# Measuring Spatial Mismatch effects in the Curitiba Metropolitan Area[1]

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## ABSTRACT

This study assessed potential economic gains in the labor market of the second largest Metropolitan Area of the south of Brazil, the Metropolitan Area of Curitiba, which had a long experience in adopting Transit Oriented Development policies for its urban consolidation. Guided by a Spatial Mismatch Hypothesis, the main objective of this study was to investigate the effects of gravitational accessibility indexes to formal job opportunities in monthly wages for workers of the study area in the year of 2017. We applied a consolidated methodology that considers a rich set of geographic information to deal with theoretical issues of determinants of spatial configuration, and allow to observe, in 2SLS models with mincerian specifications, the effects of agglomeration economics by different magnitudes: geographical sub area, educational level and transport mode. The results suggest the existence of potential economic gains related to better accessibility to formal job opportunities. The transport mode and the educational level are also determinant to the magnitudes of such effects on monthly wages for those workers, which related to the spatial unevenness access to job opportunities, might be a source of economic inequality among the Metropolitan Curitiba Area citizens.

***Keywords:*** *Acessibility to Formal Job; Spatial Mismatch Hypothesis; Urban Labor Market*

*JEL: R14; R38; O18.*

## RESUMO

Este estudo investigou os ganhos econômicos em potencial do mercado de trabalho da segunda maior Região Metropolitana do sul do Brasil, a Região Metropolitana de Curitiba, que possui uma longa experiência na adoção de políticas de Desenvolvimento Orientado ao Trânsito para sua consolidação urbana. Orientado por uma Hipótese de Mismatch Espacial, o objetivo principal deste estudo foi investigar os efeitos de níveos de acessibilidade com abordagem gravitacional a oportunidades de emprego formal nos salários dos trabalhadores da área de estudo no ano de 2017. Foi utilizada uma metodologia consolidada que considera um rico conjunto de informações geográficas para tratar de questões teóricas dos determinantes da configuração espacial, e permitir observar, em modelos 2SLS com especificações mincerianas, efeitos de economias de aglomeração em diferentes magnitudes: subárea geográfica, nível de qualificação educacional e modo de transporte. Os resultados sugerem a existência de ganhos econômicos em potencial relacionados à melhores acessibilidades as oportunidades formais de trabalho. O modo de transporte e o nível de escolaridade também são determinantes para as magnitudes de tais efeitos sobre os salários mensais desses trabalhadores, que estão relacionados à desigualdade espacial no acesso às

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oportunidades de trabalho, sendo uma fonte de desigualdade econômica entre os trabalhadores da Região Metropolitana de Curitiba.

Palavras-chave: Acessibilidade ao Trabalho Formal; Mismatch Espacial; Mercado de Trabalho

## 1 INTRODUCTION

Cities of emergent countries have had huge issues on their respective urban consolidations since the beginning of most of its processes, mainly in metropolitan areas, where the unevenness spatial distribution of accessibility to opportunities evidence big challenges to supress economic inequalities (Hernandez, 2017; Fan et al., 2018; Pereira et al., 2020).

The Spatial Mismatch Hypothesis (SMH) claims that spatial unbalances between dwellings and workplaces within some social groups may be harmful for their respective job market outcomes (Kain, 1968). This hypothesis has provided useful analytical fundaments to better understand the effects of unequal access to job opportunities in economic inequalities (Gobillon et al., 2007; Duarte, Silveira-Neto, 2020; Holzer, 1991; Matas et al. 2010).

This hypothesis has shown adherence for Brazilian large cities, since some of them have evidenced: spatial concentration of job opportunities with non-equitable distribution of transport infrastructure (Haddad and Barufi, 2017); periphery of housing location from essential urban infrastructure to poor individuals (Pacheco, 2019); and concentration of such infrastructures and job opportunities for individuals who live in central areas and aren't low-skilled qualification (Sachsida et al. 2008; Barufi and Haddad, 2017).

In the south of Brazil, the city of Curitiba had planned and implemented an urban expansion process based on Transit Oriented Development (TOD), when hierarchized land use by distance to a road infrastructure, aiming to avoid overloading of such infrastructures. Curitiba also implemented the public transport system so-called Bus Rapid Transit (BRT) since 1974, building exclusive bus lanes, fast landing platforms and bus integration terminals, which together aim to encourage the use of public transport among its citizens and improve the flow of private cars and buses on the whole transport infrastructure. The BRT system has gained increasing popularity worldwide (Cervero and Kang, 2011).

TOD policies in the urban consolidation of Curitiba resulted in an employment polycentric spatial structure (Thomé, 2020), and regional economic policies encouraged the emergence of industrial poles in surrounding cities of Curitiba (Firkoski, 2002; Carmo and Moreira, 2020), which fomented geographical integration for the Metropolitan Area of Curitiba through its transport infrastructure.

The objective of this study is to measure the existence and magnitude of effects of accessibility to formal job opportunities on monthly wages for the Metropolitan Area of Curitiba (MAC), and bring resources to assess the sources of such effects, given that its spatial configuration, together with transport infrastructure - determinant mechanisms for a SMH - show different aspects of other Brazilian Metropolitan Areas (Boijosly et al., 2019; Pereira et al., 2020).

