Revista de Economia Contemporânea REC
Revista de Economia Contemporânea (2022) 26: p. 1-30
(Journal of Contemporary Economics)
ISSN 1980-5527
http://dx.doi.org/10.1590/198055272608
elocation - e222608
https://revistas.ufrj.br/index.php/rec | www.scielo.br/rec

INTERNATIONAL TRADE, WAGES, AND SKILL PREMIUMS IN BRAZILIAN MUNICIPALITIES FROM 2000 TO 2010

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Received on 04/17/2020
Accepted on 05/23/2022
Recebido em 17/4/2020
Aceito em 23/5/2022

ABSTRACT: This study aims to assess wage and skill premium responses to international trade in Brazil, determining different local specialization patterns with municipal data. We followed the theoretical model developed by Venables and Limão, who state that distance is a non-neutral variable in determining trade patterns. We used Chiquiar's empirical model, which includes pooled regression with microdata and feasible generalized least squares in three steps. Selection bias and omitted variable biases were evaluated based on Redding and Schott and Oster. Results show that wage and skill premium responses to international trade are heterogeneous and depend on the geographic location. International trade seems to help reducing interregional inequalities in Brazil. However, it seems to intensify inter-skill wage inequalities in more distant zones, like Midwest and North Brazil.

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Thus, the reduction in income inequality due to a greater trade liberalization is not homogeneous in all regions of this developing country. Therefore, policies that geographically spread the benefits of international trade within Brazil would have to consider the occurrence of these regionally heterogeneous responses.

KEYWORDS: Specialization zones; input prices; distance; municipalities; wages.

JEL CODES: F11; F14; F16; J31.

COMÉRCIO INTERNACIONAL, SALÁRIOS E PRÊMIOS POR QUALIFICAÇÃO NOS MUNICÍPIOS BRASILEIROS NO DECÊNIO 2000-2010

RESUMO: O objetivo deste artigo é identificar no Brasil as respostas dos salários e dos prêmios por qualificação ao comércio internacional, determinando os diferentes padrões locais de especialização com dados em nível municipal. O modelo teórico foi desenvolvido por Venables e Limão, os quais sustentam que a distância é variável não neutra na determinação dos padrões comerciais. O modelo empírico foi tomado de Chiquiar e consiste em uma regressão *pooled* com microdados por mínimos quadrados generalizados factíveis em três etapas. Vieses de seleção e de variáveis omitidas foram avaliados, apoiando-se em Redding e Schott e Oster. Os resultados apontam que as respostas dos salários e prêmios por qualificação ao comércio exterior são heterogêneas, a depender da posição geográfica. O comércio internacional parece contribuir para a redução das desigualdades interregionais no Brasil, mas nas zonas mais distantes, como no Centro-Oeste e Norte, parece intensificar as desigualdades salariais interqualificações. Logo, a redução da desigualdade de rendimentos em função de maior abertura comercial não é homogênea em todas as regiões de um dado país em desenvolvimento. Sendo assim, políticas que disseminem geograficamente os benefícios do comércio internacional no país teriam que considerar a ocorrência dessas respostas regionalmente heterogêneas.

PALAVRAS-CHAVE: zonas de especialização; preço de insumos; distância; municípios; salários.

INTRODUCTION

In recent years, protectionist policies and anti-trade forces increased worldwide. The current health and economic scenario tends to strengthen this movement. Part of this increase in trade restrictions has been attributed to the adverse effects of globalization on employment and income (IMF, 2017). Rodrik (2018) estimates that trade liberalization produced uncompensated losses to some groups within the same country, especially workers, and it has encouraged the political adherence to populist proposals advocating trade restrictions.

Several studies have been carried out in Brazil and abroad to better understand the relationship between trade liberalization and income distribution. However, in Brazil, most studies were carried out with national data and few analyses focused on the particularities of each Brazilian region, state, or municipality. Thus, considering the spatial dimension and municipal data, this study aimed to better understand different patterns of regional insertion in international trade. In other words, we intended to identify if Brazil presents a heterogeneity of wage and skill premium responses to variations in international trade and different specialization zones, as shown by Venables and Limão (2002). These authors attribute different effects of trade to geographical location and transportation costs and hypothesize that, under international trade, inequality would increase in distant regions with high transportation costs while nearby regions and/or regions with low transportation costs would show the effects expected by traditional trade theory. If this hypothesis is true, using aggregate data from one country would hide regional diversity regarding the response to international trade exposure.

This study used international trade data at the municipal level to reach the lowest level of aggregated data available by official Brazilian sources. Following Chiquiar (2008), we performed the analysis with a pooled panel including data from 2000 and 2010, and the comparison between results from the beginning and end of this period showed the evolution occurred. Both 2000 and 2010 are the extremes of the period in which municipal data, such as gross domestic product (GDP), trade variables, and controls used in this study, are found in official sources. We chose 2000 as the initial year because, as well as 2010, it was a year when Brazil conducted a demographic census, which enriches the use of control variables. International trade data at the municipal level were available by official sources only after 1997, thus we disregarded the 1990 census. This study is important not only to understand the relationship between trade liberalization and income distribution considering the spatial dimension, but also as a support for industrial policies and the insertion of Brazilian municipalities in international trade.

In order to achieve our objectives, the next section presents a literature review on the topic, section 2 presents its theoretical aspects, section 3 describes our empirical strategy and the data used in the estimations, section 4 presents and discusses the results, and section 5 presents the final considerations of this study.

1. LITERATURE REVIEW

The study of the effects of globalization and trade liberalization on income distribution is a widely debated topic in the literature. The Heckscher-Ohlin (HO) international trade theory and the Stolper-Samuelson (SS) theorem are references to explain the effects of trade on income distribution among productive factors. According to the traditional theory, countries relatively abundant in unskilled labor, when trading their products with countries relatively abundant in skilled labor, tend to present a decrease in skill premiums and thus a decrease in income inequality between skilled and unskilled workers. The national and international debate on the relationship between trade and income distribution has been extensive and does not always confirm the expected results.

At the international level, Goldberg and Pavcnik (2007) present a literature review on the effects of globalization on developing countries during the 1980s and 1990s. Arbache (2001) discusses models that seek to explain why trade liberalization increased wage inequality in several developing countries. In some Latin American countries, results show that trade liberalization did not improve income distribution. Several arguments try to explain this behavior. In Colombia, for example, Attanasio, Goldberg, and Pavcnik (2004) state that the strongest tariff shock, among other factors, would have occurred in unskilled labor-intensive sectors. On the other hand, Feenstra and Hanson (2003) state that the international fragmentation of production may explain the increasing wage inequality between skilled and unskilled workers. Pedroso and Ferreira (2000) studied the relationship between trade liberalization and per capita income levels between countries, using instrumental variables and cross-section econometric models for 1988 and panel data for the 1960/1985 period. According to these authors, results show little relevance of trade liberalization in income inequalities between countries.

In Brazil, Barros et al. (2001), using a computable general equilibrium model and information from the National Household Sample Survey (PNAD), studied the effects of trade liberalization and the financial market on income distribution in 1996. Results showed that trade liberalization affected much less than capital inflow and the authors concluded that the labor market was little affected by trade liberalization and the effects on income distribution were insignificant.

On the other hand, Ferreira and Machado (2001), using the Heckscher-Ohlin-Samuelson model and data from IBGE, studied the effects of trade liberalization on employment and wages in Brazil and their results agreed with the predictions of the theory.

Labor-intensive sectors increased total employment and variations in relative prices passed on to the real wage, as expected. Machado and Moreira (2001) also used the Heckscher-Ohlin model to study the effect of trade liberalization on workers' wages in Brazil from 1985 to 1997. These authors observed a preference for less-skilled labor, as predicted by the theory, from 1990 to 1993 and a preference for skilled labor from 1993 to 1997.

