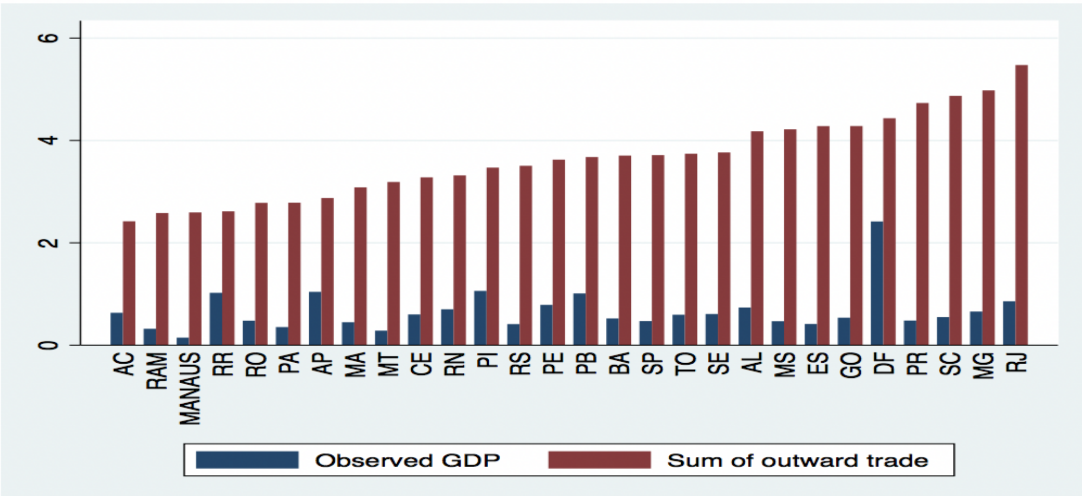
of each state (Table 3 column 6), the states that trade more than the average with their Brazilian counterparts have a higher average bilateral export efficiency in comparison to the other specification and inversely. All these findings confirm the idea that Manaus and RAM are among the best performers in term of intra-national exports in Brazil. Despite that, their respective level of trade costs does not seem to be among the lowest in the country.

In fact, the level of trade costs of these two entities is among the highest in the subset of Brazilian states. We show this by calculating each exporting state multilateral resistance term, which represents the sum of trade costs with all the trading partners (see equation 3). More specifically, we use the PPML parameter estimates of exporter fixed effects from the regression in table 3 column 4[6], and we solve for the multilateral resistance term using equation 19 as Fally (2015). The following table presents some descriptive statistics about the calculated multilateral resistance terms. As shown in equation 19, our measures are obtained using the following formula "$\Pi_i^{1-\sigma} = Y_0 Y_i \, exp(-a_i)$" ,Where $\Pi_i^{1-\sigma}$ is the variable of interest, Y_0 the GDP of the reference country (USA) in our case, Y_i the GDP of the exporting country, and a_i the estimated exporter's fixed effects.

As we mentioned earlier, estimating the multilateral resistance term with this method

[6]We do not use the PPML fixed-effects parameter estimates of column 1 table 3 because this specification with an idiosyncratic border effect for each Brazilian state amounts to exclude intra-national trade flows from the regression. Thus, the obtained fixed-effects parameter estimates are the same as for a regression with no intranational trade flows. This is a problem because multilateral resistance is supposed to affect all trade flows in the same way while this regression suggests a different multilateral resistance for each state intranational flows.

requires that the sum of exports (including trade with self) equals GDP to comply with structural gravity. Unfortunately, it is not the case with our data set because some countries did not report their exports to all destinations, and also, the trade data are not expressed in value-added contrarily to GDP. Besides, our trade data do not include trade with self except for intra-Brazilian trade flows. To take this into account, we calculated two measures of our variable of interest. The first with the observed GDP (blue), and the second with the sum of exports for each state. As we can see in the chart below, the results are approximately the same for Manaus and RAM regardless of the formula chosen.



