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Cities Export Specialization*

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Abstract

Do large and small cities exhibit different patterns of export specialization? Using highly disaggregated product-level trade data for Brazilian cities in year 2013, we find that more populated urban areas export proportionately more complex and skill-intensive goods than less populated urban areas. We also show that Brazilian urban areas that have increased more in population have also augmented more than proportionately the exports of complex and skill-intensive goods. Our empirical findings support recent models which argue that large cities attract more skilled workers and exhibit a wide range of capabilities, providing them a comparative advantage in skill-intensive and complex goods.

JEL: F11, F14, R12

Keywords: urban areas, exports, complexity, skills, comparative advantage, Brazil.

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1 Introduction

Cities are one of the most salient examples of agglomeration economies. Despite the reduction in communication costs, the value of proximity does not seem to decline and an increasing share of people live in cities (Gaspar and Glaeser, 1998; Glaeser, 2011).

Cities clearly differ in their population size.[1] In particular, cities' population in most countries tend to follow a simple rank-size distribution: there are few large cities and a much larger number of cities with a smaller magnitude (Gabaix, 1999; Soo, 2005). For example, in the year 2013, the most populated urban area of Brazil, Sao Paulo, was 100 times larger than the urban area of Chapec, which had a population close to the median.[2]

The literature shows that urban areas population is correlated with other economic variables such as human capital, firm and labour productivity, and wage. Concretely, large cities present a higher share of skilled workers, host more productive firms and pay higher wages than small cities (Glaeser and Resseger, 2010; Behrens and Robert-Nicoud, 2015). In this paper we analyze whether export specialization also varies across cities.

We argue that since cities differ in their endowments and factors of production, we should expect cities to specialize and export some products and not others. Using very detailed product-level export data for Brazilian urban areas, we find that more populated Brazilian urban areas export proportionately more complex and skill-intensive goods than less populated Brazilian urban areas. Moreover, we show that cities that have increased more in population, have also augmented more than proportionately their exports of complex and skill-intensive goods.

Complexity and skill-intensity are two alternative measures of the knowledge contended in goods. Whereas complexity focuses on the set of capabilities, or non-tradable inputs, needed to manufacture products, the skill-intensity emphasizes the qualification required to produce them. Although both dimensions seem to be similar, there are cases in which a large skill-intensity does not imply a high level of complexity. For instance, some goods such as pesticides, electrical equipment, medical diagnoses or software writing could be characterized by a high degree of skill-intensity, but at the same time they require very few capabilities to be produced (low complexity), Minondo and Requena-Silvente (2013).

Different models explain why large cities export proportionately more complex and skill-intensive goods. Regarding complexity, Hausmann and Hidalgo (2011) argue that as larger cities are endowed with a wider set of capabilities than smaller cities, they can produce, and export, more complex goods. Davis and Dingel (2014) develop a model

[1] We use the term "city" and "urban area" interchangeably.

[2] Data obtained from the Census of the Brazilian Statistical Institute. For a deeper analysis of the Zip's Law for the Brazilian case, revise Moura and Ribeiro (2006).

to explain why more populated urban areas specialize in the production of more skill-intensive goods. In their model, skilled workers are more productive if they are surrounded by other skilled workers.[3] This generates an incentive for skilled workers to concentrate geographically, leading to a hierarchy of cities where the most skilled workers are concentrated in the most populated areas, and the least skilled workers in the least populated areas. If the productivity advantage of skilled workers raises with the skill-intensity of the good, larger cities will have a comparative advantage in producing skill-intensive products, and will export them.

Our paper makes empirical contributions to the fields of urban and international trade economics. In particular, we show that population size leads to differences in export specialization across cities. Since trade data is characterized by a much larger product disaggregation than industry data, we can test predictions on cities' productive specialization with a much higher detail than previous studies. The paper also adds to the trade literature showing that variation in population might lead to differences in export specialization within a country.

The remainder of the paper is organized as follows. Section 2 describes the data sources used in the empirical analyses. Section 3 presents patterns on cities' trading structure and shows the results of the empirical analyses. The last section concludes.

2 Data

To undertake our empirical analyses we combine three data sources for the year 2013: the distribution of Brazilian municipalities in urban areas, exports at the product and urban area level, and indicators on goods' complexity and skill-intensity. A more detailed description of the data follows below.