Menezes-Filho and Arbache (2002) analyzed the determinants of inter-industry wage differentials and found that the import penetration rate in industry greatly increased after trade liberalization, changing allocations with potential effects on the labor market. According to these authors, productivity gains resulting from trade liberalization did not increase relative wage to the same extent. On the other hand, Arbache and Corseuil (2004) found that the effects of trade liberalization on employment and wage structure were neglectable. This is probably due to the high temporal stability of employment and wage structures, which is associated with the labor market structure and technology distribution among sectors.

Pavcnik et al. (2004) studied the period from 1988 to 1994 and concluded that trade liberalization in Brazil did not contribute significantly to increase wage inequality between skilled and unskilled workers by changing industry wage premiums. Bloch and Soares (2019) also found few effects of trade liberalization on inequality. These authors estimated the distributional effects of trade liberalization on income distribution among workers in the same industry sector. They performed econometric estimates of the relationship between effective protection rates and several income inequality indicators for each industry sector and found a significant but small relationship between trade liberalization and wage inequality and another one, even smaller, between trade liberalization and the ratio between wage bill and added value. Thus, a large decrease in the effective protection rate leads to a small reduction in wage inequality between sectors and an even smaller increase in functional inequality within the same sector.

Ferreira, Leite, and Wai-Poi (2007) used national data to analyze the relative importance of trade effects on industry wage premiums, skill premiums, and employment flows in Brazil as a result of changes in wage distribution from 1988 to 1995 (the trade liberalization period). These authors found that, different from other Latin American countries, trade liberalization in Brazil significantly contributed to decrease wage inequality. These effects did not occur by premium changes in specific industries, but were channeled by significant employment flows between sectors and formal categories. Changes in skill premiums across the economy were also important. In contrast, Gonzaga, Menezes-Filho, and Terra (2006) analyzed the role of the trade liberalization implemented in Brazil from 1988 to 1995 regarding the decrease in the skilled workers' relative gains. These authors found that, among other results, employment changed from skill-intensive to unskilled-intensive sectors. They also found that each sector increased skilled labor and relative prices decreased in the skill-intensive sectors. Using microdata, Campos, Hidalgo, and Da Mata (2007) studied the effects of intra-industry trade on income inequality in 22 segments of the Brazilian manufacturing industry. Income inequality between skilled and unskilled workers tended to reduce from 1997 to 2002.

The aforementioned studies generally use national data. In more recent years, studies on the effects of trade liberalization considered regional data. Fally, Paillacar, and Terra (2010) studied the effects of access to markets and suppliers on wage inequalities between Brazilian states, controlling for individual characteristics in the new economic geography methodology. These authors estimated the access disaggregated by industries and three market levels—local, national, and international—using instrumental variables and found a strong correlation between market access and wage inequalities, even after controlling for individual characteristics and market access level.

More recently, Dix-Carneiro and Kovak (2017) analyzed the regional effects of trade liberalization and found that regions with larger tariff cuts presented extended drops in formal sector employment and earnings when compared with other regions. On the other hand, Dix-Carneiro and Kovak (2019) studied several margins of labor market adjustment after trade liberalization in Brazil in the early 1990s and observed how workers and regional labor markets adjust to trade-induced changes in local labor demand. These margins include wage gains and changes, inter-regional migration, changes between tradable and non-tradable employment, and changes between formal and informal employment and non-employment.

Since Brazil is a continental country, the real effect of trade may be obscured by the use of aggregate data and negligence over the variable distance. This study contributes to the national literature by studying this topic considering municipal data. Moreover, different from the aforementioned studies, we consider distance a non-neutral variable, according to the model by Venables and Limão (2002).

2. THEORETICAL MODEL: FACTOR INTENSITY AND TRANSPORT INTENSITY[1]

If the labor force in Brazil were homogeneous and mobile, wages would be equalized across the country, except for regional amenities or the prices of non-tradable goods. In this scenario, if international trade included regionally heterogeneous shocks, the adjustment would cause the workforce reallocation between regions rather than changes in wage inequality.

However, the labor force is neither homogeneous nor mobile between regions. Hidalgo and Sales (2014) showed that wages across regions of Brazil differ and respond

[1] This section focuses on theoretical aspects and is highly supported by Venables and Limão (2002). See also: Chiquiar (2008) and Hidalgo and Sales (2014).

differently to international trade shocks. According to Chiquiar (2008), admitting imperfect factor mobility, heterogeneity in endowments, or differences in the geographical location of each region may be important to determine the local specialization pattern or input price. Thus, the heterogeneous wage response to international trade exposure is due to both the difference in factor endowments and the intensity in the use of transportation.

2.1. FACTOR AND TRANSPORT INTENSITY IN DETERMINING REGIONAL TRADE PATTERNS

Formally, the model considers a central region—the international market, in this study—and regions that are gradually more distant from it. Three products are produced and tradable (0, 1, and 2). The geographical space is the real line and its origin ($z = 0$) represents the international market. To the right of 0, regions of Brazil are arranged according to their distance from the international market.

The price, production, and unit cost of producing the good i in the region (z) are $p_i(z)$, $x_i(z)$ and $b_i(wL(z), wH(z), p_0(z))$, respectively, where $wL(z)$ and $wH(z)$ are the prices of the factors "unskilled labor" ($L(z)$) and "skilled labor" ($H(z)$), respectively. In each region where i is produced, the price is equal to the unit cost while in regions where it is not produced, the unit cost may be higher than the price, considering the additional transportation.

$$p_i(z) \leq b_i(wL(z), wH(z), p_0(z)\ x_i(z)) \geq 0, \text{ Complementary slack } i = 0, 1, 2 \tag{1}$$

The factor "market in each region" is the result of the sum of the product between the marginal cost of each good produced and the product:

$$L(z) = x_0(z) \bullet \frac{\partial b_0(wL, wH, p_0)}{\partial wL} + x_1(z) \bullet \frac{\partial b_1(wL, wH, p_0)}{\partial wL} + x_2(z) \bullet \frac{\partial b_2(wL, wH, p_0)}{\partial wL} \tag{2}$$

$$H(z) = x_0(z) \bullet \frac{\partial b_0(wL, wH, p_0)}{\partial wH} + x_1(z) \bullet \frac{\partial b_1(wL, wH, p_0)}{\partial wH} + x_2(z) \bullet \frac{\partial b_2(wL, wH, p_0)}{\partial wH} \tag{3}$$

The income level is calculated by: $y(z) = wH(z) \cdot H(z) + wL(z) \cdot L(z)$. Consumers are assumed to present utility $u(z)$ by a homothetic expenditure function, so the equality between income and expense in the region z is calculated by: $y(z) = e(p_0(z), p_1(z), p_2(z)) \cdot u(z)$.

The international market exports good 0 and imports goods 1 and 2. The price of x_0 to the international market is the unit and its income is fixed for good 0. The imports of the other two goods, $c_1(0)$, are given by import demand functions. Regions $z > 0$ can produce all three goods using primary factors and the good x_0 as an intermediate.

Thus, determining the price of the goods $p_i(z)$ is possible. The prices of goods in the international market, $p_0(0)$ (which is described as numeraire), $p_1(0)$, and $p_2(0)$, are exogenous. Transportation costs lead to "price-over-space" functions. The goods produced are subject to trade costs that grow exponentially and deliver a unit cost of the good i from region z_0 to z_i $\tau_i(z_0, z_i) = \exp t_1 \mid z_0 - z_i \mid \geq 1$.

