The Indian Journal of Labour Economics (2022) 65:689–708
https://doi.org/10.1007/s41027-022-00390-w

ARTICLE

Brazilian Wage Curve: Further Evidence Based on Spatial Interactions in Times of Recession, 2012–2019

Guilherme Cemin de Paula[1] · **André M. Marques**[1]

Accepted: 18 July 2022 / Published online: 27 September 2022

Abstract
This paper verifies the existence of a spatial Brazilian wage curve based on individual hourly real wages using quarterly data from the Brazilian National Household Sample Survey for the period 2012 to 2019, probably the largest dataset ever used in this field. Our spatial regression model enables us to estimate both the magnitude and dispersion of the local wage's rigidity and its response to variations in the level of unemployment in neighbouring states—the spatial spillover. We find strong evidence for negative and significant spatial spillovers affecting local real hourly wages in the whole sample and 13 out of 20 different worker categories. For the entire sample, a 100% increase in local unemployment reduces the individual real wage in Brazil by 2.61% while the same increase in unemployment in contiguous states leads to an additional 1.00% reduction in wages. The findings indicate an overestimation of the real wage elasticity when the regression model neglects significant spatial autocorrelation. The results are robust to spatial effects present in the data, the weak instruments problem, and endogeneity of the regressors.

Keywords Labour market · Spatial wage curve · Unemployment · Spatial spillovers · Bargaining power

JEL Classification C26 J30 J60

André M. Marques
andremmarques@yahoo.com.br

Guilherme Cemin de Paula
cemin@outlook.com

1 Department of Economics, Federal University of Paraíba, Cidade Universitária, s/n, Castelo Branco, João Pessoa, PB 58051-900, Brazil

1 Introduction

This paper verifies the existence of a spatial Brazilian wage curve based on individual hourly real wages using the Brazilian National Household Sample Survey (PNAD) for the period 2012 to 2019, probably the largest (microdata) sample ever used in this field. The central hypothesis is that the individual real wage responds negatively to local unemployment and competitive conditions in other regionally interconnected markets (e.g. contiguous states) because of labour mobility and the wage policy of enterprises. We assume that the local market conditions and labour supply in neighbouring areas affect local businesses' wage policy, leading to spatial spillovers.

The labour market's capacity to adapt the labour force to new circumstances is essential in reducing the costs of macroeconomic shocks and policies (Amadeo and Horton 1997). However, in the face of labour mobility, commuting, and lower transport costs, local competitive conditions may be subject to the prevailing conditions in nearby areas when the regions are interconnected. In particular, the unemployment rate may exhibit a significant spatial autocorrelation: the unemployment of one region is correlated with the unemployment of neighbouring locations (Manning 1994; Palombi et al. 2017; Fingleton and Palombi 2013). We may expect employers to be aware of job opportunities in the local labour market and neighbouring areas (Longhi et al. 2006).

The Institute of Applied Economic Research[1] (IPEA) indicates that since 2010, the lowest monthly unemployment rate in the metropolitan region of São Paulo was 9% (December 2011). In contrast, the highest was 18.8% (May 2017), after a reversal toward an upward trend in January 2015. This scenario corresponds to a roughly 100% increase in the unemployment rate, implying a considerable decline in the real wage in Brazil.[2]

Besides, measuring the magnitude and significance of spatial spillovers is important for policy. The competition for state revenues or a drop in the level of activity in a given state may adversely affect the local real wage and lead to a reduction in real wages in neighbouring federative units. Thus, changing conditions in interconnected markets may accentuate negative trends by spreading their adverse effects. If spatial spillovers exist, they highlight the need for coordinated policy decisions at the state level.

According to Baltagi and Rokicki (2014), neglecting spatial effects may lead to an *overestimation* bias of the elasticity of wages to local unemployment, mistakenly implying greater wage flexibility (lower costs) in response to changes in the local economic conditions. Besides, previous studies pay little attention to misspecification issues. In contrast, we adopt formal specification tests for the weak

[1] Instituto de Pesquisa Economica Aplicada in Portuguese.

[2] In the same year, the IPEA estimated a decrease of 3.55% in the real GDP, which was the most profound slack in decades. Holland (2019) discusses the adopted economic policies which led to the most substantial slowdown in decades and other political and economic issues associated with the abrupt fiscal crisis in the Brazilian economy from 2014 to 2017.

instruments problem and the exogeneity of the regressors. Neglected endogeneity and unaccounted-for heterogeneity might lead to inconsistent estimates.

This paper contributes to the wage-curve literature in four aspects. First, while most studies in this field analyse developed countries, we use the largest micro-database that includes Brazil's current conditions. Further, we obtain the disaggregated estimate for the elasticity of individual real wages for the whole sample and 20 different worker segments (e.g. men and women; rural and urban) and not only for aggregated data. Elhorst et al. (2007) and Buettner (1999) use only the mean of the variables.