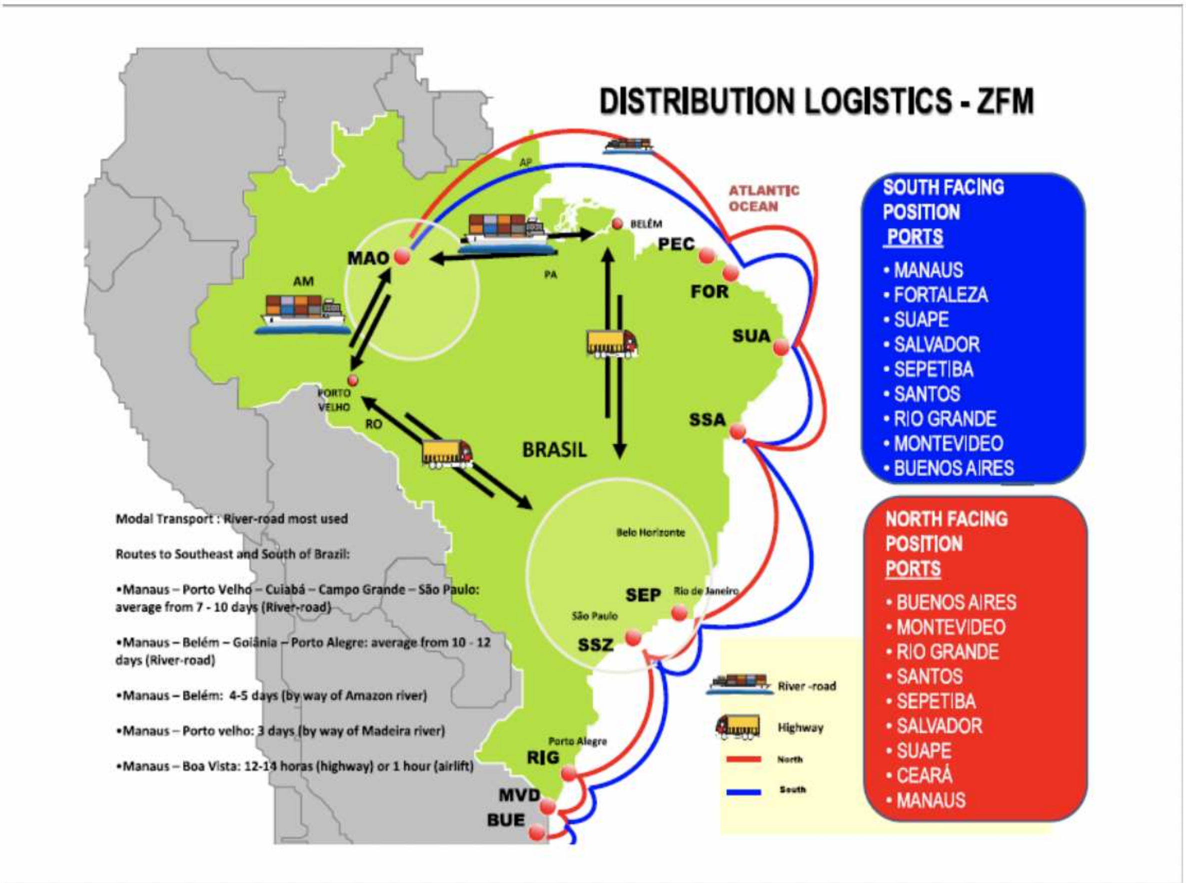
Source: Author's calculations

Figure 5: Brazilian states exporter multilateral resistance

We should note that we are interested in Π_i and not $\Pi_i^{1-\sigma}$. As $\sigma > 1$, a high $\Pi_i^{1-\sigma}$ means a low Π_i. In this regard, Manaus is among the entities with the highest level of trade costs in the subset of Brazilian states since its $\Pi_i^{1-\sigma}$is well below the average, and close to the minimum in each case. The rest of Amazonas also presents a below-average $\Pi_i^{1-\sigma}$ which means that its multilateral resistance term is also among the highest in Brazil. The geographical situation of Manaus certainly plays a prominent role in explaining this situation.