This study used the databases of the Origin-Destination Survey and RAIS for MAC in 2017, in addition to geographical information about its rivers network, aiming to implement the empirical methodology developed by Haddad and Barufi (2017), by estimating the effects of accessibility indexes on wages in mincerian equations, dealing with the endogeneity issue between these two variables with 2SLS models. Besides studying such hypothesis for a good referenced metropolitan area in relation to its urban consolidation, a contribution of this study was to investigate such agglomeration effects through accessibility on formal job opportunities for specific social groups that were observed based on educational level.

The results suggest the existence of positive effects of accessibility on wages. Groups of individuals that had at least frequented a university had lower inequalities in the potential of catching such effects on wages. Transport modes are also determinant for such potential in economic gains.

The six sections of this study are divided in: this introduction, a literature review that grounds this investigation, a brief contextualization of the MAC, the empirical strategy used by this study, the results obtained and the final remarks.

## 2. LITERATURE REVIEW

The urban geography provides useful evidences for understanding economics aspects of regions, such as jobs outcomes and its implications. The Spatial Mismatch Hypothesis, introduced by Kain (1968), aims to investigate labor market outcomes implications of social segregation faced by minority groups on the location of their job and residences. Thus, the interaction of these respective locations with the spatial configuration of the area of interest might be a mechanism that explains social and economics inequalities, as long as they have heterogeneous accessibility conditions.

Differences in accessibility conditions between zones of a city may influence on the choice of location of firms and residences. Fujita and Ogawa (1982) state that firms might endogenously choose areas with higher potential in economic gains due to agglomeration effects. Given that such effects are supposed to provide higher profits to firms, Melo and Graham (2009) defend that in equilibrium, agglomeration effects should increase worker's wages. In this framework, Lucas and Rossi-Hansberg (2002) suggest that the productivity level of zones will be positively related to the employment level of its neighbor zones. Consequently, as long as individuals that work on places with great productivity face higher commuting costs due to the values of their hourly wage, in mixed land use equilibrium, these workers should endogenously choose to live closer to areas with more job's densities.

Geography may also influence on the decision of firms for hiring workers in large urban areas. Zenou (2002) defend that commuting to jobs can be exhaustive for workers, implying that travel time is positively related with this exhaustion, and may negatively influence the respective worker's productivity, and therefore, on firm's profit. Therefore, in the seeking of profit maximization, firms will discriminate workers whose dwelling are located too far from their headquarters.

From the above discussion, if we assume that: 1) agglomeration economies have positive influence on urban wages; 2) local of dwellings are endogenously determined by individuals who earn higher wages; and 3) firms discriminate workers based on their respective local of dwelling, jobs that offer the highest wages will be more accessible opportunities to individuals who have economic conditions to live close enough to the respective firms. Therefore, this phenomenon will foster economic inequality in urban areas.

Empirical evidence has shown that this mechanism is reasonably appliable for Brazilian cities. Pereira et al. (2020) discuss that in the 25 largest metropolitan areas of Brazil, higher accessibility to formal jobs opportunities is provided to areas where the residents with higher monthly wages live, and that the spatial distribution of transport infrastructure tends to be concentrated on central regions, which are evidences of a spatial configuration pattern for Brazilian large cities, where poor individuals tend to live on suburbs. Hernandez (2017) defends that structural constraints in urban areas tend to directly affect the potential of individuals to lift their economics conditions up.

As what see to be a consequence of such spatial configuration and urban infrastructure distribution for Brazilian large cities, Barufi and Haddad (2017) found strong negative relation between monthly wages and commuting travel time between residences and job.

These authors also claim that wages are higher for individuals that live in work cities than for those who live in dormitory cities, reinforcing evidences that the statement of endogenous choice of place of dwellings near to zones with higher density of jobs (Lucas and Rossi-Hansberg, 2002) holds in Brazilian large cities, such as a pattern of low densities of job opportunities in suburb areas.

However, measuring SMH only by commuting time between place of dwelling and work has analytical weakness. It is important to control for individual characteristics, transport mode and the endogeneity of individuals who choose their respective place of residence (Holzer, 1991, Ihlanfeldt, 1992). Simultaneity between the variable that quantifies the SMH and job's outcomes might bias the effects of the SMH toward zero (Ihlanfeldt and Sjoquist, 1998).

Regional and urban economics studies have been outlining endogeneity issues through the use of econometric instruments that observe geographic and historical characteristics of their respective study areas (Duranton and Turner, 2011; Burchfield, 2006; Baum-Snow, 2007). The power of such approach comes from the reasonably assumption that early regional geographic characteristics play important roles on the respective human occupation.

In a SMH investigation, Haddad and Barufi (2017) have used rivers network information of Metropolitan Area of São Paulo (MASP) as instrument for dealing with simultaneity between accessibility indexes and wages, given that the rivers of that area became important transit corridors for its transport infrastructure network in the early 20$^{th}$ century. In a SMH investigation for the city of Recife, Duarte and Silvera-Neto (2020) claimed that the rail roads' network of this area in the 19$^{th}$ century were a decisive agent for the present accessibility infrastructure, because it reflected the best routes in the face of soil conditions. In both SMH investigations, the coefficient that represents the measure of accessibility increase after controlling the endogeneity bias between job outcome and the measure of accessibility.