Second, we use 1-year lagged unemployment as an instrumental variable with region fixed effects, as suggested by Blanchflower and Oswald (1995), Baltagi and Blien (1998) and Elhorst et al. (2007). Therefore, our methods account for the unobserved heterogeneity and endogeneity of unemployment beyond estimating the magnitude of spatial spillovers. In contrast to Baltagi and Blien (1998), Baltagi et al. (2017), and Baltagi and Rokicki (2014), who ignore the problem of weak instruments and lack tests for endogeneity, we overcome these limitations by presenting formal hypothesis testing for both potential difficulties of the instrumental variable (IV) estimator.[3]

Third, our spatial regression model enables us to estimate the magnitude of the local wage's rigidity (direct effect) and its response to variations in the level of unemployment in neighbouring states (indirect effect)—the spatial spillover. Hence, our methods complement previous studies of Brazil that ignore these different sources of impact. Finally, using a considerably larger sample size, we obtain precise estimates and greater power for hypothesis testing than in previous studies [see, for example, Baltagi et al. (2017)].[4]

When considering the whole sample, a 100% increase in local unemployment reduces the individual real hourly wage in Brazil by 2.61% while the same increase in unemployment in contiguous states leads to an additional 1.00% reduction in real wages. The same increase in unemployment reduces men's real hourly wage by 2.45% and women's hourly wage by 2.29%. Further, spatial spillover is significant only for men. The female labour market is not affected by competitive conditions in contiguous states. Our findings are robust to spatial effects present in the data, the weak instruments problem, and the endogeneity of the regressors.

After a comparative analysis, we conclude that the assumption of independence of observations tends to generate an overestimated elasticity for the wage curve, as pointed out by Baltagi and Rokicki (2014). When we neglect spatial dependence, we observe an *overestimation effect* for the whole sample, men and women, formal and informal sectors, youth, and other categories. Besides, in contrast to Longhi

[3] We put all the specification test results in the Appendix. See Table 8.

[4] Card (1995) and Baltagi and Blien (1998) observe that the relevant number of observations for our model specification is the number of individuals multiplied by the number of regions ($4,045,664 \times 27$ *states* $= 109,232,928$). In their study for Brazil, Baltagi et al. (2017) use a sample of only $739,490 \times 27$ *states* $= 19,966,230$ that corresponds only to 18.27% of our sample data. In the case of Poland, Baltagi and Rokicki (2014) use only $102,924 \times 16$ *states* $= 1,646,784$ observations, which corresponds to just 1.51% of our sample data.

et al. (2006), Baltagi et al. (2012), and Baltagi and Rokicki (2014), who have found inconsistently positive spatial spillovers, our estimates consistently show that both the direct effect and the spatial spillovers exhibit a statistically significant negative sign, following the theory.

The remainder of the paper is organized as follows. Section 2 compares previous estimates and discusses related literature. Section 3 presents the methodology. Section 4 presents the results for the traditional and spatial wage curve, and Section 5 concludes. We provide relevant additional information in the Appendix.

2 Literature Review

2.1 The Wage Curve

The determination of workers' real wages and their response to economic conditions and individual characteristics has been the subject of study since the 1970s. Mincer's (1975) pioneering work studied the relationship between wages and aspects related to individuals' productivity, such as years of schooling and work experience.

Since the study of Mincer (1975), subsequent studies have tested the inclusion of new variables that have the potential to explain the formation of individual real wages. In one of the most innovative studies, Blanchflower and Oswald (2005) documented a negative relationship between real wages and the level of unemployment in the workers' region (estimated at −0.10) for the economies of the UK and USA. This indicates that a 100% increase in the unemployment rate is associated with a decrease in individual real wages by 10%, on average.

This result's invariance in various countries led Blanchflower and Oswald to name this empirical finding "the wage curve".[5] The elasticity measures the degree of rigidity of the local real wage, containing information on the labour market's adjustment costs in response to changing economic conditions. The fundamental limitation of the wage curve originally formulated is the absence of consideration of regional aspects of the labour market and the likely dependence between the observations, as documented in Buettner (1999), Elhorst et al. (2007), Baltagi et al. (2012), and Fingleton and Palombi (2013), among others. The initial assumption of the wage curve is that only the local unemployment level influences the determination of the individual real wage (Longhi et al. 2006).

Longhi et al. (2006) suggest testable hypotheses that help explain the performance of the local labour market. First, if labour markets are interconnected, they may be subject to common factors that affect their competitive conditions. In this case, the spatial autocorrelation will be statistically significant. Second, wage elasticity concerning unemployment corresponds to an index of the bargaining power of enterprises. For example, in isolated regions (e.g. rural areas), the real wage

[5] Baltagi and Blien (1998, p. 135–6) observed that "The wage curve is simply a standard wage equation normally used to estimate the returns to education of the male-female wage gap but with the addition of the local unemployment variable to the set of regressor".

response tends to be higher than that in heavily populated areas and easier to access (e.g. urban areas).