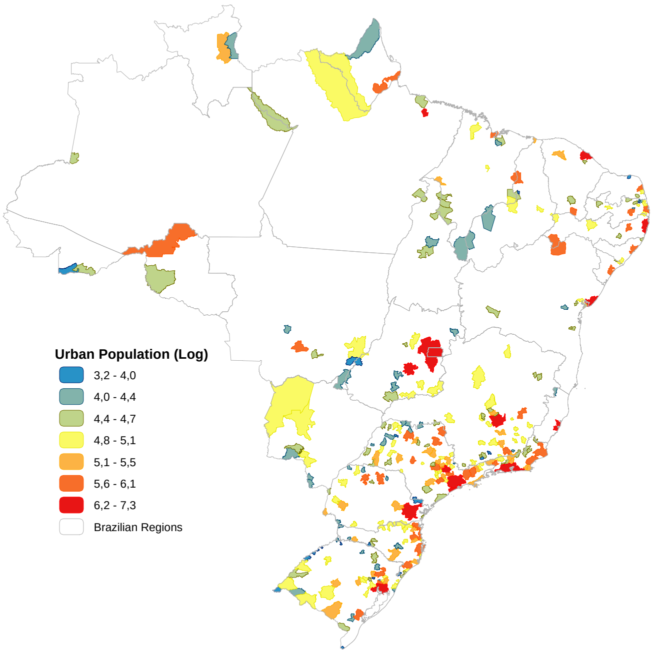
2.1 Urban areas

The Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE) identifies urban areas (*arranjos*) attending to commuting labor movements. For this study, we select urban areas with a minimum of 50,000 inhabitants. This leaves us with 156 urban areas which are shown in Figure 1. The most populated urban areas are Sao Paulo (11.3 million), Rio de Janeiro (6.3 million), Salvador (2.7 million), Brasilia (2.6 million) and Fortaleza (2.5 million), whereas the less populated

[3]The idea that big cities present advantages over small cities is also shared by other authors. In particular, Kok and Weel (2014) argue that big cities have the ability to geographically connect people that perform multiple tasks with different levels of skills. In the same spirit, Bacolod et al. (2009) show that social and cognitive abilities are more rewarded in big cities.

urban areas are Barra and Viana, both with 50.000 inhabitants.[4] Brazil is characterized by an unequal population distribution across cities. The Gini coefficient for population takes the value 0.73 in 2013; a previous estimate of the Zip's coefficient of around 2.26 for 2000 by Moura and Ribeiro (2006) confirms this unequal pattern. Attending to the spatial distribution, we can see that most urban areas are located in the south and near the coast, while areas in the north-west part of the country or the Amazon River tend to be much less populated.

Figure 1: Urban areas in Brazil (2013).



Source: Own elaboration from IBGE.

2.2 Trade flows

Data on cities exports is obtained from the *DataViva* project.[5] *DataViva* uses firm-level exports data from the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC), and assigns exports to a municipality according to the location of the firm's headquarter. Data is then collapsed at the municipal level and 4-digit HS product classification. We aggregate municipalities exports data into the 156 urban areas identified above. We restrict the sample to narrowly defined manufacturing industries, removing those where natural resources play a major role in determining comparative advantage.[6]

[4] Urban area population is obtained from the Census of the Brazilian Statistical Institute and calculated using the *arranjos* definition.

[5] Available at `http://en.dataviva.info/`

[6] The narrow definition of manufacturing industries excludes agricultural and mineral raw materials, food and beverages, wood products, and non-metallic minerals.

This leaves a sample of 780 manufactures. We have export data for the years 2000, 2005 and 2013; we use year 2013 for the baseline cross-section analyses and add the other two years for robustness checks and panel data analyses.

Brazil's exports grew above 300% between 2000 and 2013, with remarkable changes in the export patterns of the Brazilian cities during this period. Table 1 shows the average exports per city (intensive margin) and the number of different products exported per city (product extensive margin) in the years 2000 and 2013. As it can be observed, the intensive margin almost triples its value. In addition, cities exported more products in 2013 than in 2000 (272 vs. 297 at the HS4 level). The third column indicates that not only trade volumes, but also the number of exporting cities increased over the period of analysis.