It is the case because the only differences between Amazonas and the other Brazilian states trade costs factors are 2 geographical variables notably distance and the contiguity dummy (See equation 14). It suggests that the states located in the northern part of Brazil as Amazonas are relatively far from the economically large Brazilian states, but also from the economically large countries in the world. The following map of Manaus' transport network provided by SUFRAMA confirms the consistency of this idea.

This map shows that Manaus (MAO) is among the entities located the farthest from Sao Paulo (SSZ), the economic hearth of the country. On top of that, because of the lack of direct connections with the rich southern states, the goods from Manaus need to bypass by other states as Rondonia (RO) or Para (PA) which are also far from the economic centre, implying longer distances to cover and therefore higher transports costs. This effect is nevertheless not accounted in our multilateral resistance term since we simply used the direct geographic distance between each state's capital. Still, as we can see, the estimated multilateral resistances for states like Para or Rondonia which are nearly as far as Manaus from the economic hearth of the country are also among the highest of the Brazilian sample (See table 4).



Source: Suframa

Figure 6: Amazonas inter-state transport network

To sum up, the second point was to say that Manaus and RAM level of trade costs were among the highest in the subset of Brazilian states. Despite this fact it appears that they are also among the top performers in term of intra-national exports in Brazil. In other words, the high level of trade costs does not impeach these two entities to outperform the average Brazilian state in term of intra-national exports. It is therefore very likely that another factor is at play here.

This leads us to our third point, which is to envisage the tax incentives provided by the Free Trade Zone of Manaus as one of the main explanations to the state of Amazonas trade performance. To assess the relevance of this idea, we carried out a stochastic frontier estimation with a specification allowing the inefficiency term to be heteroskedastic. As explained in section 3.3, this kind of specification is very interesting because it also permits to determine the variables that influence the inefficiency term. We therefore estimated a fixed-effects stochastic frontier model, and we modelled the variance of the bilateral inefficiency term as a function of bilateral man-made restrictions such as the existence of trade agreements between the two partners, and WTO membership. Besides, considering that manufactured goods are among the more traded goods in term of value,[7] and also less sensitive to transport costs than primary goods as Xu (2015) for example showed, a high share of manufactured goods in GDP should have a positive influence on trade performance. We therefore assumed that the variance of the bilateral inefficiency term also depends on the exporter's manufactured goods share in GDP.

It is important to note that in Brazil in 2008, the entity that had the highest manufactured goods share in its GDP was Manaus. This manufactured production was essentially attributable to the companies installed in the Free Trade Zone, and which directly benefit from the Brazilian authorities' tax incentives. We can therefore argue that this ratio captures at least a share of the Free Trade Zone impact on Manaus production. The following table displays the results of the regression. The first column presents the independent variables.

Except ldist and lva_indr (the log of the manufactured value-added share in GDP), all these are dummy variables. They are all described in table 2. The second column presents the coefficients associated to the independent variables that determines the log of exports, whereas columns Usigma and Vsigma represent respectively the inefficiency component and the two-sided noise component of the error term variance. As said earlier in section 3.3, the variance of the error term is ($\sigma^2 = \sigma_v^2 + \sigma_u^2$).

The estimation is made in one step on the assumption of a normal distribution for the two-sided noise component and an exponential distribution for inefficiency. We can see in the table that Vsigma is constant since it does not depend on any covariates unlike Usigma. It appears that except for the constant, all the variables explaining the inefficiency variance are significant at the 1% level and have a negative sign. It means that a trade agreement

[7] According to WTO, the share of manufactured goods in total merchandise exports was 70 percent in 2015

for example has a negative impact on the variance of trade inefficiency, and therefore a positive impact on the efficiency variance.