Considering the price of good 0, $p_0(0)$, as we move away from $z = 0$, the price function grows exponentially. The regions can be sufficiently distant for the import to be 0, $c_1(z) = 0$. To the left of this region $c_1(z) \geq 0$, the price is determined by imports from the center, $p_0(z) = \tau_0(z)$. To the right of this region, $c_i(0) = 0$, all regions are disconnected from the international market and present $p_0(z) \leq \tau_0(z)$. Then, these regions would be self-sufficient in good 0 and its price would be determined by local conditions, which would provide the autarky price.[2]

The prices of the other two goods, $p_1(z)$ and $p_2(z)$, have two components: prices established by the international market— $p_1(0)$ and $p_2(0)$ —and distances regarding the international market. Therefore, they depend on transportation costs, as well as in determining $p_0(z)$; however, since these products will be shipped to the international market, this function presents a negative gradient. A cut-off point or region, where it would no longer be profitable to export these goods, would exist. To the left of these points, prices would be determined by the central region transportation costs. To the right, regions would be self-sufficient and pricing would be autarkic.

Thus, the functions "product prices" and "factor prices" are determined according to distance and transportation costs. In regions where a given good is self-sufficient, the equality of local supply and demand determines its price. This hypothesis is supported by transportation costs that exceed the price of a good if it is locally produced. For free trade products, the global supply and demand determine "price" functions.

SPECIALIZATION ZONES

Differing from the traditional Heckscher-Ohlin model, the model used in this study considers that the production and trade patterns in different regions would be determined not only by different factor endowments, but also by different transport intensities, which could be compensated with a shorter distance or better infrastructure. By optimizing choices, the interaction between geography and relative factor endowment would make economic activities organize themselves in such a way that the regions in which they are located would

[2] Autarky price is the price of goods in a closed economy.

developed zones with different trade and production patterns. Some regions—for which the relative transport intensity is determinant—would be export-oriented: they would produce transport-intensive goods and the short distance from trade centers would compensate the high transportation cost. In turn, distant regions oriented to import substitution would exist, since the long distance from trade centers would make it autarkic. Between these two extremes there would be regions that, as distance increases, would substitute trade for production, producing more transport-intensive goods and trading less transport-intensive goods.

Venables and Limão (2002) define specialization zones based on the result of the interaction between geography and factor endowment. To structure the interaction model, they considered regions with uniform relative endowment of production factors deciding to import good 0 (to use it as a production input) and produce goods 1 and 2 (considering good 1 more transport-intensive than good 2). The transport intensity of goods is the proportional change in the transportation cost of an increase in distance per unit of value added. The intensity is higher when the transportation cost and the share of imported input (0) in its cost are higher. Therefore, they define trade and production patterns in space by establishing five specialization zones:

Zone I: Regions specialized in the production of exportable goods and located close to the international market. They produce and export the transport-intensive good 1 and import goods 0 and 2.

In this zone, transportation costs cause equiproportional drops in factor prices, thus transportation costs do not change income inequality—this inequality would only be affected by the difference in the intensity of factors used in the production of goods 1 and 2. Moreover, the profitability of good 2 (less transport-intensive than good 1) would depend on the relative transport intensity and the relative change in factor abundance in these regions. If regions become more abundant in skilled labor and good 2 is intensive in this factor, its profitability increases.

Zone II: Regions that produce goods 1 and 2 and export good 1. The production of good 1 decreases with distance while the production of good 2 increases because of the lower transport intensity. In zone II, both activities are active. Goods 1 and 2 present different factor intensities and good 2 is more intensive in skilled labor, which leads to a divergence in factor prices.

Since good 1 is transport-intensive, the relative price of the intensive factor in good 1 (unskilled labor) decreases as distance increases because its production decreases. It encourages both industries (goods 1 and 2) to become more intensive in unskilled labor, as it becomes cheaper. The full use of factors requires industry 1 to reduce and industry 2 to expand.

This zone presents characteristics of a Heckscher-Ohlin type economy, as it exports the good that uses its abundant factor intensively and its trade is inter-industry, which encourages specialization. Factor prices change only because of transportation costs and are independent of factor endowments. The more distant from the international market, the higher the price of skilled labor and the lower the price of unskilled labor, which makes it achieve the usual Stolper-Samuelson effect.

Zone III: This zone is sufficiently distant to make the production of good 1 unprofitable. It is self-sufficient in good 1 and continue to export good 2 and import good 0.

Therefore, local conditions determine the price of good 1 while sales to the international market determine the price of good 2. In this zone, importing good 0 is more preferable than producing it locally, as its transportation cost per unit is still lower than its production cost per unit. It is not a Heckscher-Ohlin type zone because only good 2 is produced and, thus, factor prices depend on local endowments and preferences.

Zone IV: It is an import substitution zone. Importing good 0 from the international market becomes so expensive that it becomes more profitable to produce it locally. In this zone, each region imports good 0 and exports good 2, but in progressively smaller quantities inland.

This zone produces all three goods. Goods 0 and 2 are tradable to the international market while good 1 is produced for local sale. Factor prices become independent of their endowments and preferences. The transport intensities of industries 0 and 2 determine factor prices. The price of skilled labor decreases and the price of unskilled labor increases if good 0 is unskilled labor-intensive in comparison with good 2.

Zone V: It would be the autarky zone. Local supply and demand determine all prices.

Based on the characteristics of the zones and according to the hypothesis of homogeneity in the relative factor abundance, a country abundant in unskilled labor would produce in all its regions products that are intensive in this factor (good 1, for example). If this product was still transport-intensive, as distance increases, the different regions would exchange production of the abundant intensive good (good 1) for the non-abundant but low transport-intensive good (good 2). The result in factor prices as a function of trade would be increased inequality in distant regions.

3. EMPIRICAL STRATEGY AND USED DATA

3.1. EMPIRICAL STRATEGY

The empirical strategy follows the approach used by Chiquiar (2008) and analyzes input price behavior patterns[3] to determine in Brazil the specialization zones established by Venables and Limão (2002) and presented in the previous section.

[3] Inputs are unskilled labor and skilled labor and their prices are absolute wages at 2000 prices. The regression uses the variable “years of schooling” to determine the premium for each additional year of qualification so that intercepts represent wages between people of equal skill level or less skilled.

Chiquiar (2008) studies the effect of NAFTA on the Mexican economy. The author predetermines the regions considered close to and distant from the US and observes the movement of the coefficients of regional dummies, which represent the regional differential in wages and skill premiums, by inserting control variables of local characteristics and trade exposure variables.

This study addresses the international trade of Brazil in general, not regarding a specific trade center. Over the decade, the international trade of Brazil has been choosing different destinations with a significant volume, as selecting one of them as the center of relevant trade seems inappropriate. Thus, establishing in advance which region is distant or close seems inappropriate. This study aimed to analyze the patterns of the zones established by Venables and Limão (2002), based on the movement of the coefficients of regional dummies, according to Chiquiar (2008), and establish which regions in Brazil can be considered distant and which can be considered close to determine specialization zones.

REGRESSION WITH MICRODATA AND MUNICIPAL DATA, AUTO-SELECTION, AND OMITTED VARIABLES

We regressed a three-step equation using feasible generalized least squares (FGLS),[4] based on data from the extreme years of the 2000s. Each stage included different control groups, with wages (y) depending on: i) individual characteristics (years of schooling, experience, squared experience, gender, and industry sector); ii) municipal characteristics;[5] iii) international trade exposure variables. We included dummies in each regression for the 136 Brazilian mesoregions, in addition to the base group, to evaluate the wage differential in response to the control groups. We also included mesoregional dummies

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[4] Due to the verification of the presence of heteroscedasticity by the Breusch-Pagan and White tests in the regressions by OLS, we opted for FGLS, which minimizes its effects. If the error terms were correlated and/or if the error term was correlated between observations, two of the questions that classified the estimator by OLS as the best non-biased estimator were not satisfied. In this case, an estimator commonly mentioned in the literature as a better non-biased estimator was the one that obtained it by generalized least squares (GLS), at least asymptotically (STOCK; WATSON, 2004). The exact functional form of heteroscedasticity is hardly known. However, it can be estimated using data to estimate the unknown parameter of GLS, which makes it feasible. The procedure requires: i) performing the model regression by OLS and obtaining the residuals ($\hat{u}$); ii) creating In ($\hat{u}^2$) ; iii) regressing In ($\hat{u}^2$) against the model variables and taking the estimated values ($\hat{g}$); iv) taking the exponential of the estimated values $\hat{g}$, $\hat{h}$ = exp($\hat{g}$); v) estimating equation 4 using $1/\hat{h}$ as a weight on all variables (WOOLDRIDGE, 2002).