Table 1: Descriptive Statistics.

Year	*Average Exports per City* (in millions)	*Number of different products per City (mean)*	*Number of Exporting Cities*
2000	2,33	272	147
2013	6,84	297	156

2.3 The complexity and skill-intensity indicators

Data on products' complexity is obtained from the Observatory of Economic Complexity.[7] Complexity is calculated through an iterative process between countries diversification level, the number of products that countries export with a revealed comparative advantage, and products ubiquity, the number of countries that have a revealed comparative advantage in the product (Hausmann and Hidalgo, 2014). According to these authors, the complexity indicator measures the non-observable capabilities (know-how) required in the production of goods.[8]

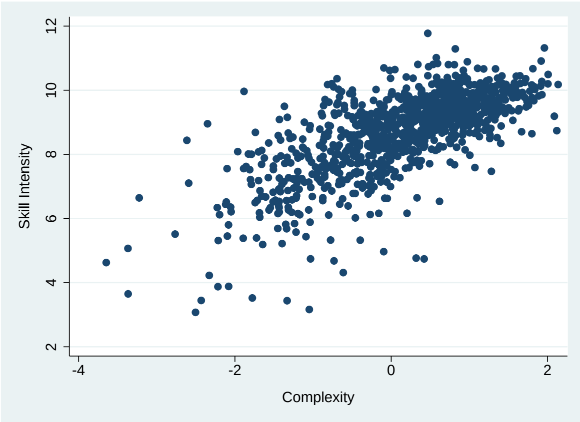
Products' skill-intensity is proxy by the UNCTAD's Revealed Human Capital Intensity Index (Shirotori et al., 2010).[9] The index is a weighted average of schooling years of the countries that have a revealed comparative advantage in the product. The data covers the period 1980-2007 with annual frequency. We use the latest available year (2007) for our empirical tests.

Both indicators capture the products' skill-content taking two different but complementary perspectives. While complexity focuses on the diversity of skills used in the

[7]Available at http://atlas.cid.harvard.edu/rankings/
[8]Complexity is a time-varying variable as it is calculated for each year.
[9]Available at http://www.unctad.info

production process, the skill-intensity pays attention to the level of qualification required to manufacture a product. Overall, there is a strong positive correlation between the complexity and the skill-intensity index: 0.71. However, as shown in Figure 2, for a given level of skill-intensity there is ample variation in complexity. Note that for lower levels of complexity, the skill intensity indicator presents much more variability than for higher levels of complexity.

Figure 2: Complexity Vs. Skill-Intensity Indicators (2013).



Source: Own elaboration from the Atlas of Economic Complexity and UNCTAD.

3 Empirical analyses

After describing the data set, we now analyze whether larger cities export disproportionately more complex and skill-intensive goods. For that purpose, we divide our analysis into two parts. First, we provide a descriptive analysis on the export specialization pattern of the Brazilian cities and, then, we perform the non-parametric and parametric tests to validate our hypotheses.

3.1 Descriptive analysis: Brazilian cities trade pattern

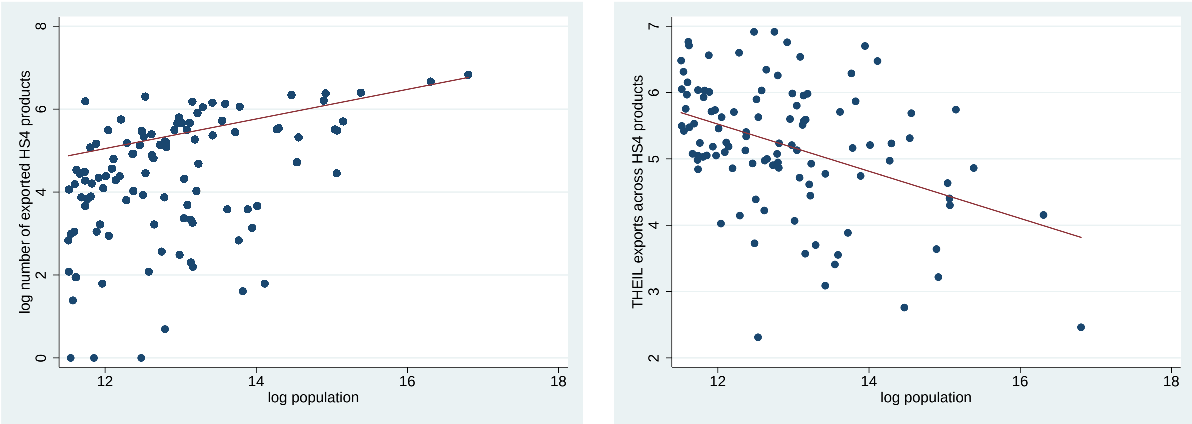
According to Hausmann and Hidalgo (2011), since large cities command a larger set of capabilities, they can produce a wider set of goods than smaller cities. Figure 3 gives evidence on these differences between small and large cities. Panel (a) shows the relationship between city's population and the number of exported products. Clearly, big cities trade more products than small ones. Attending to the extent of diversification in the export product portfolio, panel (b) plots the Theil index against the urban population.[10] The Theil index is inversely related with a city's export diversification level: the larger