If there is a historical-geographic aspect that exogenously determines the present spatial configuration or infrastructure of an urban area, so this exogenous aspect can be powerful for dealing with the theoretical issue of spatial equilibrium determinants (Lucas and Rossi-Hansberg, 2002; Ihlanfeldt and Sjoquist, 1998, Haddad and Barufi, 2017).

## 3. Metropolitan Area of Curitiba, some stylized facts.

With 1,9 million inhabitants, Curitiba is the main economic city of the Metropolitan Area of Curitiba, which is the second largest metropolitan area in the south of Brazil, with over 3,6 million inhabitants. In the first half of 20$^{th}$ century, the city of Curitiba has implemented urban master planning plans that aimed to bring infrastructure and connect its central area with dispersed districts, through large avenues on a linear urban expansion. From 1970's on, Curitiba had adopted urban master planning plans that focused on sustainable mixed land use, defining the localities of residences and economic activities based on the level of road infrastructure near to them.

This city has also implemented the public transport system called Bus Rapid Transit (BRT) that built exclusive bus corridors in the main avenues of Curitiba, aiming to provide more speed on travel for both bus and car transport modes. Therefore, the disciplined urban expansion of this city, that conciliated hierarchized land use with the BRT system, followed Transit Oriented Development policies, that aimed to optimize the use of its road infrastructure and promoted poli centric configuration of employment (Thomé and Porsse, 2019).

In the 70´s decade, policies for fostering industrial parks resulted in the Industrial park of Curitiba, in its southwestern board, and in the city of Araucária, located in the west board,

such as discussed by Carmo and Moreira (2020). Firkoswk (2002) claim that later in the 90´s the city of São José dos Pinhais, located in the southeast board of Curitiba, was also benefited by these industrial incentives.

This economic integration designed the Metropolitan Area of Curitiba's geography, with some concentration of qualified jobs in the metropolitan cities located in the limits of Curitiba (Nojima, Moura and Silva, 2009). Since the implementation of the BRT in 1974, the integration of Curitiba's transport system was most focused on the neighbor cities, having its expansion to peripherical metropolitan cities started from the 1990´s.

Figure 1 shows that the urban expansion of MAC resulted in a spatial distribution of income in which the central region of the city of Curitiba have most of the high-income residents.

The limiting cities of Curitiba are the ones that show incomes similar to the central region of the Parana's capital at most, evidencing effects of the early economic and physical integration with this city. There is also spatial correlation between BRT corridors and incomes.

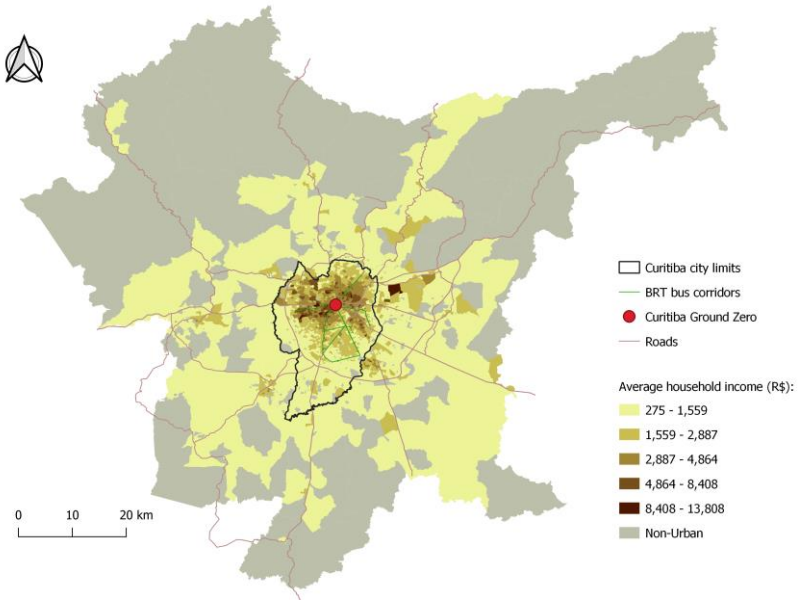


Figure 1 – Income distribution for Metropolitan Area of Curitiba.
Source: Brazilian Census 2010.

Figure 2 shows a dispersed distribution of formal jobs over Metropolitan Area of Curitiba. This might be a result of the industrial policies that had started from the 1970´s, as well as the urban planning master plans adopted by the city of Curitiba (Thomé and Porsse, 2019).

This distribution over the observed area is favorable for good accessibility to formal job opportunities, if the transport system is effective in connecting the different zones of this Metropolitan Area.