[5] The variables of municipal characteristics were the dummy for the population size range of the municipality, average schooling level of workers, altitude and average annual rainfall, percentage of the economically active population in the total population (for the labor factor), planting area by municipality (for the land factor), and vehicle fleet (for the capital factor).

iterated with education to evaluate the return according to the schooling level in each mesoregion. In order to test the statistical significance of these dummies, we evaluated if the inclusion of controls modifies the observed change in wages.[6]

The trade exposure variables were variables of interest. Their vector included the openness coefficient, distance to the economic center, and, according to Hanson (2003) and Chiquiar (2008), the fraction of personnel employed in the agriculture and industry sectors as proxy of the orientation of the municipality regarding tradable sectors. The inclusion of these variables in the model caused changes in the regional intercepts. These changes were the input for the analysis of the effects of trade exposure on wages and skill premiums.

Thus, the estimated equation was:

$$Y_{iz} = \beta_0 + \beta_1 Ex_{iz} + \beta_2 Ex_{iz}^{\ 2} + \beta_3 AE_{iz} + \boldsymbol{\beta_{Di} Di_{iz}} + \boldsymbol{\beta_{Cl} Cl_z} + \boldsymbol{\beta_{CExt} CExt_z} + \boldsymbol{\beta_{Dz} Dz_i} + \boldsymbol{\beta_{DzAE} DzAE_i} + \varepsilon_{iz} \quad \textbf{(4)}$$

In (4), Y_{iz} is the average annual absolute wage of worker i in country z at 2000 prices, in natural logarithm, Ex_{iz} is the worker i's experience, AE_{iz} is the worker i's years of schooling, Di_{iz} is a vector of dummies of individual characteristics (gender and industry sector), Cl_z is the vector of controls for municipal characteristics, $CExt_z$ is the vector of international trade exposure variables, Dz_i is the vector of dummies for mesoregions, and $DzAE_i$ are the dummies for mesoregions iterated with years of schooling. We regressed this equation twice, once for 2000 and once for 2010.

In order to analyze the change that occurred over the decade, we performed a third regression with data from 2000 and 2010, appended for a pooled regression, in accordance with Chiquiar (2008). We added a dummy for year and iterated it with all variables. This dummy assumed a value of 1 for 2010 and 0 for other years. Thus, its coefficient (β_4) represents the difference of the 2010 intercepts in comparison with 2000 (β_0). The iterated coefficients of this dummy with other variables represent the differential sensitivity of the dependent variable regarding the independent variables between one year and the next. It allowed us to test the statistical significance of the

[6] The existence of self-selection in the decision to participate is an issue that may arise. For example, skilled workers are more mobile and the activity concentration can increase the productivity of these workers, either via scale economies or widespread connections in sectors abundant in skilled workers (REDDING; SCHOTT, 2003). We performed a spatial analysis of the distribution of the Brazilian workforce and it showed no significant changes between regions according to schooling level, age group, and time. Moreover, municipal controls, which include variables of urban agglomeration, local amenities, and factor endowments, should minimize it. Another issue includes individual heterogeneity not observed and family and demographic characteristics. However, while it may affect the estimation of return by schooling level, it would hardly affect mesoregional dummies. Even so, we performed the robustness test regarding non-observables, according to Oster (2014).

differences in coefficients between 2000 and 2010. Equation (5) represents this third regression, where the variables and coefficients in bold represent vectors.

$$\begin{aligned} Y_{iz} = {} & \beta_0 + \beta_1 Ex_{iz} + \beta_2 Ex_{iz}^{\;2} + \beta_3 AE_{iz} + \boldsymbol{\beta_{Di} Di_{iz}} + \boldsymbol{\beta_{Cl} Cl_z} + \boldsymbol{\beta_{CExt} CExt_z} \\ & + \boldsymbol{\beta_{Dz} Dz_i} + \boldsymbol{\beta_{DzAE} DzAE_i} + \beta_4 D_{2010} + \beta_5 D_{2010} Ex_{iz} \\ & + \beta_6 D_{2010} Ex_{iz}^{\;2} + \beta_7 D_{2010} AE_{iz} + \boldsymbol{\beta_{Di_{2010}} D_{2010} Di_{iz}} \\ & + \boldsymbol{\beta_{Cl_{2010}} D_{2010} Cl_z} + \boldsymbol{\beta_{Ext_{2010}} D_{2010} CExt_z} + \boldsymbol{\beta_{Dz_{2010}} D_{2010} Dz_i} \\ & + \boldsymbol{\beta_{DzAE_{2010}} D_{2010} DzAE_i} + \varepsilon_{iz} \end{aligned} \qquad (5)$$

In order to assess the existence of omitted variable bias, we used the method presented by Oster (2014), who evaluated the movements in the coefficients with the inclusion of controls combined with an evaluation of the movements in R^2. This method uses the hypothesis of proportional covariance relationship in observables and non-observables and suggests (1) calculating the bias under the hypothesis $\delta = 1$ and/or (2) calculating the value of δ so that $\beta = 0$.[7]

STRATEGY TO INTERPRET RESULTS

In order to interpret the results, first, we evaluated the movement of the regional wage differential (betas of mesoregional dummies [Dz_i]) at the three control groups (individual characteristics, municipal characteristics, and trade exposure variables). Second, when determining specialization zones, we added the regression constant (β_0) to the coefficient of the mesoregional dummy (β_{Dz_i}) to obtain the wage in the estimated natural logarithm for each mesoregion. We also added the coefficient of the variable "years of schooling" (β_3) to the coefficient of the iteration (β_{DzAE_i}) to obtain the education premium in the estimated natural logarithm for each mesoregion. Thus, three steps were necessary to determine specialization zones:

- First: We performed a first regression with the wages (Y_{iz}), depending on the vector of individual characteristics (Ex_{iz}, $Ex_{iz}^{\;2}$, AE_{iz}, and Di_{iz}) from mesoregional

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[7] $Y = \beta X + \gamma w_1^{\,0} + W_2 + \epsilon$, where X represents the treatment and $w_1^{\,0}$ and W_2 the observables and non-observables, respectively. Since W_2 is non-observable, it is not present in the regression and provides bias. The proportional selection hypothesis is $\delta \frac{\sigma_{1x}}{\sigma_{11}} = \frac{\sigma_{2x}}{\sigma_{22}}$, where $\sigma_{ix} = Cov(W_i, X)$ and $\sigma_{ii} = Cov(W_i)$, and δ is the proportionality coefficient. Also considering $\dot{\beta}$ and $\dot{R}$ the coefficient and the R^2 of the regression between Y and X, $\tilde{\beta}$ and $\tilde{R}$ are the coefficient and the R^2 of the regression between Y, X, and $w_1^{\,0}$. Finally, R_{max} is the R^2 of the hypothetical regression of Y on $w_1^{\,0}$ and W_2. The selection bias is , $\dddot{\beta} = \tilde{\beta} - \delta\left[\dot{\beta} - \tilde{\beta}\right]\frac{R_{max} - \tilde{R}}{\tilde{R} - \dot{R}}$,where $\dddot{\beta} \xrightarrow{p} \beta$ and $\delta \approx \frac{\tilde{\beta} - \dddot{\beta}}{\dot{\beta} - \tilde{\beta}} \cdot \left(\frac{\tilde{R} - \dot{R}}{R_{max} - \tilde{R}}\right)$ .Thus, when calculating δ, we seek to know how great the bias should be so that the effect of treatment β could be 0. A value greater than the unit is sought, for example: $\delta = 2$, which means that non-observables would need to be two times more important than observables to produce a treatment effect = 0. If $\delta=1$, non-observables are at least as important as observables (OSTER, 2014).

dummies (Dz_i), which were iterated with education ($DzAE_i$). Then, we obtained wages ($\beta_0 + \beta_{Dz_i}$) and skill premiums ($\beta_3 + \beta_{DzAE_i}$).