In Brazil, some studies estimate the wage curve; however, they typically ignore regional or geographical aspects of the labour market in a more precise form (see the Methodology section); in other cases, the estimates limit the exclusive use of aggregated data to specific groups of workers.

De Carvalho Filho and Estevão (2012) estimate the wage curve for Brazil in the period 1981–1999 based on PNAD. The elasticity decreases from an initial value of −0.117 from 1989 to 1999 and then reverts to its early higher values from 1999. Silva et al. (2015) have found that the elasticity of the real wage in Brazil varies between −0.04 and −0.03 from the period 2002 to 2009. Based on PNAD data for 1990–1999 and distinguishing between skilled, semiskilled, and unskilled labour in Brazil, Reis (2006) estimates the elasticity of the wage curve as −0.013 for the first group of workers and −0.051 for unskilled labour.

Barufi et al. (2016) present evidence of the wage curve for Brazil by controlling for spatial dependence. Using data from the annual PNAD for 2003–2015 (and from the censuses for 1991 and 2010), they conclude that the elasticity of wages is sensitive to the inclusion of neighbouring regions. Beyond a negative relationship with the workers' region's unemployment rate, individual wages also have a relationship with the unemployment rate of adjacent areas, which characterizes the influence of spatial spillovers.

Three observations must be made regarding the study by Barufi et al. (2016): the period studied by them does not include the recent economic crisis described in Holland (2019) affecting the labour market in Brazil—only the periods 2003–2015 and 1991–2010 are analysed. They include only male workers in the sample (15–59 years of age). The authors estimate the autoregressive spatial coefficient but do not compute the direct, indirect, and total effects. The absence of this information prevents the measurement and application of a significance test for spatial spillovers (LeSage and Pace 2009; Elhorst 2010). The approach proposed in this study differs substantially from the work by Barufi et al. (2016), as described in detail in the Methodology section.

Baltagi et al. (2017) provide evidence of the wage curve for the Brazilian labour market, and their estimate of the whole sample is −0.076. However, when they sort the estimates by gender, men's elasticity grows to −0.134 while the elasticity estimate for women drops to 0.002 (wrong sign and not statistically significant). They claim that these results are in line with other studies from Brazil. However, the spatial spillover's statistical significance in the Brazilian labour market suggests that there are problems involved in their estimates. They assume that the Brazilian regional labour markets are "isolated islands" in a national economy. This assumption typically leads to an overestimation bias for the wage curve elasticity (Baltagi and Rokicki 2014).

In contrast to the findings of Baltagi et al. (2017), we provide strong evidence for the existence of a wage curve for both men and women workers in Brazil in all specifications. The same observation applies to the rural workers, which stands in stark contrast to the main results of Baltagi et al. (2017). The smaller sample used by Baltagi et al. (2017) and the restrictive assumption of independence between observations partially explain the different findings, leading to higher uncertainty estimates and overestimation bias of the real wages' elasticity.

In other countries, studies tend to corroborate the initial estimate of Blanchflower and Oswald (1995). Boushey (2002) estimates the wage curve for metropolitan areas of the United States based on individual wages per week and per hour worked in the 1986–1996 period. The aggregate estimate is different from individual figures for the two groups of workers. This finding indicates that aggregate estimates may be subject to aggregation bias. In particular, the elasticity is significantly higher for aggregate data than when the individual wages are analysed separately.

Kennedy and Borland (2000) estimate the wage curve for Australia using individual wages for 42,413 observations, including both men and women. They conclude that wage elasticity concerning local unemployment is between −0.07 and −0.09, which is very close to the initial estimate of −0.10 (Blanchflower and Oswald 1995). For Belgium, Janssens and Konings (1998) estimate the response of wages to unemployment as −0.04 when it includes men and women aggregated in the data. However, taking men and women separately, the estimate does not differ from −0.10. The authors argue that the women's labour market is more competitive and less influenced by unions than men.

From a sample of 40,852 individuals covering 142 regions of Germany in the period 1981–1990, Baltagi and Blien (1998) find evidence of differences in the wage curve between youths and adults, men and women, and high- and low-skilled workers. The estimate for all workers is −0.11. Baltagi et al. (2012) once again analyse the German labour market based on a specification that makes it possible to obtain the magnitude and test the significance of spatial spillovers. The elasticities are −0.023 and −0.047 for short- and long-term unemployment, respectively. The authors find the existence of positive and statistically significant spillovers (0.020 in magnitude), one unexpected result that may invalidate the wage curve empirically in certain circumstances.