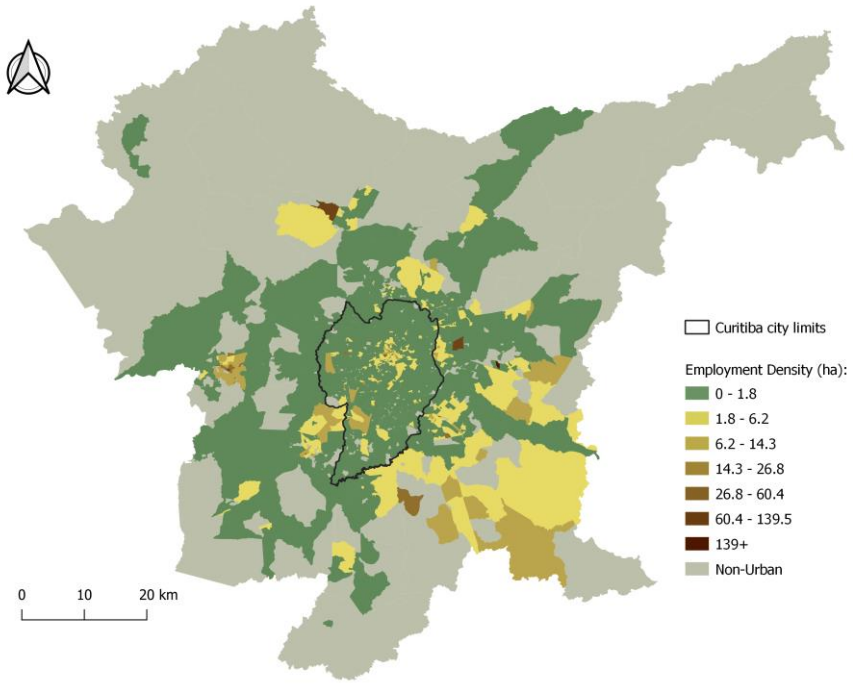


Figure 2 – Formal Employment density for Metropolitan Area of Curitiba.
Source: RAIS 2017.

## 4. Data and Empirical Strategy

### 4.1 Data

This study had three different sources to form the databank. Information of individual socioeconomic characteristics, transport mode, travel time, dwelling and work locations came from the 2017 Origin-Destination survey (OD survey) of Curitiba, conducted by the Institute of planning research of Curitiba (IPPUC). This survey collected information about 17 municipalities of Metropolitan Area of Curitiba in 955 zones. For the present analysis, 5,604 observations were used from this sample, representing over 641 thousand residents.

Information about formal jobs[4] came from the 2017 Annual Social Information Relation (RAIS), which is provided by the Brazilian ministry of labor. This databank contains very detailed information about firms and workers, including their respective workplace, allowing for geocoding each[5] formal job of Metropolitan Area of Curitiba, making it possible to estimate the number of jobs in each of the 954 zones of the Origin-destination survey.

The third data source consisted of geographic information of rivers in the study area. It is described in the sub-section about the econometric instrument used in this study.

### 4.2. Empirical Strategy

This empirical analysis used Ordinary Least Square and Two Stage Least Square regressors to evaluate causality between accessibility to formal jobs and monthly wages in MAC. The econometric models follow specifications based on Mincer (1974):

$$lnW_{imj} = \varphi + A\delta_{imj} + X\beta_{imj} + \varepsilon \qquad (1)$$

[4] In Brazil, this job category has rights and guarantees by law, being considered as better job opportunities than informal jobs. However, the RAIS database is limited to observe only formal jobs.
[5] A total of 89% of the total sample in the RAIS databank was geocoded. 11% of the geocoded jobs did not present consistency of their respective location.

where *W* represents the *ln* of the monthly wage of individual *i*, who uses the transport mode *m* to reach workplace *j*. *A* is the accessibility index of the individual's workplace zone *j*, in addition to an array of individual characteristics *X*, which contains:

i) a dummy variable that indicates whether the individual is male;
ii) a dummy variable that indicates one of the 7 individual's level of education;
iii) the age of the individual in ln;
iv) the ln of the individual's age squared;
v) two dummy variables that give information about the respective work areas of the individuals: one for those who live and work in the same place and another that indicates whether the individual works in a Rural Census Sector.

The magnitude of the Spatial Mismatch is based on a measure of accessibility, which consists of gravitational accessibility indexes based on Hansen (1959) that aims to observe available opportunities:

$$A_{mj} = \sum_{j=1}^{954} \frac{Ej}{dij(t)} \qquad (2)$$

where *A* is the accessibility index for workers of zone *j*, of modal *m*, that is explained by *E*, the quantity of formal jobs in zone *j*, which is divided by an impedance function *d*, that ponders the availability of each formal job by the mobility conditions between zones *i* and *j:*

$$dij(t) = e^{\alpha t} \qquad (3)$$

thus, $d_{ij}$ is the linear distance between zones *i* and *j*, explained by the mean commuting time between these zones in two log-log Ordinary Linear Squared models, for the modes: 1) Private Vehicles, that encompassed cars, taxis and motorcycles trips; and 2) Public Transport, composed by all the trips made by BRT users and Metropolitan buses.

The time information for the trips of both observed modes were collected from the OD survey, feeding two quadratic mean travel matrixes, making it possible to have two different estimated $\alpha$.

Table 2 – Descriptive Statistics of the main variables of databank.

| | Private | | Public | | Total | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Acessibility Private Vehicle | 13,098 | 10,428 | - | - | - | - |
| Acessibility Public Transport | - | - | 8.136 | 7.842 | - | - |
| Monthly Wage (R$) | 2,519 | 2,173 | 1.643 | 1.477 | 2.038 | 1.876 |
| Distance from residence to CBD | 11.613 | 7.842 | 12.592 | 7.662 | 12.219 | 7.508 |
| Travel time (minutes) | 29 | 20 | 49 | 34 | 40 | 30 |
| | Individuals | (%) | Individuals | (%) | Individuals | (%) |
| Expanded Sample | 289,614 | 47.14 | 351.682 | 54.83 | 641.296 | 100 |

Source: Own elaboration, from OD survey and RAIS 2017.