As discussed by Parmeter et al. (2014) the sign of the inefficiency variance covariates coefficients is also informative about the sign of their effect on the expected value of inefficiency. We can thus say that an increase of the exporter's share of manufactured goods in GDP exerts a negative impact on its trade inefficiency, and therefore a positive impact on its trade efficiency. The magnitude of the coefficients however tells us nothing about their marginal effects on inefficiency, since the relationship between the expected value of inefficiency and the covariates is nonlinear. Still, if the level of Manaus manufactured goods share in GDP is the result of the tax incentives provided by the Free Trade Zone (which is probably the case to some extent), it would mean a positive impact of the Free Trade Zone on Manaus intra-national export performance. All these results therefore suggest that the goal of fostering the state of Amazonas economic linkages with other Brazilian states that motivated the creation of Manaus FTZ has been achieved, and that this Free Trade Zone played a role in the process.

Table 4: Border effect coefficients of Brazilian states[5]

States	(1) PPML	(2) OLS	(3) Frontier
RAM	6.409***	6.793***	5.631***
AC	6.123***	6.078***	5.383***
RR	5.742***	5.419***	4.814***
SE	5.292***	3.962***	3.272***
DF	5.208***	5.092***	4.207***
MANAUS	5.169***	5.754***	4.845***
PI	4.371***	4.346***	3.738***
RN	4.367***	4.689***	3.994***
PB	4.326***	4.053***	3.561***
PE	4.173***	3.674***	3.092***
CE	3.978***	3.818***	3.405***
TO	3.866***	5.214***	3.065***
RO	3.792***	3.859***	3.236***
AP	3.145***	2.832***	1.343
SP	2.939***	2.570***	2.513***
GO	2.895***	2.604***	2.135***
AL	2.887***	2.359***	1.146***
MA	2.873***	4.659***	3.344***
MS	2.813***	2.475***	2.061***
BA	2.622***	3.092***	2.513***
SC	2.541***	2.253***	2.154***
RS	2.505***	2.120***	2.052***
MT	2.495***	2.551***	1.881***
PR	2.445***	2.379***	2.295***
RJ	2.292***	4.366***	3.827***
MG	2.043***	2.240***	1.889***
ES	1.846***	2.274***	1.542***
PA	1.808***	2.602***	1.794***

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

Table 5: Determinants of the bilateral trade efficiency variance

VARIABLES	(1) lexport	(2) Usigma	(3) Vsigma
Ldist	-1.513***		
	(0.0254)		
Contig	0.520***		
	(0.110)		
comlang_off	0.631***		
	(0.0496)		
Smctry	2.918***		
	(0.136)		
Comcol	0.637***		
	(0.0674)		
Colony	1.006***		
	(0.100)		
RTA	0.110*	-1.350***	
	(0.0617)	(0.104)	
both_wto	0.156	-0.486***	
	(0.178)	(0.0515)	
lva_indr		-0.765***	
		(0.0401)	
Constant	40.92***	-0.114	0.521***
	(0.330)	(0.104)	(0.0294)
Exporter fixed effects	YES		
Importer fixed effects	YES		
Observations	24,556	24,556	24,556

Cluster-robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

6 Concluding remarks

The goal of this paper was to determine Manaus and the Rest of Amazonas level of integration into the Brazilian economy and to examine the eventual role of the Free Trade Zone of Manaus to explain their situation. To do so, we used a structural gravity model and derived some measures of trade costs and trade performance in order to compare Manaus and RAM with the other Brazilian states. We showed that these two entities presented in 2008 the highest level of trade costs among Brazilian states, but despite this fact, were among the most efficient intra-national exporters in Brazil. To explain this puzzle, we envisaged the free trade zone of Manaus as the main explanation because of the wide range of tax incentives it provides to firms in this region. To support this idea, we established that the manufactured value-added share in total value-added has a positive impact on the trade efficiency scores. As manufactured goods are the main products fabricated by the firms in this FTZ which besides, amounts to a high share of Manaus GDP; we judged that this idea was not devoid of sense. It therefore appears that a good set of tax incentives as those of Manaus FTZ could offset the disadvantages associated with remoteness and high transport costs, and stimulate a given country exports. Examining the conditions that led to this outcome and the potential impact of this FTZ type of tax incentives on intra-regional trade in other regions of the world could hence be an interesting future direction of research.