Longhi et al. (2006) obtained similar results when estimating the wage curve for 327 regions of Germany over the 1990–1997 period for aggregated data. They conclude that wages are less elastic in most agglomerated areas (higher population density) and more flexible in regions that are more difficult to access, which indicates that enterprises have more (less) market power in less (more) populated areas. Contrary to the theoretically expected sign, the results show—like in Baltagi et al. (2012)—the occurrence of positive and statistically significant spillovers (of magnitude 0.1368). Baltagi and Rokicki (2014) examine Poland's regional labour market (16 NUTS 2 regions) using microdata for the 1999–2010 period. They find a significant negative relationship with the local unemployment in which individual wages also have an inverse relationship with the neighbouring regions' unemployment rate. However, for workers with permanent employment (tenure) and the public sector, the results sometimes indicate the absence of positive spillovers.

3 Methodology and Data Description

3.1 Data Description

We use the Continuous National Household Sample Survey (PNAD Contínua), a survey conducted by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE). The data are compiled from 2012 to 2019 and cover the 27 federative units.[6]

After analysis, we use the following variables: normal monthly income, hours usually worked, occupation, activity, sector (public or private), household location (rural or urban), type of work (formal or informal), type of area (metropolitan region or another region), number of years and months of employment in the primary job, age, sex, years of schooling, race, and federative unit where each person works. Besides, we use the following variables to calculate the annual unemployment rate for each state: employment status and whether the person (for persons 10 years of age and older) took any steps to find work in the reference week.

From the remuneration and hours worked, the real hourly wage was calculated for each worker, where the weekly hours were multiplied by 4.34524 (the average number of weeks per month). The remuneration was then deflated using the deflators disclosed by the IBGE specifically for the PNAD data, based on the Broad Consumer Price Index (Índice de Preços ao Consumidor Amplo, IPCA), calculated for the different federative units. We join the variables worker occupation and service activity.

We split the occupation variable into nine categories and the schooling variable into four categories. Finally, we separate the race variable into two groups: white- and yellow-skinned people and black- and brown-skinned and indigenous people. We split the company activity variable into ten categories (see Tables 6 and 7 in the Appendix).

Another widely studied undesirable feature of the PNAD data is wrongly stated information that leads to outliers. To avoid this problem, we make the following adjustments to the variables: a maximum remuneration of R$ 100,000.00 and a minimum at the level of the minimum wage deflated for each year; maximum age of 80 years; a maximum of 60 years worked and a minimum of 10 hours worked per week; and a maximum of 60 years for the employment relationship. Additionally, we exclude from the sample workers who produce for their own consumption, self-employed workers, and unemployed people.

Table 1 shows the descriptive measures of the data. Regarding the essential variables in the analysis, we notice that the mean unemployment rate in the period is 9.76%, with a standard deviation of 3.6%, while the mean real hourly wage is R$ 13.27.

Figure 1 displays the path of the standardized variables unemployment rate and real hourly wage. It highlights the inverse correlation between variables over the years, as expected theoretically. We use the shapefile of the Brazilian states provided

[6] https://www.ibge.gov.br/.

Table 1 Basic descriptive statistics

Variable	Observations	Mean	Std. deviation	Min.	Max.
Real hourly wage	4,045,664	13.27	18.49	0.38	2711.52
Unemployment rate	4,045,664	9.760	3.574	2.583	21.669
Age	4,045,664	37.293	12.317	14	79
Time in the job	4,045,664	6.573	8.101	0	70
Years of schooling	4,045,664	10.979	3.837	1	16
Race	4,045,664	0.551	0.497	0	1
Sex	4,045,664	1.451	0.498	1	2
State/federative unit	4,045,664	32.736	10.922	11	53
Occupation	4,045,664	5.302	2.544	0	9
Activity	4,045,664	4.500	2.708	0	10
Sector	4,045,664	1.660	0.984	1	4
Rural	4,045,664	0.157	0.364	0	1
Informal	4,045,664	0.254	0.435	0	1
Metropolitan region	4,045,664	0.431	0.495	0	1