It is shown in Table 2 that accessibility is higher among Private Vehicle users. These individuals also have higher average monthly wages than Public Transport users. Individuals who use Private Vehicles face 20 minutes less than Public Transport users on average.

Taken together, this set of information brings some evidence of implications of mobility conditions on jobs outcomes (monthly wages). The mechanism starts from the travel time, which directly depends of the transport mode.

Figures 3 and 4 show the spatial distribution of the accessibility indexes for Private and Public transport modes. These indexes are the observed formal jobs pondered by the impedance function in equation (2). Therefore, in the MAC transport infrastructure, Private Vehicles provide higher accessibility to formal jobs than Public Transport users. Such as the formal job spatial distribution, the accessibility indexes are dispersed over MAC, and they see to be positively related to the road infrastructure.

Thus, it is expected that the accessibility indexes have positive effects on monthly wages, as they represent potential effects of economics of agglomeration in the job market (Melo and Graham, 2009; Haddad and Barufi, 2017).

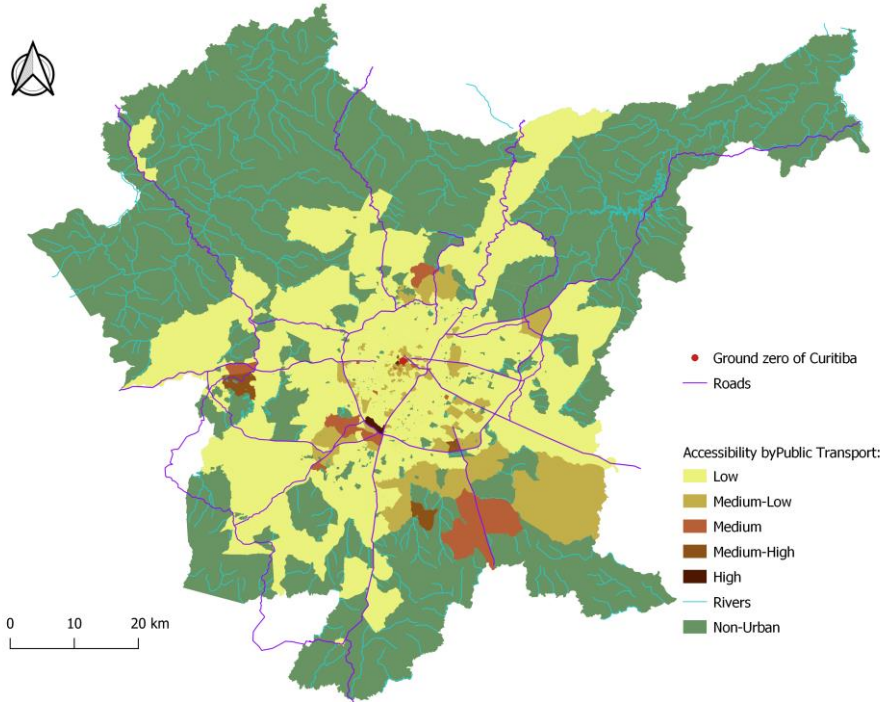


Figure 4 – Acessibility indexes for Public Transport users in CMA.
Source: Own elaboration from the data base

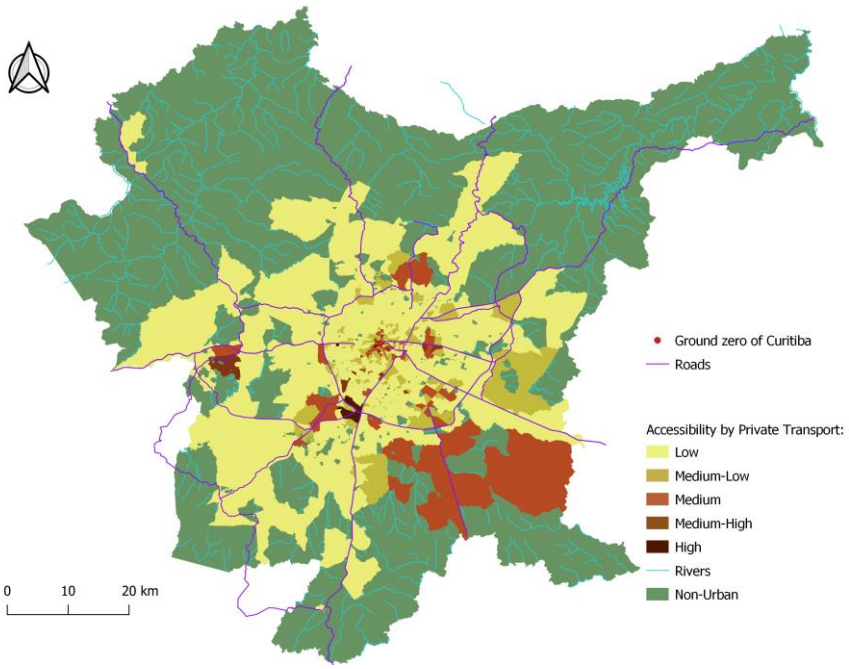


Figure 5 – Acessibility indexes for Private Vehicle users in CMA.
Source: Own elaboration, from the data base

We assume the hypothesis of simultaneity between the accessibility indexes and monthly wages, which might cause bias on an econometric estimation in equation (1). Therefore, Mincerian equations were also tested with 2SLS models, using a geographic instrument.