- Second: We performed a second regression including to the first one the municipal characteristics (Cl_z) listed under footnote 6. These variables represent the set of items that determines the municipal factor endowment profile. We computed the regions in where estimated wages ($\beta_0 + \beta_{Dz_i}$) and skill premiums ($\beta_3 + \beta_{DzAE_i}$) decreased. Regions where they increased and regions where they did not change significantly were compared with the ones obtained in the first regression.
    - Decreased wages ($\beta_0 + \beta_{Dz_i}$), due to the inclusion of factor endowments (Cl_z), show that the wage premium previously attributed to the region can actually be attributed to factor endowments—their absence in the first regression overvalued the regional intercept. It would show that non-skilled wage would increase as a function of factor endowment in the mesoregion. According to the theoretical model, this movement in the sum of coefficients is probably due to a relative abundance in unskilled labor or the production of unskilled labor-intensive products.
    - Increased wages ($\beta_0 + \beta_{Dz_i}$) shows a negative premium in wages attributed to factor endowments—their absence previously undervalued the regional intercept. It would show that low-skilled labor loses wages due to endowments. According to the theoretical model, we could hypothesize that the analyzed region presents low relative endowment of unskilled labor or produces products that are not intensive in the use of this factor.
    - Regions without significant changes in wages ($\beta_0 + \beta_{Dz_i}$) show that their regional wage is little responsive to factor endowments.
    - We performed the same analysis with estimated qualification premiums ($\beta_3 + \beta_{DzAE_i}$) . If it decreased, the region presented a positive education premium, which is attributed to factor endowments. In this case, the region was relatively abundant in skilled labor or produced labor-intensive products. If it increased, the region presented a negative education premium, which is attributed to factor endowments. The region would produce products that are not intensive in this factor. Unchanged coefficients represent regions with education gains that are little responsive to factor endowments.
- Third: We performed a third regression including international trade exposure variables ($CExt_z$). We computed regions where wages ($\beta_0 + \beta_{Dz_i}$) and skill premiums ($\beta_3 + \beta_{DzAE_i}$) decreased, regions where they increased, and regions where they did not change significantly. As well as in the previous step, the next task involves the following interpretations:

- Decreased wage shows that the positive wage premium that previously overvalued the regional intercept, when compared with the second regression, may be attributed to the international trade exposure. Thus, wages in these regions respond positively to the international trade exposure. According to the theoretical model, they would be relatively abundant in unskilled labor, produce products intensive in this factor and/or not have their gains compromised by transport intensity. Moreover, their participation of imported inputs would be low or null. Mesoregions that presented this movement, in addition to a high openness coefficient, could be categorized as zones I or II, but never IV or V.
- The same movement in the skill premium $(\beta_3 + \beta_{DzAE_i})$ shows a positive education premium attributed to international trade. In these regions, skilled labor earns more in the presence of international trade and wage inequality increases. According to the theoretical model, if a country is relatively abundant in unskilled labor, the presence of trade can promote a wage gain in skilled labor if the product that is intensive in this factor is also non-intensive in transport or the share of the imported input in its composition is low. Mesoregions with this characteristic can be classified as zone II or III if they present a positive openness coefficient, and IV or V if the openness coefficient is low or zero.
- Increased wages shows a negative premium in the region attributed to international trade—its missing variables previously undervalued the regional intercept. In these regions, wages respond negatively to international trade exposure. It means that low-skilled labor loses with trade. According to the theoretical model, it would occur if: i) the region produces products that are intensive in other production factor; and/or ii) the region makes unskilled labor-intensive products also intensive in transportation costs and/or has a high share of imported inputs. These regions would be classified as zones III, IV, and V, depending on the degree of trade liberalization, but never I or II.
- The same movement in the skill premium shows a negative education premium attributed to international trade. In these regions, skilled labor decreases in the presence of trade and wage inequality also decreases. It means that skilled labor loses with trade. According to the theoretical model, it occurs if the region is abundant in unskilled labor and produces products that are intensive in this factor. Moreover, these products have low transport intensity and/or the share of imported inputs in their composition is low. If the country has low relative abundance in skilled labor and the region presents a high openness coefficient, it can be classified as zone I or II, but never V.

This interpretation is quite counterintuitive, since it associates decreases in coefficients with increases in the variables they represent, so it requires a special mental effort to appreciate the results. Therefore, we suggest you take a moment to structure this new mental map and truly understand it. Chart 1 presents how zones were defined based on the combined movement in coefficients of wages ($\beta_0 + \beta_{Dzi}$) and skill premiums ($\beta_3 + \beta_{DzAE_i}$) with the insertion of the factor endowment and trade exposure variables.

Chart 1 – Wage and skill premium movements in the regression steps and classification of Brazilian mesoregions according to the specialization zones by Venables and Limão (2002)

Movements in the regression coefficients			Mesoregion classification
Inclusion of variables	Variations in ($\beta_0 + \beta_{Dz_i}$)	Variations in ($\beta_3 + \beta_{DzAE_i}$)	
Second regression compared to the first – Factor endowment	Undefined	Undefined	Zone I
Third regression compared to the second – Trade exposure	Decreased	Unchanged	
Second regression compared to the first – Factor endowment	Unchanged	Unchanged	Zone II
Third regression compared to the second – Trade exposure	Increased	Decreased	
Second regression compared to the first – Factor endowment	Increased	Increased	Zone III
Third regression compared to the second – Trade exposure	Unchanged	Unchanged	
Second regression compared to the first – Factor endowment	Unchanged	Unchanged	Zone IV
Third regression compared to the second – Trade exposure	Decreased	Increased	
Second regression compared to the first – Factor endowment	Undefined	Undefined	Zone V
Third regression compared to the second – Trade exposure	Unchanged	Unchanged	

Source: Authors' elaboration.

We expect that regions classified as zone I increase wages (decrease by $\beta_0 + \beta_{Dzi}$), as they would be exporters of the intensive good in the abundant factor. On the other hand, we expect the skill premium to remain unchanged, as the skilled labor factor would be employed in non-exportable products. In contrast, the expected effect of factor endowment is undefined, as coefficients can either increase or decrease depending on the factor distribution throughout zone I.

Regions classified as zone II are both producers and exporters of intensive goods in the abundant factor and producers of intensive goods (non-intensive in transportation) in the non-abundant factor. Factor prices respond more to transportation costs and are independent of endowments. Therefore, we expect that, as a function of factor endowments, the wage and skill premium coefficients remain unchanged. On the other hand, as a function of trade, we expect wages to decrease (increase by $\beta_0 + \beta_{Dz_i}$) and the skill premium to increase (decrease by $\beta_3 + \beta_{DzAE_i}$), gradually intensifying inequality.

Regions classified as zone III export non-transport intensive goods. Factor prices depend on local endowments and preferences. Therefore, we expect that inserting trade variables will not change coefficients, but that the endowment variables will increase both wages and skill premiums. The income inequality movement depends on the relative abundance of factors and the demand for the products they would produce.

Regions classified as zone IV are import substitution regions. Microregions would produce products that are intensive in both factors. While one exports goods that are intensive in the abundant factor, other starts producing products that are imported by other zones. If the imported inputs now produced are unskilled labor-intensive, the price of this factor increases (decrease by $\beta_0 + \beta_{Dz_i}$) by import substitution while the skill premium decreases (increase by $\beta_3 + \beta_{DzAE_i}$).

Regions classified as zone V are closed to trade because the transport intensity makes exports and imports impossible. In this case, we do not expect coefficients to vary with the insertion of variables. The insertion of factor endowment variables changes coefficients depending on the relative abundance of these factors in the region, thus the variation can be either favorable or unfavorable to reduce inequality.