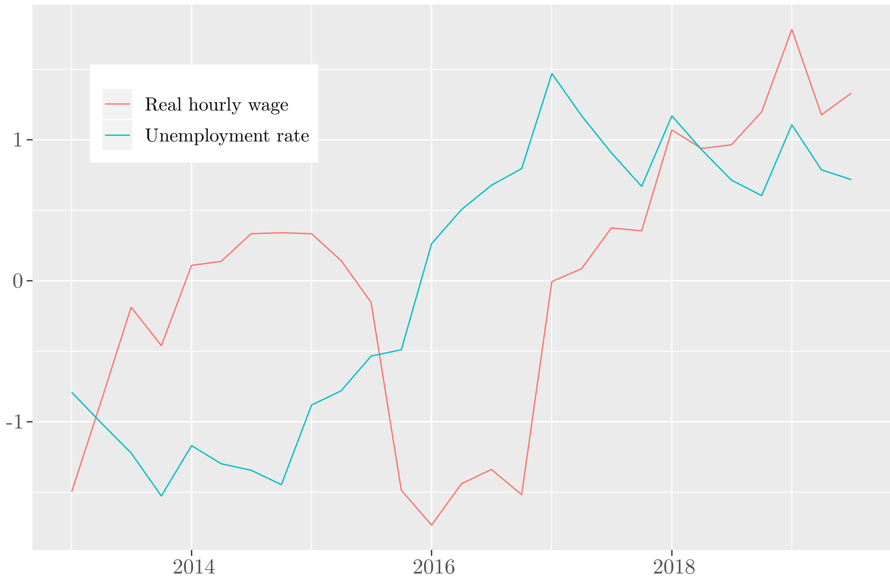

Fig. 1 Average real wage and unemployment—Brazil—in standard deviation units

by the IBGE to generate the W matrix. This file contains the information required to create the spatial weight matrices. The W matrix is square, with dimensions of 27×27, and its main diagonal elements are zero because no state neighbours itself.

Following the literature, we adopt the most straightforward and widely used matrix of geographic proximity, namely, the queen contiguity matrix—which has weights for regions that share borders and vertices (Anselin and Rey 1991). The W matrix is standardized so that the sum of the rows results in the unit.

Our fundamental motivation for choosing the spatial regression model is the theoretical considerations of LeSage (2014) and mainly Halleck Vega and Elhorst (2015). They consider the spatially lagged *X* (SLX) model the best point of departure to estimate spatial effects, apply significance tests, and provide ease of interpretation of the direct and indirect (spillover) effects. According to Halleck Vega and Elhorst (2015, p. 342), part of the explanatory variables *X* and their spatially lagged values can be employed to assess the spatial spillovers. Baltagi and Rokicki (2014) also recently used this model specification.[7]

When local spillovers are significant, neglecting these effects in regression models leads to estimates suffering from omitted variable bias (LeSage and Pace 2009; LeSage 2014). In a study of the German labour market, Buettner (1999) concludes that neglecting spatial interactions linked to the labour market leads to a biased estimate of the response of wages to local unemployment. The spatial regression model that describes the wage curve in Brazil is expressed by:

$$\log(w_{\mathrm{irt}}) = \alpha + \beta\log(u_{\mathrm{rt}}) + \chi\left(\sum_{s} W_{\mathrm{rs}}\log(u_{\mathrm{st}})\right) + X'_{\mathrm{irt}}\gamma + \mu_r + \lambda_t + v_{\mathrm{irt}} \qquad (1)$$

in which w_{irt} is the real hourly wage of each individual i, u_{rt} is the unemployment rate of each state r, W_{rs} is the matrix of spatial weights to express the relationship between each state r and its neighbour s, u_{st} is the unemployment rate in neighbouring states, and X'_{irt} is a matrix with all the other classic control variables for determination of the wage, described in detail in Table 5 in the Appendix. Lastly, μ_r is the region effect, λ_t is the time effect, and v_{irt} is the error term with the traditional properties. The parameters of interest are β and χ.

The hypothesis initially formulated by Blanchflower and Oswald (1995) is that β is negative. However, neglecting spatial interaction [with the assumption that $\chi = 0$, as done in Baltagi et al. (2017)] influences the estimate of β. Hence, the alternative hypotheses in the present paper are that both β and χ are likely to be *negative* in most worker categories for the Brazilian labour market. We test the existence of spatial autocorrelation in (1) by testing the null of $\chi = 0$ using the standard t-statistic.

To interpret the results, we observe that the partial derivative of the local wage to the unemployment of the own-state is given by $\frac{\partial w_i}{\partial u_i} = \beta$ (direct effect), while the indirect effect (spillover) is given by the partial derivative of the local wage to the unemployment in neighbouring states: $\frac{\partial w_i}{\partial u_j} = \chi$ where $i \neq j$.

[7] We do not include all spatially lagged values of the explanatory variables *X* because we do not have the point coordinates of the individuals. Halleck Vega and Elhorst (2015, p. 346), when referring to the SLX model, observe: "a strong aspect is that there are no prior restrictions imposed on the ratio between the direct effects and spillover effects, which was a limitation of the SAR and SAC models". In LeSage (2014) and Halleck Vega and Elhorst (2015), the acronym SAC refers to the spatial autoregressive combination model, while the SAR model refers to the spatial autoregressive model. The SAR model accounts for endogenous interaction effects, and the SAC model accounts for both endogenous interaction effects in combination with the interactions among the error terms.

As LeSage (2014) and Halleck Vega and Elhorst (2015) explain, one of the advantages of the above specification is the possibility of directly interpreting the magnitude of these two effects and testing their statistical significance with the *t*-statistic without relying on Monte Carlo simulations.[8] The estimation of Eq. (1)—with the restriction that $\chi = 0$ (i.e. by imposing the independence assumption between observations)—results in the wage curve initially proposed by Blanchflower and Oswald (Blanchflower and Oswald 1995), in which β represents the elasticity of the real hourly wage to local unemployment.