In addition to the described methodology, we also tested the hypothesis of different magnitudes of such effects on monthly wages, which are based on workers' level of qualification.

Therefore, we created two skilled-based groups: 1) Skilled 1, that are individuals who had at least started or even completed a bachelor course, in addition to individuals who had completed a postgraduation education; 2) Skilled 2, with individuals who had completed a bachelor or a postgraduation course.

As base line, we created non-skilled groups: for individuals who haven't started a bachelor course in comparison to Skilled 1; and individuals who haven't completed a bachelor course for Skilled 2.

With the skill-based groups indicated by dummy variables, we had interacted them with accessibility indexes predicted in two[6] first stage equation of 2SLS models that used the geographic instrument as the exogenous variable.

After that, four 2SLS models were obtained, with two models for each transport mode, aiming to measure possible differences of the measures of accessibility between non-skilled group against Skilled 1 and and non-skilled group against Skilled 2.

## 4.3 The Instrument

As mentioned in section 2, Regional and Urban studies that face the problem of simultaneity have been outlining such issue with historical and geographical information as instruments. Therefore, the strategy to deal with the issue of simultaneity adopted by the

[6] For the Public and Private Transport modes.

present study is the one developed by Haddad and Barufi (2017) for the MASP, by using geographical information of rivers network, assuming this aspect as being decisive on the present spatial configuration of the observed area by their study.

The Metropolitan Area of Curitiba is located in a very irregular mountain topographic site, which is 935 meters above sea level. This geographical condition implied in strong difficulties for transporting commodities from and to this area at the first steps of its urban consolidation, in the 19th century, as discussed by Karpinski (2011).

Rivers brought transport solutions for early explorers, and influenced on the location of its first villages and farms, as related by (Schimidlin et al., 2009). Thus, human occupation and transport infrastructure were encouraged to be close of the rivers.

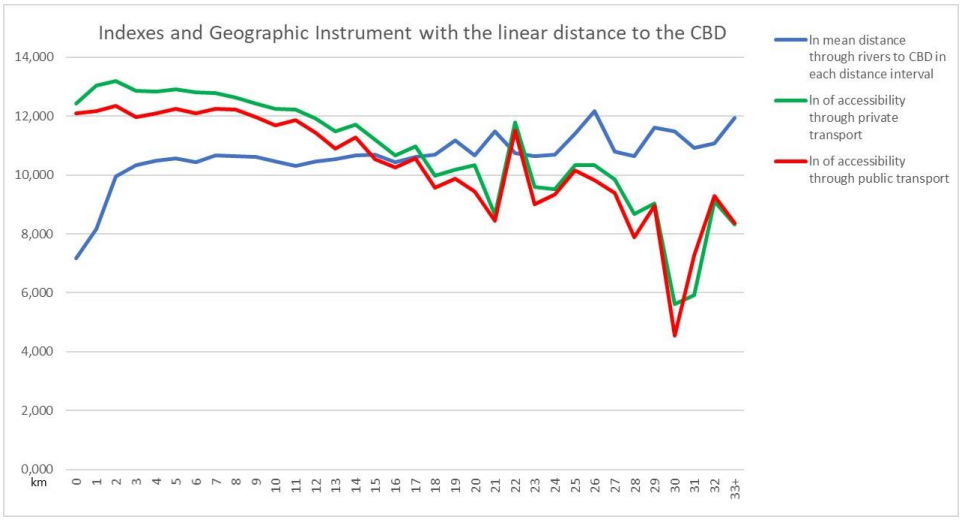


Figure 6 – Accessibility to formal jobs and Linear Distance to Curitiba CBD.
Source: Calculated from the Databank.

Given the historical and geographical configuration of the study area, we assume that rivers exogenously influenced on the present location of its firms and residences. Therefore, as well as Haddad and Barufi (2017), the strategy to observe this variable was by computing the distance of each zone centroid to the closest river, and adding such distance to the distance from the closest river bank to the CBD of the city of Curitiba[7], traversing the network of rivers shown in Figures 4 and 5.

This procedure was made to all of the 954 zones of this study area. The resulted variable from this procedure presents negative correlation with both the accessibility indexes, as is illustrated in figure 6.

## 5 Results

According to the results obtained by the main linear coefficients of interest, there are positive effects of better job accessibility on monthly wages for all of the workers of CMA. There are also higher effects on workers who have commuted to workplace by private vehicles and completed a bachelor course.

[7] The Central Business of this city in the edge of the economic formation of CMA. In the early years of its urban consolidation, merchants used to meet in the CBD to trade commodities, and explorers, to rest from long trips. In the recent spatial configuration, this central area still plays an important role on the location of jobs for the city of Curitiba, as claims Thomé and Porsse (2019).

5.1 The Spatial Mismatch effects on workers of Metropolitan Area of Curitiba

The models in panel A of Table 2 tested the linear prediction of the accessibility indexes by the instrumental variable in addition to the independent covariates set in equation (1). The first stage tests indicate significant linear negative correlation between distance to CBD through rivers and both of the accessibility indexes, which suggests some contribution of the instrument to deal with endogeneity.

In panel B, OLS and 2SLS coefficients predict ln of monthly wages with the *X* set of individual information in equation (1) as control variables. All of the accessibility indexes coefficient are significant at 1% level, and OLS and 2SLS models have different magnitudes of effects of the accessibility to job opportunities in the monthly wages.