3.2. DATA USED

We performed the analysis with microdata from the Annual Social Information Report (RAIS – *Relação Anual de Informações Sociais*, in Portuguese), which included all active employees in December 2000 and December 2010. This database provided the value of the average annual income and the workers' individual characteristics. We collected 28,345,964 observations for 2000 and 43,270,151 for 2010.[8] We removed a random sample of 15% of the 2000 data and 7,5% of the 2010 data. Municipal data presented no trade data before 1997. Therefore, we did not use data from the 1991 census. Chart 2 shows the selected variables and their sources.

[8] The sample size was defined by the technological constraints available for this study, a server with 32G RAM, octacore, working with regressions in the statistical programs R and Stata 13.0.

Chart 2 – Variables and information sources

Variables	Description	Source
Dependent variable (y_{it})		
Wage (Y_{iz})	Annual average value of the absolute wage received by individual *i* in municipality *z* at 2000 prices, with the 2010 values deflated by the IGP-di.	RAIS and FGV
Variables of interest (x_z)		
Openness coefficient	Ratio between the sum of municipal exports and imports and the GDP in dollars of municipality *z*.	SECEX, IBGE, and IPEADATA
Fraction of personnel employed in agriculture and livestock	Logarithm of the participation of the personnel employed in agriculture and livestock per municipality.	RAIS
Fraction of personnel employed in industry	Logarithm of the participation of the personnel employed in industry per municipality.	RAIS
Distance from the economic center	Calculation according to Smarzynska (2001)	
Individual controls		
Experience	Calculated as age – 6 – years of schooling.	RAIS
Experience^2/100	The variable "experience" squared.	RAIS
Years of schooling[9]	The worker's degree of education, obtained by converting the achieved education level into years.	RAIS
Age group dummy	Age group of individual *i* in municipality *z*. In this study, we considered individuals aged 18 to 64 years old. The base group is from 30 to 39 years old.	RAIS
Sector dummy	Sector in which individual *i* works, with trade as the base group.	RAIS
Municipal controls		
Spillover	Average schooling level of workers in municipality *z*, representing the human capital spillover.	RAIS
Municipality size dummy	Municipality size range. Two categories: less and more than 500,000 inhabitants. The base group was a population of less than 500,000 inhabitants, representing the urban agglomeration effect.	IBGE
Altitude	Altitude of the municipality, according to the political-administrative division into force in 2000.	IPEADATA
Rainfall	Average of the estimates of quarterly rainfall averages.	IPEADATA
Labor factor endowment	Percentage of the economically active population within the total population.	IBGE
Earth factor endowment	Amount of planting area, in natural logarithm[10].	IPEADATA/ IBGE
Capital factor endowment	Vehicle fleet as proxy, in natural logarithm.	DENATRAN

Source: Authors' elaboration.

[9] Years of schooling may be inaccurate, as they are estimated based on the schooling level reported. When the schooling level was incomplete, we attributed the number of years that corresponds to half of the way to complete it. In this sense, the variable "experience" is also innacurate.

[10] Regarding municipalities that did not present planting areas in the years studied, we attributed the maximum value of the planting area of municipalities within the same population range in the group.

Besides these variables, we included mesoregional dummies, with the macro-metropolitan area of São Paulo as the base group, which presented the median of the average wage in 2000. The municipal GDP for the period was changed into dollars in the average annual exchange rate provided by IPEADATA.

4. RESULTS

This section presents the results of the estimation of equations (4) and (5). Table 1 shows it in greater detail. The results in column I come from wages depending only on individual variables and show that wages, represented by the constant, increased and the skill premium decreased during the decade in Brazil, although this change was not statistically significant. The experience gain became flatter while the gender wage gap decreased by about 5%.

In the first regression, some mesoregions presented large intercepts[11] and lower return to education, which became a pattern in regions close to the international market, according to the model. Other mesoregions presented low intercepts and higher return to education, which became a pattern of regions distant from the international market. We ranked these coefficients to obtain the positioning of the mesoregions in Brazil according to wage and skill premium. Ten of the 136 mesoregion dummies and 78 of the iterations were not statistically significant. For these regions, the analysis was complemented by the ranking of the openness coefficient and average annual wages.

Mesoregions with the pattern of regions close to the international market were concentrated in South, Southeast, and Midwest Brazil, besides some in the northeastern coast. Mesoregions with the pattern of regions distant from the international market were concentrated in North and Northeast Brazil, besides some mountainous mesoregions in Midwest and Southeast Brazil. The most positive changes in wages during the 2000s, according to an analysis of the regional evolution in the period, occurred in North and Northeast Brazil, showing a process of reduction in the regional wage inequality. The change in the education premium was also higher in mesoregions in North and Midwest Brazil, showing that inequality between qualifications continues to grow in these regions, which are considered distant, corroborating the theoretical hypothesis. These mesoregions also presented a significant increase in trade exposure, especially

[11] In order to save space, we did not report the dummy coefficients of the 136 mesoregions and their iterations. In their place, we created maps that present the movements observed in these coefficients when including the trade exposure variables (stage III), which was the main objective of this study.

Midwest, so trade contributes to reduce inter-regional inequality, although it does not yet contribute to reduce intra-regional or inter-skill inequality.

Table 1 – Regression results

Variables	I			II			III		
	2000	2010	Change	2000	2010	Change	2000	2010	Change
Years of schooling	0.0903[a]	0.0842[a]	-0.00619	0.0875[a]	0.0822[a]	-0.00530	0.0871[a]	0.0819[a]	-0.00523
	(0.00606)	(0.00239)	(0.0055)	(0.00575)	(0.00188)	(0.0054)	(0.00567)	(0.00178)	(0.00533)
Experience	0.0495[a]	0.0303[a]	-0.0192[a]	0.0481[a]	0.0296[a]	-0.0185[a]	0.0480[a]	0.0296[a]	-0.0184[a]
	(0.0008)	(0.0005)	(0.0010)	(0.00080)	(0.00053)	(0.00101)	(0.00080)	(0.00054)	(0.00101)
$Experience^2$	-0.0627[a]	-0.0338[a]	0.0290[a]	-0.0606[a]	-0.0327[a]	0.0279[a]	-0.0604[a]	-0.0325[a]	0.0279[a]
	(0.00181)	(0.00061)	(0.00203)	(0.00166)	(0.00063)	(0.00188)	(0.00165)	(0.00063)	(0.00189)
Women	-0.269[a]	-0.223[a]	0.0457[a]	-0.265[a]	-0.222[a]	0.0434[a]	-0.265[a]	-0.220[a]	0.0451[a]
	(0.00454)	(0.00405)	(0.00413)	(0.00419)	(0.00392)	(0.00375)	(0.00416)	(0.00393)	(0.00376)
Age	Yes	Yes		Yes	Yes		Yes	Yes	
Sectors	Yes	Yes		Yes	Yes		Yes	Yes	
Mesoregional dummies	Yes	Yes		Yes	Yes		Yes	Yes	
Mesoregional dummies iterated with education	Yes	Yes		Yes	Yes		Yes	Yes	
Municipal characteristics	No	No		Yes	Yes		Yes	Yes	
Trade exposure	No	No		No	No		Yes	Yes	
Constant	5.058[a]	5.716[a]	0.658[a]	4.324[a]	5.237[a]	0.913[a]	3.533[a]	4.879[a]	1.346[a]
	(0.0451)	(0.0355)	(0.0355)	(0.0734)	(0.0528)	(0.0583)	(0.211)	(0.0988)	(0.184)
Observations	3,700,633	3,118,047	6,818,680	3,700,633	3,118,047	6,818,680	3,700,633	3,118,047	6,818,680
R^2	0.444	0.346	0.504	0.455	0.353	0.514	0.458	0.356	0.517

Note: In parentheses, the robust standard errors clustered by municipalities, where *a, b*, and c indicate $p<0.01$, $p<0.05$, and $p<0.1$, respectively.