The SLX model adopted in Eq. (1) differs substantially from the SAR model used in the study by Barufi et al. (2016). First, the SLX model can be estimated using the ordinary least squares (OLS) method, as it is unnecessary to use the maximum likelihood estimator. Second, the test for the significance and magnitude of spatial spillovers can be performed directly through the partial derivative of the expected value of (1), without relying on the computation of the direct, indirect, and total effects matrices and their dispersion measurements, as is the case for SAR/SAC and spatial Durbin models. Therefore, obtaining the coefficients is computationally more straightforward, and their interpretation is uncomplicated.

Barufi et al. (2016) use a SAR model; however, they do not present the magnitude of potential spillovers or test their statistical significance through the direct, indirect, and total effects with their dispersion measurements. The current interpretation of regression models (based only on isolated β coefficient) does not apply to SAR/SAC and spatial Durbin models, because these models involve endogenous feedback effects with a multiplication of the estimated parameters (LeSage and Pace 2009; Palombi et al. 2017).[9]

As referred to in the Introduction, despite its suggestion by a large number of authors in the field of labour market literature, the above-cited papers lack the formal application of the Wu-Hausman test to choose the best estimator for the data, as suggested in Greene (2003 Section 5.5). Furthermore, the widely known weak instrument problem (low correlation between the instruments and endogenous variables) pervades the instrumental variables literature (Staiger and Stock 1997). We implement both types of tests to choose the best estimator for our data.

The specification tests are essential because the FE2SLS (two-stage least squares fixed effects) estimator used by Baltagi et al. (2017) and Baltagi and Rokicki (2014), among others, is less efficient than the OLS estimator when the explanatory variables are exogenous, implying substantial standard errors when the null of the

[8] In relation to the SAR model chosen by Barufi et al. (2016), LeSage observed that "Global spillover specifications are more difficult to estimate and correct interpretation of estimates from these specifications is more difficult" (LeSage 2014, p. 15).

[9] For example, the direct effect in the SAR model is given by $\frac{(3-\rho^2)}{3(1-\rho^2)}\beta_k$, and the indirect effect (spillover) is given by $\frac{(3\rho+\rho^2)}{3(1-\rho^2)}\beta_k$, for k explanatory variables and $N = 3$. After obtaining these values, it is necessary to test their significance to assess their validity in the population, obtaining their dispersion measurements through Monte Carlo simulations. The valid method for inference with SAR/SAC and spatial Durbin spatial models involves obtaining the effects matrices and their corresponding dispersion measurements [see LeSage and Pace (2009) and also Elhorst (2010)]. The spatial Durbin model accounts for both endogenous and exogenous interaction effects but not for interaction effects among the error terms.

Wu-Hausman test cannot be rejected. The weak instrument test evaluates whether the 1-year lagged unemployment is a relevant instrument for estimation. We implement both types of tests to help us choose the best estimator, adding more reliable information for our conclusions.

The next section presents our main findings, and we discuss in some detail only the results based on the FE2SLS estimator since our specification tests indicate it as the best alternative estimator for the Brazilian microdata.

4 Results and Discussion

4.1 Traditional Wage Curve

In this subsection, we present the unemployment elasticity of real wages β based on the restriction of $\chi = 0$ for the whole sample and 20 different categories, for the FE (OLS fixed effects) and the FE2SLS estimators.[10] The elasticity of wages to unemployment is interpreted as the proportional variation in the individual real hourly wage in response to a 100% increase in the unemployment rate.

The fourth column in Table 2 (FE2SLS) presents the results for our preferred specification because the implemented tests strongly reject both the null of the weak instrument and the exogeneity of unemployment (see Table 8 in the Appendix). We find that a 100% increase in unemployment is associated with a 3.7% reduction in the real hourly wage for the whole sample in Brazil, which is very similar in magnitude to the value for Germany (−0.037), according to Baltagi et al. (2012). However, the same increase in unemployment reduces men's real hourly wage by 5.2% and women's hourly wage by 1.37%.

We also observe that less experienced workers suffer a more accentuated reduction in individual real hourly wages than more experienced workers. Besides, informal sector workers (−0.0683) contrast considerably with rural workers (−0.0414) and white people (−0.0486). At the same time, young workers (−0.0585) and workers with higher education (−0.0755) suffer the highest reduction in real wages in times of recession.

The above explicit contrasts between the formal (−0.028) and informal (−0.068), rural (−0.041) and urban (−0.014), and private (−0.028) and public (−0.009) sectors correspond to the theoretical hypotheses discussed in the literature, especially those discussed by Card (1995), Longhi et al. (2006), and Baltagi and Rokicki (2014). For example, Barufi et al. (2016) and Longhi et al. (2006) theoretically argue that the individual real wage is more sensitive in areas that are less dense and more difficult to access (rural sector), which diminishes workers' bargaining power. However, in areas of high agglomeration, job opportunities are generally better and easier to access, indicating that workers' elasticity in the urban sector tends to be significantly lower. Our results confirm these hypotheses.