As we assume endogeneity between monthly wages and the accessibility indexes, due to higher power of dwelling location response to workers who earn higher wages, it is theoretically expected that if an endogenous model computes information of individuals who have chosen to face longer travels to work in order to consume local amenities, then it tends to vanish the effects of the accessibility measure on monthly wages (Sjoquist, 1992; Holzen, 1991).

If the 2SLS models are better than OLS models to estimate the causality of accessibility to formal job opportunities on monthly wages, thus higher magnitudes of the coefficients that observe the Spatial Mismatch on job outcomes are expected, because they correct part of the bias generated by endogeneity. In Panel C, robust F statistics and R partial testes suggest that the models with instrumented variables contribute significantly to predict wages.

Table 2 – Results of OLS and 2SLS models with tests

| Panel A: Main first stage linear coeficients | OLS | OLS |
|---|---|---|
| ln Acessibility Index (Dependent Variable) | Private | Public |
| ln Distance to CBD through Rivers | -0.194*** | -0.226*** |
| Adjusted R squared | 0.155 | 0.186 |
| F Statistics | 3,460 | 4,589 |

| Panel B: Main linear coeficients | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| | OLS | OLS | 2SLS | 2SLS |
| Transport Mode: | Private | Public | Private | Public |
| ln Acessibility Index | 0.038*** | 0.036*** | 0.126*** | 0.112*** |
| Instrumented by distance to CBD through rivers: | NO | NO | YES | YES |
| Number of observations | 2,579 | 3,025 | 2,579 | 3,025 |
| Adjusted R squared | 0.267 | 0.246 | 0.254 | 0.227 |
| F Statistics | 6,251.96 | 6,024.78 | - | - |

| Panel C: | Adjusted R2 | Partial R2 (Shea) | Robust F statistics | Prob > F |
|---|---|---|---|---|
| ln Distance to CBD through Rivers (Private) | 0.155 | 0.122 | 15.034 | 0.000 |
| ln Distance to CBD through Rivers (Public) | 0.186 | 0.160 | 48.661 | 0.000 |

Source: Own Elaboration, from the database.
Note1: p-Value<0.1*, p-Value<0.05** and p-Value<0.01***.
Obs: Additional controls for Panel B models: age, age squared, gender, level of education dummies, sector of activity, dummies to indicate if the individual works and lives in the same zone, dummies to indicate if he works on an urban zone, constant term. Sampling weights are applied to the estimation.

Therefore, the coefficients obtained in models 3 and 4 in Panel B are used by this analysis to measure the Spatial Mismatch effects in monthly wages of workers in the

Metropolitan Area of Curitiba who commuted by private or public transport modes, attributed to economics of agglomeration effects (Melo and Graham, 2009; Haddad and Barufi, 2017).

Given the existence of spatial heterogeneity in the level of accessibility to formal job opportunities (Figures 4 and 5) among zones of work, the values of the 2SLS models indicate economic advantages for specific workers in MAC, due to their respective workplace and transport mode.

The hypothesis for such effects on monthly wages is that these accessibility indexes synthesize agglomeration economics effects, mainly from the transport infrastructure and the density of jobs for each zone. Therefore, this structural mechanism for individual economic earnings, related to the spatial configuration of the study area (formed by the distribution of jobs, dwellings and transport infrastructure), is a source for economic inequality among MAC citizens.

Models 3 and 4 suggest some difference on potential earnings due to the transport mode. As long as these linear coefficients represent some sensitivity of the monthly wages by the magnitudes of the accessibility indexes at each workplace, and taking in consideration that workers who commuted by public transport have lower mean wages and accessibility than those who used private transport (Table 2), we found some evidence that transport mode can also be a source for economic inequality in the study area.

Transport mode effects on the labor market outcomes corroborate the founds of Haddad and Barufi (2017) and Matas et al. (2010), where the mechanism might be related to lower efficiency in commutation along the urban space for the public transport mode.

## 5.2 Results for the Spatial Mismatch within transport mode based on Skill level

The models in Table 3 aim to investigate more specific effects of agglomeration economics based on groups of educational level: Skilled 1 and Skilled 2. Therefore, by interactions between the accessibility indexes and individual educational levels, the dummy coefficients aim to test the hypothesis of more effects of the measures of accessibility on individuals who had at least started a bachelor course (Models 1 and 2) or concluded bachelor course (Models 3 and 4), with both groups being compared to non-skilled groups.

Table 3 – Results of 2SLS models and tests, with interaction dummies for skill level

| Models with interaction dummies indicating skill level: | | | | |
|---|---|---|---|---|
| | Model 1<br>Skilled 1 | Model 2<br>Skilled 1 | Model 3<br>Skilled 2 | Model 4<br>Skilled 2 |
| Transport Mode: | Private | Public | Private | Public |
| ln Acessibility Index x Skill dummy | 0.100*** | 0.188*** | 0.170*** | 0.210*** |
| ln Acessibility Index (Instrumented) | 0.087*** | 0.050*** | 0.085*** | 0.072*** |
| Coef. Ratio (Skill dummy x Index and Index): | 1.14 | 3,76 | 2 | 2,91 |
| Number of observations | 2,561 | 3,017 | 2,561 | 3,017 |
| R squared | 0.258 | 0.256 | 0.259 | 0.249 |
| First Stage Tests for ln Distance to CBD through Rivers as instrument: | | | | |
| Adjusted R2 | 0.155 | 0.194 | 0.154 | 0.192 |
| Partial R2 (Shea) | 0.055 | 0.138 | 0.079 | 0.153 |
| Robust F statistics | 16,745 | 56,309 | 24,756 | 63,639 |
| Prob > F | 0.000 | 0.000 | 0.000 | 0.000 |

Source: Own Elaboration, from the database.
p-Value<0.1*, p-Value<0.05** and p-Value<0.01***.