Source: Authors' elaboration.

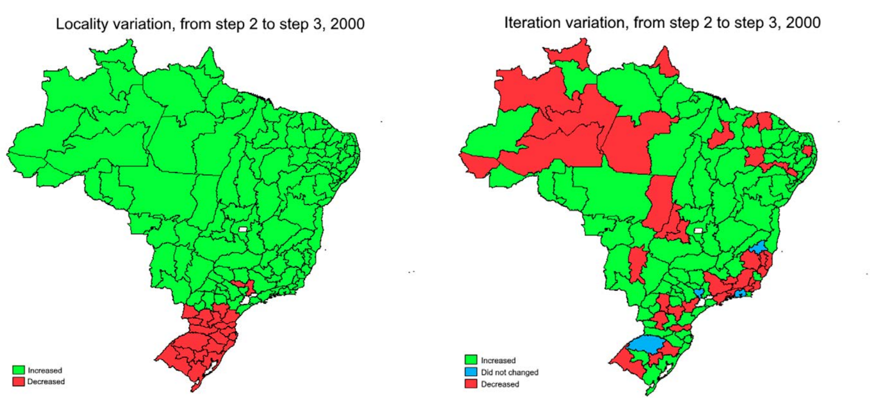
Column II includes variables related to municipal characteristics, representing local amenities, economic orientation, and factor endowment, and showing how much they contribute to the regional wage differentials presented by the regression in column I. This set of variables did not affected control variables, although the constant is significantly lower. Thus, although they affect wages, these variables do not change differences in gender, age, and experience.

The positive coefficient for the metropolitan mesoregion of São Paulo decreased significantly, showing that the premium observed in this mesoregion is possibly related to city size, human capital agglomeration, and industrial orientation. The negative coefficient became even larger, especially in mesoregions in North (especially in the Free Economic Zone of Manaus), Midwest, South, and Southeast Brazil (especially in metropolitan regions), as well as in the northeast coast. In this regression, only seven mesoregions lost significance, besides seven that did not even presented it in the first. Most mesoregions with non-significant coefficients are concentrated in São Paulo, showing no significant differences in wages in comparison with those in the base group after adding controls related to municipal characteristics.

In column III, we added controls related to international trade exposure. We performed the test proposed by Oster (2014) for omitted variable bias, considering the null hypothesis that the coefficient of the variable "openness coefficient" would be biased. The test showed no omitted variable bias after the inclusion of variables related to local characteristics. The value of δ was 8.13 for 2000 and 8.57 for 2010, showing that the omitted variables would need to be at least about eight times more important in determining wages than those included in the model to consider the openness coefficient biased.

Similarly to the previous regression, the inclusion of the trade exposure variables affected wages but not the gender, age, and experience differentials. Figure 1 shows the movements occurred in the mesoregional and iteration dummies in 2000 by the inclusion of the trade exposure variables.

Figure 1 – Movements of the coefficients of the mesoregional (left) and iterated dummies with years of schooling (right) to international trade exposure in 2000



Source: Authors' elaboration.

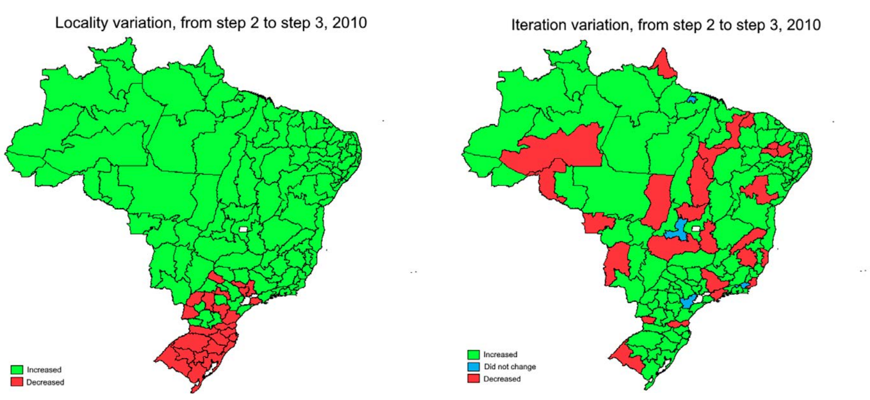
All mesoregions in Rio Grande do Sul and Santa Catarina, six of the ten mesoregions in Paraná, and two in São Paulo (Araraquara and Campinas) showed a decrease in their municipal coefficients (on the left, in red). It shows that part of the wage premium attributed to these mesoregions is due to trade exposure. Moreover, an increase in the coefficients of dummies iterated with education (on the right, in green) predominates in these mesoregions, showing that international trade can be associated with a reduction in the education premium. Thus, a reduction in wage inequality can be associated with greater trade exposure. The mesoregions in South Brazil where the education premium decreased (on the right, in red), showing an increase in the education premium attributed to international trade, are mountainous regions in Paraná and western Rio Grande do Sul with low trade exposure. Thus, transportation costs may be not only associated with distance, but also with geographical conditions.

In all other Brazilian mesoregions, the locality coefficients increased by the inclusion of international trade controls (on the left, in green). Therefore, we can associate the reduction in wages with international trade. This reduction was smaller in regions in Southeast Brazil and in the four mesoregions of Paraná that were not included in the previous group, and the largest reduction percentages were concentrated in North, Northeast, and Midwest Brazil. Thus, trade reduces wages mainly in the more distant regions.

The north, northeast, and midwest regions presented an association between an increase in the regional dummy and a decrease in the coefficient of the education premium when international trade variables were included. Therefore, besides a reduction in wages in general, international trade is also associated with an increase in the skill premium, which further increases inter-skill inequalities in these locations. Southern Bahia and some mountainous regions of Paraná, Rio de Janeiro, eastern Minas Gerais, and Espírito Santo also presented this pattern.

The pattern in 2010 changed little in comparison with 2000. Figure 2 shows the movement occurred in the mesoregional and iteration dummies when the trade exposure variables were included in 2010.

Figure 2 – Movements of the coefficients of the mesoregional (left) and iterated dummies with years of schooling (right) to international trade exposure in 2010



Source: Authors' elaboration.

Inter-skill wage inequalities increased in mesoregions that associated an increase in the wage differential (left) and a decrease in the skill premium differential (right). Regions associated with Stolper-Samuelson responses are those that combine decrease (in red)—in the map, on the left—and increase (in green)—in the map, on the right—and they were mainly concentrated in mesoregions in Southern and Southeastern Brazil.

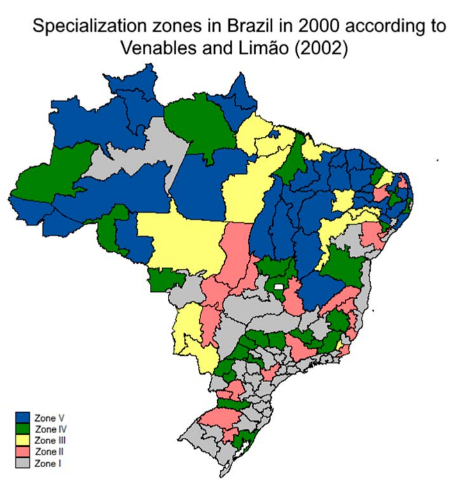
4.1. DETERMINING SPECIALIZATION ZONES

When determining specialization zones, we considered the reaction of the estimated wages and skill premiums of each mesoregion to two sets of control variables: factor endowment and international trade exposure after abstracting the individual determinants.

SPECIALIZATION ZONES IN 2000

We established specialization zones from I to V, from the most open to the most closed. Figure 3 presents the Brazilian mesoregions distributed among these zones in 2000. Mesoregions in North Brazil and in the northeast inland presented characteristics of zones VI and V, that is, the most closed ones. The only mesoregion in North Brazil characterized as zone I is where the Free Economic Zone of Manaus is located. The most open zones are concentrated in South, Southeast, and Midwest Brazil.