[10]The Theil index is defined as:

the index, the lower the diversification level. This sub-figure confirms that exports are less concentrated in large urban areas in Brazil.[11]

Figure 3: Cities' trading-patterns (2013).

(a) Number of Varieties (b) Theil



Source: Own elaboration from Dataviva.

Next, we divide cities in two groups according to their population: cities with population above the national median (large cities) and cities with population below the national median (small cities). Then, for each product, we calculate the ratio of the share of exports in large cities over the share of exports in small cities. If the theoretical predictions are correct, we would expect the ratio to become larger as the complexity (and the skill-intensity) of the good increases. Figure 4 presents the non-parametric relationship between the ratio of export shares and the complexity (panel a) and skill-intensity (panel b) indicators.[12] In both indicators, we observe that the share of exports in big cities relative to the share of exports in small cities rises as we increase the complexity and skill-intensity of the good. These two figures give the first insights on the pattern between the nature of the product and cities' exports: big cities specialize in more complex and skill-intensive goods. In the next section, we test the validity of these visual findings using alternative techniques.

$$T = \frac{1}{J}\sum_{i=1}^{J}\frac{x_i}{\mu}\ln(\frac{x_i}{\mu}), \tag{1}$$

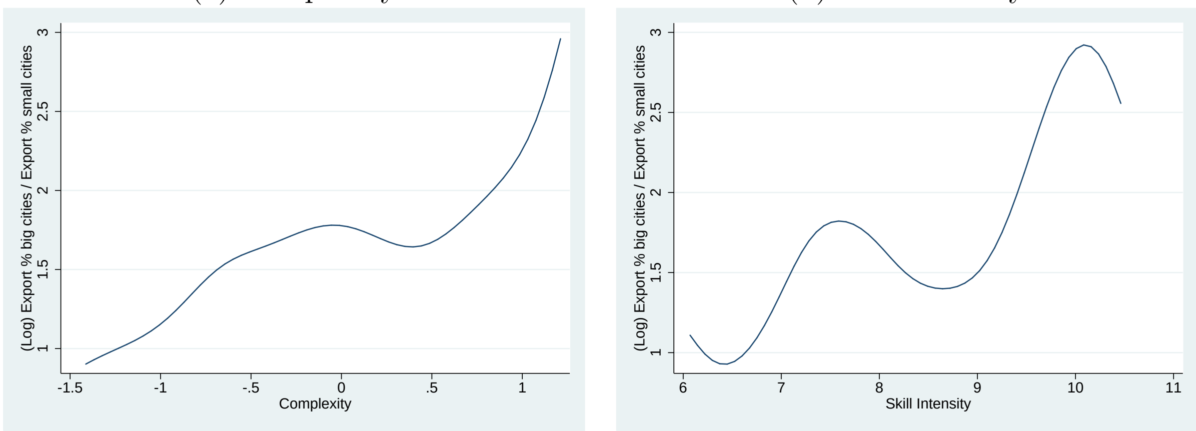
where $\mu = \frac{\sum_{x_i=1}^{J} x_i}{J}$, J is the total number of products and x_i denotes the amount of urban area exports of product i.

[11] Similar results are obtained using the Herfindahl and Gini indexes as measures of exports concentration.