Obs: Additional controls for the 2SLS models: age, age squared, gender, level of education dummies, sector of activity, dummies to indicate if the individual works and lives in the same zone, dummies to indicate if he works on an urban zone, constant term. Sampling weights are applied to the estimation. Skilled 1 correspond to individuals who had started or completed a bachelor course, as well as completed a postgraduation course. Skilled 2 correspond to individuals who had completed a bachelor or completed a postgraduation course.

Within transport mode groups, the results in Table 3 suggest the existence of higher effects of the measures of accessibility on monthly wages for Skilled 1 workers, and even higher effects for Skilled 2 workers.

In this comparison within transport mode groups, it is also possible to quantify the differences of magnitudes of such economic gains based on skill level, observing the ratio between the accessibility indexes resulted by dummy interactions and the accessibility indexes. From this, the lowest differences of potential economic gains based on skill level is among private transport users, when potential economic gains between skilled 1 and non-skilled individuals are compared in Model 1.

In models 3 and 1, the differences in potential economic gains between Skilled 2 and the non-skilled individuals that used private cars suggest higher differences in economic gains than between Skilled 1 and non-skilled individuals that also used this transport mode. But the opposite is valid for public transport users in Models 2 and 4, which indicate that within individuals of this transport mode group, skilled 1 workers had higher differences in potential gains.

Therefore, differences in economic gains among skill level-based groups are higher for the public transport users. A reasonable source for such outcome in MAC's job market may be related to spatial equilibrium determinants, as we suppose the existence of endogenous choice of place of residence location for this study area, where wealthier individuals had shown preference to live in areas that with more intense BRT infrastructure (Figure 1).

The differences in economic gains for public transport users may reflect the existence of spatial segregation[8] among them (Hernandez, 2017, Pereira et al., 2020; Gobillon et al., 2007). The spatial and job markets equilibrium determinants discussed by Lucas and Rossi-Hansberg (2002) and Zenou (2002) may also play a role in such differences, if richer individuals have more response power in the housing market, choosing to live in areas with more densities of job opportunities, given that the TOD policies of Curitiba and MAC regional integration had also incentivized the creation and growth of employment centers and industrial poles, with the provision of transport infrastructure (Thomé, 2020; Firkowski, 2002;Carmo and Moreira, 2020).

Therefore, by having a bachelor or postgraduation course, the economic inequality related to the spatial configuration of the study area decreases, because it allows for the access to more job opportunities, and consequently, for more decision-making power for high skilled[9] individuals. Among transport modes, the inequality in potential economic gain is higher for the public transport users, which might reflect higher spatial concentration of better transport infrastructure than for the private transport mode.

## 6 Final Remarks

[8] It is important to state that the de decision of the local of residence is not necessarily strongly based on the proximity to the near BRT infrastructure in MAC. However, it is reasonable to affirm that in this area, such infrastructures were prioritized to be allocated in central areas, where in parallel, high income individuals lived even before the existence of the BRT system, in 1974. After that, the Curitiba TOD urban expansion policies usually suggested more densities of job and dwellings near BRT infrastructures.

[9] Which were defined in this study as workers who had at least started a bachelor course.

There was a trend in Brazilian metropolitan areas of consolidating their urban spaces under unplanned spatial expansions, with lack of economic resources that in the present reflect on spatial uneven access to urban infrastructure, resulting in spatial inequalities of economic opportunities. We investigated the effects of heterogeneous accessibility levels among the workers of Metropolitan Area of Curitiba on their respective monthly wage in 2017, in order to understand such economic effects in a metropolitan area that is considered a good reference on urbanization strategies worldwide.

The present investigation found empirical evidence of positive effects of the measures of accessibility to formal jobs on monthly wages for the study area. We attribute such causality to agglomeration effects, related to the spatial density of formal jobs and transport infrastructure. Such effects on the observed uneven spatial distribution of accessibility might be a source of economic inequality in the Metropolitan Area of Curitiba.

We also found different magnitudes of such effects on the monthly wages based on social groups. Skill level and transport mode matter for the accessibility effects of formal job opportunities on economic earnings. High Skilled Individuals that traveled to work by private vehicles had the lowest unequal potential economic gains in the labor market attributed to the observed effects of accessibility. Such inequality in potential economic gains is stronger among public transport users, but it decreases among those who were high skilled.

The implications of the spatial configuration of Metropolitan Area of Curitiba on the job market corroborate a Spatial Mismatch Hypothesis. Therefore, even though the study area has had innovative urban consolidation policies, there is necessity of spatial relocation of job, dwellings or infrastructure, to achieve an urban space that promotes equal opportunities of potential economic gains in such labor market. Future researches could investigate the magnitudes of the needed spatial relocations, as well as identify effective policies to vanish geographic barriers on the local labor market.

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