Figure 3 – Mesoregions of Brazil and specialization zones according to Venables and Limão (2002) in 2000



Source: Authors' elaboration.

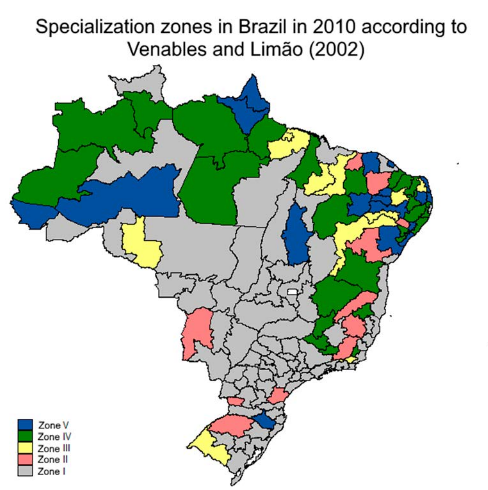
- Zone I (in gray): In 2000, 44 mesoregions presented the characteristics of zone I and were concentrated in South, Southeast, and Midwest Brazil, but also on the coast of Bahia and in the central Amazon mesoregion, where the Free Economic Zone of Manaus is located.

- Zone II (in orange): In 2000, 20 mesoregions spread over western Rio Grande do Sul and Paraná, northern Minas Gerais, central Midwest Brazil, and two on the Northeast coast (Paraíba and Rio Grande do Norte) presented characteristics of zone II.
- Zone III (in yellow): In 2000, 12 mesoregions spread over western Mato Grosso do Sul, northern Mato Grosso, eastern and northern Pará, northern Maranhão, central Bahia, southern Pernambuco, eastern Piauí, and on the coast of Ceará presented characteristics of zone III.
- Zone IV (in green): In 2000, 25 mesoregions presented the characteristics of zone IV and were concentrated in western Santa Catarina, Paraná, and São Paulo, eastern Minas Gerais, northern Goiás, southern Bahia, and in some mesoregions in North Brazil.
- Zone V (in blue): In 2000, 35 mesoregions presented the characteristics of zone V and were concentrated in northern and western Northeast Brazil. These regions are, in fact, the ones with the lowest openness coefficient.

SPECIALIZATION ZONES IN 2010

Figure 4 presents the mesoregions distributed among specialization zones in 2010. The most open areas expanded considerably in comparison with 2000. Mesoregions in South, Southeast, and Midwest Brazil presented characteristics of more open zones while the most closed ones remained in mesoregions in North and Northeast Brazil.

Figure 4 – Mesoregions of Brazil and specialization zones according to Venables and Limão (2002) in 2010



Source: Authors' elaboration.

- Zone I (in gray): In 2010, 71 mesoregions, located in Midwest, Northeast, North, South, and Southeast Brazil, as well as in the central region of Brazil (Minas Gerais, Goiás, Mato Grosso, and eastern Mato Grosso do Sul), western Tocantins, and eastern Pará presented the characteristics of zone I. This reduction can be associated either with improved infrastructure or cheaper access to capital.
- Zone II (in orange): In 2010, only 11 mesoregions, located in western Rio Grande do Sul, Paraná, and Mato Grosso do Sul, eastern Minas Gerais, southern and northern Bahia, northern Piauí, and southern Ceará, presented the characteristics of zone II. This movement reinforces the hypothesis of a relative reduction in transportation costs.
- Zone III (in yellow): In 2010, only 11 mesoregions, especially in Northeast Brazil—western Bahia, southern Pernambuco, eastern Rio Grande do Norte, and western Paraíba—as well as eastern Rondônia and southern Rio Grande do Sul, presented the characteristics of zone III. A reduction in the "labor" factor endowment may be associated with this reduction in zone III.
- Zone IV (in green): The number of mesoregions classified as zone IV remained unchanged, however, they migrated to North and Northeast Brazil. This movement shows that the north and northeast regions presented an advance related to cheaper transportation costs for production inputs.
- Zone V (in blue): In 2010, 18 mesoregions, mainly located in North and Northeast Brazil, but also on the coasts of Bahia, Rio Grande do Norte, and Ceará, in eastern Tocantins, and in the mountainous region of Santa Catarina, presented the characteristics of zone V.

CONCLUSION

This study discusses the growing disagreement between traditional theoretical predictions and the results of recent empirical studies regarding the relationship between wages and skill premiums and trade liberalization in developing countries. Two hypotheses raised by current theoretical contributions are that this discordance is due to: first, empirical studies that implicitly consider that different regions of a country are equally linked to international trade, and second, the use of aggregate country-level data to study this relationship.

This study addresses these two hypotheses explicitly by analyzing the relationship between wages and international trade in Brazil during 2000 and 2010. Thus, we used disaggregated municipal data available in Brazilian official sources to assess the heterogeneity of wage and skill premium responses to variations in trade exposure depending on the geographical location.

According to the theoretical model used, we determined specialization zones by the relationship between international trade and transportation costs, which in turn induced wage and skill premium responses in the regions, depending on their distance from trade centers. This study determined specialization zones in Brazil based on wages and education premium responses to the trade exposure variables, after controlling them using individual determinants and local characteristics. The hypothesis considered was that, if the theoretical model presented empirical adherence, regions considered distant by their wage and skill premium behavior would show low openness coefficient, low wages, and high skill premiums. On the other hand, those considered close to the trade center would present high openness coefficient, high wages, and low skill premiums.

Our results met these expectations. Thus, according to the decreasing level of trade liberalization, we determined specialization zones from I to V in Brazil in 2000 and 2010 to assess their evolution. In 2000, specialization zones I, II, and III—considered to be more open to international trade—were concentrated in South, Southeast, and Midwest Brazil, and in the coast of Northeast Brazil, as well as in the northern mesoregion where the Free Economic Zone of Manaus is located. Specialization zones considered to be more closed to trade were concentrated in North and Northeast Brazil, in the mountainous regions of South and Southeast Brazil, and also in part of the midwest region. In 2010, zone I expanded considerably to practically all South, Southeast, and Midwest Brazil, part of the north region, and the coast of Northeast Brazil, showing that commercial expansion reached areas previously more closed to trade during the decade. This movement suggest that increased trade exposure favored Stolper-Samuelson responses. Changes in the relative intensity of transportation costs for traded goods can also explain this expansion. In turn, zones IV and V, which are more closed to trade, began to be concentrated in North and western Northeast Brazil in 2010.

The results also reveal that Stolper-Samuelson responses occured only in regions considered closest to the trade center, in accordance with the theoretical model used. While in southern and some southeastern mesoregions, income inequality decreased due to international trade, in regions in North, Northeast, and Midwest Brazil, this intra-regional inequality increased. However, this decrease in income inequality between regions during the period studied is remarkable.

These results seem to confirm the assumptions of Venables and Limão (2002) about the relationship between wages, skill premiums, and international trade. They also indicate that Stolper-Samuelson responses would be valid depending on the geographical location of a region, its distance from trade centers, and the relative transport and factor intensity of the traded products. Therefore, policies that geographically spread the benefits of international trade within Brazil would have to consider the occurrence of these regionally heterogeneous responses.

The main limitation of our study was related to the formation of an international trade database that considered the tax residence of the exporting firm and not the producing municipality to register the trade occurrence at the municipal level. It can distort input price responses to trade variations. Another limitation was forming the sample, as it did not consider stratification by skill level. It may have caused a high occurrence of non-significance in mesoregional dummies iterated with years of schooling. The use of mesoregional and not micro-regional or even municipal dummies was also a limitation, as it was driven by the constraints of the technological resources available for this study. Future research should improve the understanding on the reasons why certain regions of Brazil do not respond positively to international trade.

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