References

Aigner, D., Lovell, C. K., and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*, 6(1):21–37. 13

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. *The American Economic Review*, 69(1):106–116. 8

Anderson, J. E. and Van Wincoop, E. (2003). Gravity with gravitas: a solution to the border puzzle. *American economic review*, 93(1):170–192. 8

Baldwin, R. and Taglioni, D. (2006). Gravity for dummies and dummies for gravity equations. Technical report, National bureau of economic research. 8

Battese, G. E. and Coelli, T. J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of econometrics*, 38(3):387–399. 14

Bergstrand, J. H. (1989). The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *The review of economics and statistics*, pages 143–153. 8

Buys, P., Deichmann, U., and Wheeler, D. (2006). *Road network upgrading and overland trade expansion in Sub-Saharan Africa*. The World Bank. 3

Caudill, S. B., Ford, J. M., and Gropper, D. M. (1995). Frontier estimation and firm-specific inefficiency measures in the presence of heteroscedasticity. *Journal of Business & Economic Statistics*, 13(1):105–111. 14

Combes, P.-P., Lafourcade, M., and Mayer, T. (2005). The trade-creating effects of business and social networks: evidence from france. *Journal of international Economics*, 66(1):1–29. 9, 11

Costinot, A. and Rodríguez-Clare, A. (2014). Trade theory with numbers: Quantifying the consequences of globalization. In *Handbook of international economics*, volume 4, pages 197–261. Elsevier. 9

Daumal, M. and Zignago, S. (2010). Measure and determinants of border effects of brazilian states. *Papers in Regional Science*, 89(4):735–758. 19

De Benedictis, L. and Vicarelli, C. (2005). Trade potentials in gravity panel data models. *The BE Journal of Economic Analysis & Policy*, 5(1). 8

Egger, P. (2002). An econometric view on the estimation of gravity models and the calculation of trade potentials. *World Economy*, 25(2):297–312. 8

Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics*, 97(1):76–85. 12, 22

Farole, T. and Akinci, G. (2011). *Special economic zones: progress, emerging challenges, and future directions*. The World Bank. 5

Guilhoto, J. and Sesso Filho, U. (2010). Estimation of the input-output matrix using preliminary data from national accounts: application and analysis of economic indicators for brazil in 2005. *Economy & Technology UFPR/TECPAR. Year*, 6. 15, 16

Head, K. and Mayer, T. (2014). Gravity equations: Workhorse, toolkit, and cookbook. In *Handbook of international economics*, volume 4, pages 131–195. Elsevier. 11

Johansson, H. and Nilsson, L. (1997). Export processing zones as catalysts. *World Development*, 25(12):2115–2128. 5

Jondrow, J., Lovell, C. K., Materov, I. S., and Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of econometrics*, 19(2-3):233–238. 14

Kang, H. and Fratianni, M. (2006). International trade efficiency, the gravity equation, and the stochastic frontier. Technical report, Indiana University, Kelley School of Business, Department of Business 15

Kumbhakar, S. C. and Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge university press. 14

Kumbhakar, S. C., Wang, H.-J., and Horncastle, A. P. (2015). *A practitioner's guide to stochastic frontier analysis using Stata*. Cambridge University Press. 15, 33

Limao, N. and Venables, A. J. (2001). Infrastructure, geographical disadvantage, transport costs, and trade. *The World Bank Economic Review*, 15(3):451–479. 2

Madani, D. (1999). *A review of the role and impact of export processing zones*. The World Bank. 3

Meeusen, W. and van Den Broeck, J. (1977). Efficiency estimation from cobb-douglas production functions with composed error. *International economic review*, pages 435–444. 13

Nunes, B. F. (1990). La zone franche de manaus, l'échec régional d'une industrialisation réussie. pages 49–64. 2