[12] We estimate kernel regressions to obtain these non-parametric relationships.

Figure 4: Ratio of exports shares big cities/small cities vs complexity and skill-intensity (2013).

(a) Complexity (b) Skill-intensity



Source: Own elaboration from Dataviva.

3.2 A non-parametric analysis: The elasticity test

We present here the so-called elasticity-test, recently proposed by Davis and Dingel (2014) to analyze whether the population elasticity of exports is increasing with the level of complexity (skill-intensity) of the products. If we compare a complex (skill-intensive) product with a non-complex (unskilled-intensive) product, we expect exports to rise more with population in the former than in the latter. That is, if large cities export proportionately more complex goods, then the population elasticity of exports should increase with products complexity. To test this hypothesis, first, we estimate the population elasticity of exports for each product in the following way:

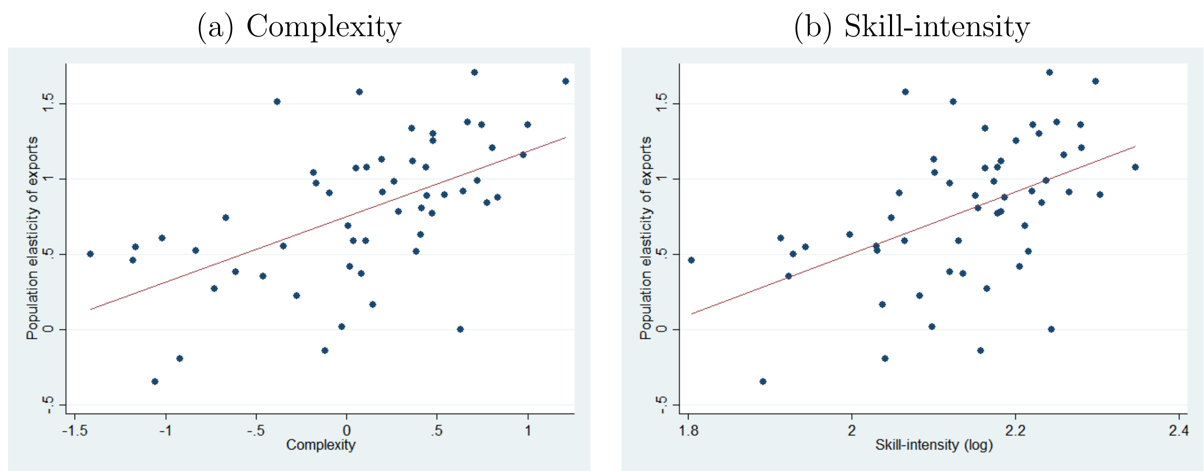
$$\ln x_i^k = \alpha^k + \beta_k' \alpha^k \ln pop_i + \epsilon_i^k \tag{2}$$

where x_i^k are exports of product k by urban area i, α^k is a dummy variable if exports correspond to industry k and zero otherwise, pop_i is the population of urban area i and ϵ_i^k is the error term. Our coefficient of interest is β_k', which is a vector that comprises all the population elasticities for the k-products.

If we use our 4-digit product HS classification, we can distinguish 780 different manufactured products; unfortunately, the number of urban areas exporting product k will be, in many cases, very small. In those cases, the regression cannot be estimated; or, even when the estimation is feasible, the elasticity coefficient will have a large standard error. To overcome this problem, we collapse exports at the 2-digit HS classification, which distinguishes 59 manufactured groups. To ensure the precision of the estimation, product k should be exported, at least, by 10 urban areas. This condition reduces the sample of products to 55, but they still represent 98% of exports.

Figure 5-panel (a) presents the scatter diagram between products' complexity and the population elasticity of exports; panel (b) presents a similar scatter diagram for products' skill-intensity. We can see a positive relationship between both indicators and the population elasticity of exports. It is important to note that there are 4 products that have negative elasticities. These negative signs are awkward as we expect more populated cities to export more of any good. Nevertheless, the 4 negative coefficients are not statistically significant, so we cannot reject the hypothesis that their true values are zero. More important, their inclusion in the sample does not alter the outcome of the elasticity test. We have also run the test including only products whose elasticities are statistically significant. In that case the sample is reduced to 44 products and the conclusions are not altered.