[10] For the sake of brevity, we only report β, but the full results are available upon request.

Table 2 FE and FE2SLS—Results. Real hourly wage elasticity by worker category

Category	FE		FE2SLS	
	$\hat{\beta}$	se($\hat{\beta}$)	$\hat{\beta}$	se($\hat{\beta}$)
Total	−0.0309 ***	0.0008	−0.0374 ***	0.0011
Men	−0.0500 ***	0.0011	−0.0522 ***	0.0016
Women	−0.0064 ***	0.0011	−0.0137 ***	0.0016
Age (*min*, 29)	−0.0374 ***	0.0012	−0.0585 ***	0.0017
Age (30, 44)	−0.0251 ***	0.0012	−0.0237 ***	0.0018
Age (45, *max*)	−0.0172 ***	0.0016	−0.0267 ***	0.0023
Elementary, incomplete	−0.0031**	0.0015	−0.0031	0.0021
High school, incomplete	−0.0113 ***	0.0016	−0.0134 ***	0.0024
Higher education, incomplete	−0.0372 ***	0.0011	−0.0524 ***	0.0016
Higher education, complete	−0.0821 ***	0.0024	−0.0755 ***	0.0032
Experience (0, 2)	−0.0221 ***	0.0011	−0.0340 ***	0.0017
Experience (2, 10)	−0.0308 ***	0.0011	−0.0376 ***	0.0016
Experience (10, *max*)	−0.0301 ***	0.0021	−0.0325 ***	0.0029
Private sector	−0.0189 ***	0.0008	−0.0276 ***	0.0012
Public sector	−0.0176 ***	0.0021	−0.0092**	0.0028
Whites	−0.0432 ***	0.0011	−0.0486 ***	0.0017
Non-whites	−0.0212 ***	0.0010	−0.0280 ***	0.0015
Rural sector	−0.0330 ***	0.0008	−0.0414 ***	0.0012
Urban sector	−0.0119 ***	0.0019	−0.0136 ***	0.0027
Formal	−0.0177 ***	0.0008	−0.0277 ***	0.0012
Informal	−0.0676 ***	0.0018	−0.0683 ***	0.0024

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$ se(.) stands for the standard error of the estimate

In sum, consistent with expectations, for the whole sample and 19 out of 20 different categories, we find strong evidence of the wage curve in Brazil. For the entire sample, the unemployment elasticity of real wages is estimated as −0.037 and is statistically significant at the 1% level. For the 19 remaining different worker categories (except elementary education), we observe that all coefficients are statistically significant at the 1% and 5% probability levels and all have the theoretically expected negative sign. These results contrast sharply with the findings of Baltagi et al. (2017) since the latter do not find evidence of the wage curve for women, rural, and low-skilled workers by using Brazilian data.

Besides, our findings also confirm the results of Barufi et al. (2016) regarding the substantive difference between formal (−0.028) and informal workers (−0.068), beyond the contrast between less dense areas (rural workers) and highly agglomerated areas (urban workers). Hence, the Brazilian labour market's adjustment costs are not equally distributed across these 20 categories.

4.2 Spatial Wage Curve

In this subsection, we present the main findings of the paper: the unemployment elasticity of real wages β and the spatial spillover unemployment elasticity χ for the whole sample and 20 different categories based on the FE2SLS estimator.[11] We obtain these findings based on the best spatial regression model because the implemented specification tests strongly reject both the null of the weak instrument and the exogeneity of unemployment (see Table 8 in the Appendix).

As before, we find evidence for the spatial wage curve based on Brazilian data since we reject the null of $\beta = 0$ against $\beta < 0$ for the whole sample and 16 out of 20 different worker categories at the 5% level. We also reject the null of $\chi = 0$ against $\chi < 0$ for the whole sample and 13 out of 20 different worker categories at the 5% level. We consistently find the statistically significant negative sign for both parameters, which is different from most previous reported studies.

For the entire sample, a 100% increase in local unemployment reduces the individual real hourly wage in Brazil by 2.61%, while the same increase in unemployment in contiguous states implies a 1.00% reduction in real wages.

However, the same increase in unemployment reduces men's real hourly wage by 2.45% and women's hourly wage by 2.29%. Another noticeable difference between men and women workers is the statistical significance of spatial spillovers for men. It implies that a 100% increase in unemployment in neighbouring states is associated with an additional reduction of 2.44% in their real wages. In contrast, the female labour market is not affected by competitive conditions in contiguous states (locally limited). The above results imply that the labour market in Brazil is more competitive for men than for women.