Parmeter, C. F., Kumbhakar, S. C., et al. (2014). Efficiency analysis: a primer on recent advances. *Foundations and Trends® in Econometrics*, 7(3–4):191–385. 26

Ravishankar, G. and Stack, M. M. (2014). The gravity model and trade efficiency: A stochastic frontier analysis of eastern e uropean countries' potential trade. *The World Economy*, 37(5):690–704. 15

Redding, S. and Venables, A. J. (2004). Economic geography and international inequality. *Journal of international Economics*, 62(1):53–82. 16

Schmidt, P. and Lin, T.-F. (1984). Simple tests of alternative specifications in stochastic frontier models. *Journal of Econometrics*, 24(3):349–361. 15

Silva, J. S. and Tenreyro, S. (2006). The log of gravity. *The Review of Economics and statistics*, 88(4):641–658. 11

Tinbergen, J. J. (1962). Shaping the world economy; suggestions for an international economic policy. 2

Xu, K. (2015). Why are agricultural goods not traded more intensively: High trade costs or low productivity variation? *The World Economy*, 38(11):1722–1743. 25

Yücer, A., Guilhoto, J., and Siroën, J.-M. (2014). Internal and international vertical specialization of brazilian states–an input-output analysis. *Revue d'économie politique*, 124(4):599–612. 3, 4

6.A LR tests on the existence of inefficiency in the data

As Kumbhakar et al. (2015) explain, a LR test for a stochastic frontier normal-half normal model with OLS as the restricted model amounts to testing the hypothesis that the inefficiency variance σ_u^2=0. According to them, the LR test statistic has a mixture of chi-square distribution with 1 degree of freedom since only σ_u^2 is restricted. The critical values of this distribution are as follows:

Table 6: Critical values of the mixed chi-square distribution

	Significance level						
Degree of freedom	0.25	0.1	0.05	0.025	0.01	0.005	0.001
1	0.455	1.642	2.705	3.841	5.412	6.635	9.500

Source : Table 1, Kodde and Palm (1986, Econometrica).

More precisely, if there is no inefficiency, in the data, the OLS residuals are described by the following equation:

$\varepsilon_{ij} = v_{ij} + E\left(v_{ij}\right)$, With $E\left(v_{ij}\right) = 0$

Otherwise, if there is inefficiency, the residuals are better described by

$\varepsilon_{ij} = v_{ij} - u_{ij} + E\left(u_{ij}\right) + E\left(v_{ij}\right)$, With $E\left(u_{ij}\right) >$=0

We can estimate the latter model by applying the standard stochastic frontier model presented earlier, assuming a standard normal distribution N $(0, \sigma_v^2)$ for v_{ij} and an exponential distribution N+ (σ_u^2) for u_{it} both being i.i.d. The former model is estimated via OLS, and we perform the likelihood ratio test to determine which model better explains the error term. The likelihood ratio test statistic is -2[L(H_0)- L(H_1)] where L(H_0) and L(H_1) are likelihood values of the restricted model (OLS) and the unrestricted model (stochastic frontier).

Following the test, we obtain a LR statistic equal to 1503.06 which means a significance at the 1% level. This test thus confirms the existence of inefficiency in the estimated model.

6.B List of Brazilian states

Acronym	Name of State
RAM	Rest of Amazonas
AC	ACRE
RR	RORAIMA
SE	SERGIPE
DF	DISTRITO FEDERAL
MANAUS	MANAUS
PI	PIAUI
RN	RIO GRANDE DO NORTE
PB	PARAIBA
PE	PERNAMBUCO
CE	CEARA
TO	TOCANTINS
RO	RONDONIA
AP	AMAPA
SP	SAO PAULO
GO	GOIAS
AL	ALAGOAS
MA	MARANHAO
MS	MATO GROSSO DO SUL
BA	BAHIA
SC	SANTA CATARINA
RS	RIO GRANDE DO SUL
MT	MATO GROSSO
PR	PARANA
RJ	RIO DE JANEIRO
MG	MINAS GERAIS
ES	ESPIRITO SANTO
PA	PARA