Figure 5: The population elasticity of exports vs. complexity and skill intensity (2013).



Source: Own elaboration from Dataviva.

To confirm the visual appreciation from Figure 5, the elasticity test compares whether a more complex (skill-intensive) product has a higher population elasticity of exports than a less complex (skill-intensive) product. More concretely, for any given pair of products k and j, the elasticity test is defined as:

$$Complexity_k > Complexity_j \iff \beta'_k > \beta'_j \tag{3}$$

That is, if k is a more complex product than j, we should expect the population elasticity of k to be higher than j. According to the previous expression, we define an indicator (I_{kj}) that takes the value 1 if equation 3 holds, i.e. $\beta'_k - \beta'_j > 0$, and 0 otherwise. The elasticity test calculates the number of cases such as I_{kj}=1 among all possible (k,j) pairs. More concretely, it takes the following expression:

$$Elasticity\_Test_{kj} = \frac{[\sum_{kj}(I_{kj})]}{N_{kj}} \tag{4}$$

Where N_{kj} represents the total number of pairs (k,j). If all the pairs (k,j) fulfill equation 3, the final indicator will reach the value 1 (100% of the cases), fully confirming the hypothesis. Notice that if equation 4 takes a value of 0.5 (50% of matches are correct), the performance of the test is quite poor. In this case, similar to the sign test used to validate the Heckscher-Ohlin-Vanek equation, our theory would predict as well as flipping a coin (Trefler, 1995).

As shown in Table 2, the hypothesis is confirmed for 71% of cases when products are classified by complexity, and in 69% of cases when products are classified by skill-intensity.[13] The table also reports the success rate for weighted comparisons. We argue that it is more damaging for the test when a low complexity product has a higher population elasticity than a high complexity product, than if a low complexity product has a higher population elasticity than a moderately more complex product. To take that into account we weight the success events by the difference in complexity (skill-intensity) of the products that are compared. The weighting (W) version of the elasticity test takes the form:

$$I^W = \sum_{kj} I * \left(\frac{\mid complexity_k - complexity_j \mid}{\sum_{kj} \mid complexity_k - complexity_j \mid} \right), \forall\, (\beta'_k - \beta'_j) > 0 \tag{5}$$

Where I reflects the indicator from equation 4. Then, for the cases such as $\beta'_k - \beta'_j > 0$, we weight by the differences in complexity (skill-intensity) between the products k and j. With weighting, the success rate improves to 81% for complexity and 78% for skill-intensity. These percentages confirm the hypothesis that large cities specialize in more complex and skill-intensive products. This result is in line with those obtained by Davis and Dingel (2014) for the US who find that the population elasticity of sectoral employment is increasing in skill-intensity.

Table 2: Results for the elasticity test (% of successful comparisons)

Variable	Unweighted (%)	Weighted (%)
Complexity	71	81
Skill-intensity	69	78

[13]Concretely, we perform (55 coefficients x 54 coefficients)/2= 1,485 comparisons.

3.3 A parametric analysis: The log-supermodularity regression

The elasticity test gives the first confirmation of our hypothesis; now we turn to the parametric test to corroborate it. This test is based on a log-supermodularity regression. As explained by Costinot (2009a), two variables have a log-supermodular relationship when increasing one variable is relatively more important when the other variable is high. In our analysis, if large cities export proportionally more complex (skill-intensive) goods, then exports should be log-supermodular in population and complexity (skill-intensity). To test the log-supermodularity hypothesis, we estimate the following regression equation adapted from previous studies (Costinot, 2009b; Chor, 2010):

$$\ln x_{ik} = \beta(\ln pop_i * complexity_k) + \mu_i + \mu_k + \epsilon_{ik} \tag{6}$$

where x_{ik} are product k exports from urban area i, pop_i is urban area i population, $complexity_k$ is the complexity (skill-intensity) of product k, μ_i is an urban area fixed effect, μ_k is a product fixed effect, and ϵ_{ik} is the error term. If exports are log-supermodular in population and complexity, we should expect a positive value for the coefficient β. We estimate a similar equation substituting complexity with skill-intensity as product-specific explanatory variable.

We estimate equation 6 by OLS. However, due to the large number of zeros in our sample, the estimation might be biased. To test the robustness of our estimations, we also estimate equation 6 using the pseudo-maximun likelihood (PPML) model proposed by Silva and Tenreyro (2006). In Table 3, columns (1) to (4) present the results for 2013 of the OLS estimation. In columns (2) and (4) we include zero exports transforming all zeros into ones, so logarithms become zero. Columns (5) and (6) estimate the equation with the PPML estimator.

Attending to the results, we can see that coefficients for the interaction variables are positive and statistically significant in the OLS estimations, both for the complexity and the skill-intensity indicators, giving support to our hypotheses on log-supermodularity. As expected, the OLS coefficients are slightly higher than those obtained with the PPML estimation, specially for the complexity variable. Note also that results are robust in the PPML estimations. Hence, we can conclude that exports are log-supermodular in complexity (skill-intensity) and population.

Table 3: Log-supermodularity regressions. Regression results for 2013.

	OLS				PPML	
	(1)	(2)	(3)	(4)	(5)	(6)
Pop*complex	0.178***	0.171***			0.114**	
	(0.035)	(0.039)			(0.053)	
Pop*skills			0.111***	0.0839***		0.101***
			(0.022)	(0.023)		(0.038)
Zero exports	No	Yes	No	Yes	Yes	Yes
Observations	12142	114816	12142	114816	114816	114816

Note: All regressions include urban area and product fixed effects. Standard errors clustered at the urban area level in parentheses. *** statistically significant at 1%, ** statistically significant at 5%.

We test whether exports' log-supermodularity also holds in the long run. We expect exports of complex goods to increase more in urban areas where population has grown more. To test this hypothesis, we extend the database for the years 2000, 2005 and 2013 to estimate the following expression:

$$\ln x_{ikt} = \beta(\ln pop_{it} * complexity_{kt}) + \mu_{ik} + \mu_t + \epsilon_{ikt} \tag{7}$$

This test is similar to the quasi-Rybczynski effect analyzed, among others, by Ventura (1997) and Romalis (2004). Note that we resort to panel data techniques to estimate equation 7. To control for zeros, we use Poisson fixed-effects regression techniques including year (μ_t) and city-product (μ_{ik}) fixed effects.

Table 4 shows the results for the two indicators using the within-groups estimation in columns (1) to (4) and the Poisson-fixed effects estimation in columns (5) and (6).[14] All the interaction coefficients are positive and significant for complexity and skill-intensity, in line with those obtained in Table 3. They confirm that exports of complex goods have grown more in cities that have experimented larger increases in population. All these findings confirm the export specialization patterns observed in previous sections.

4 Conclusions

Previous research shows that large cities have more productive firms, pay higher wages and have a superior share of educated workers than small cities. In this paper we test whether cities also differ in another economic aspect: export specialization. We analyze whether large cities export proportionately more complex and skill-intensive goods than

[14]The Hausman test indicates that the model should be estimated with fixed effects. Results for the Poisson estimation are the same either using random or fixed effects; thus, we select the fixed effects estimation because its equivalency with the PPML estimator when resorting to a panel database.

Table 4: Log-supermodularity regressions. Panel regression results for 2000, 2005 and 2013.

	PANEL				POISSON	
	(1)	(2)	(3)	(4)	(5)	(6)
Pop*complex	2.826***	1.414***			2.658***	
	(0.130)	(0.051)			(0.000)	
Pop*skills			0.530***	0.247***		0.528***
			(0.016)	(0.006)		(0.000)
Zero exports	No	Yes	No	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	31660	342868	31660	342868	51151	51151

Note: All regressions include city-product and year fixed effects.
Standard errors in parentheses. *** statistically significant at 1%, ** statistically significant at 5%.

small cities. To carry out the empirical analyses we use very detailed product-level export data for Brazilian urban areas. We find that cities differ in their trading-structure: large cities have a more diversified export product portfolio and tend to specialize in more knowledge-intensive products.

The elasticity test and the log-supermodularity regressions provide strong empirical support to the hypothesis that large cities specialize in complex and skill-intensive goods. We also provide evidence that as cities grow in population they tend to specialize in more complex goods. These results suggest that a large population facilitates the development of a comparative advantage in complex and skill-intensive goods.

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