Under the hypothesis of endogenous unemployment with spatial interactions, we find the greatest elasticities of the real wages to unemployment in neighbouring states (spatial spillovers) in the following categories: low-skilled workers (−0.030), more experienced workers (−0.060), workers with the highest level of education (−0.061), and urban sector workers (−0.026), followed by the category of men in general (−0.024). Under the same conditions, we find the greatest elasticities of the real wages to unemployment in the local labour market in the following categories: young workers (−0.038), less educated workers (−0.038), less experienced workers (−0.035), white people (−0.041), informal workers (−0.076), and rural sector workers (−0.033). According to Amadeo and Horton (1997), the informal sector is structurally large in developing countries and may play an essential role as a buffer in adjustment periods. Our findings provide support for this view of the labour market flexibility mechanism.

When we compare the results of Tables 3 and 2, a clear pattern emerges. The spatial interaction between labour markets in Brazil, as indicated by the rejection of $\chi = 0$, decreases the sensitivity of the real wage to the variations in the level of local unemployment. For instance, the wage elasticity for male workers neglecting spatial interactions is −0.0522, but when we control spatial dependence, that magnitude

[11] For brevity, we only report β and χ, but the full results are available upon request.

Table 3 FE2SLS—Spatial wage curve results. Real hourly wage local elasticity and spillover effect

Category	FE2SLS estimator			
	$\hat{\beta}$	se($\hat{\beta}$)	$\hat{\chi}$	se($\hat{\chi}$)
Total	−0.0261 ***	0.0047	−0.0100 **	0.0039
Men	−0.0245 ***	0.0066	−0.0244 ***	0.0055
Women	−0.0229 ***	0.0067	0.0081	0.0056
Age (*min*, 29)	−0.0385 ***	0.0072	−0.0178 ***	0.0060
Age (30, 44)	−0.0228 ***	0.0075	−0.0008	0.0062
Age (45, *max*)	0.0011	0.0096	−0.0242 ***	0.0079
Elementary, incomplete	−0.0376 ***	0.0089	0.0302 ***	0.0074
High school, incomplete	−0.0294 ***	0.0098	0.0143**	0.0083
Higher education, incomplete	−0.0106	0.0066	−0.0369 ***	0.0055
Higher education, complete	−0.0053	0.0134	−0.0607 ***	0.0109
Experience (0, 2)	−0.0349 ***	0.0070	0.0008	0.0059
Experience (2, 10)	−0.0309 ***	0.0068	−0.0058	0.0057
Experience (10, *max*)	0.0363 ***	0.0123	−0.0599 ***	0.0101
Private sector	−0.0208 ***	0.0049	−0.0061	0.0041
Public sector	0.0305**	0.0126	−0.0346 ***	0.0104
Whites	−0.0411 ***	0.0063	−0.0066	0.0052
Non–whites	−0.0169**	0.0071	−0.0097**	0.0059
Rural sector	−0.0328 ***	0.0052	−0.0077**	0.0043
Urban sector	0.0171	0.0109	−0.0264 ***	0.0088
Formal	−0.0129**	0.0052	−0.0131 ***	0.0044
Informal	−0.0761 ***	0.0103	0.0068	0.0085

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$ se(.) stands for the standard error of the estimate

decreases to −0.0245, which means there is a clear overestimation bias. The same is true for almost all examined cases.

Under the hypothesis of labour market isolation (labour markets as "floating islands"), any positive variation in the local unemployment level likely reduces individual real wages more quickly. These findings suggest that commuting and mobility of labour in Brazil permit a broader search for job opportunities in interconnected areas and increase workers' bargaining power. This mechanism helps explain why Baltagi and Rokicki (2014) find an overestimation effect when one neglects the spatial autocorrelation in the data.

Table 4 (FE) presents an estimate of the spatial wage curve based on the assumption that the unemployment rate is an exogenous variable, perhaps reflecting changes in the macroeconomic conditions. Based on the Wu-Hausman test, data reject that hypothesis at the 1% level. Thus, we consider these results only as a piece of supplementary information. In sum, data reject the null hypothesis of $\beta = 0$ against $\beta < 0$ for the whole sample and 17 out of the 20 different worker categories at the 5% level. Furthermore, from these findings, data also reject the null hypothesis of $\chi = 0$ against $\chi < 0$ for the whole sample and 17 out of 20 different worker categories at the 5% level.

Table 4 FE—Spatial wage curve results. Real hourly wage local elasticity and spillover effect

Category	FE estimator			
	$\hat{\beta}$	se($\hat{\beta}$)	$\hat{\chi}$	se($\hat{\chi}$)
Total	−0.0161 ***	0.0022	−0.0164 ***	0.0023
Men	−0.0229 ***	0.0031	−0.0300 ***	0.0032
Women	−0.0088 ***	0.0032	−0.0027	0.0033
Age (*min*, 29)	−0.0175 ***	0.0034	−0.0220 ***	0.0035
Age (30, 44)	−0.0149 ***	0.0036	−0.0113 ***	0.0037
Age (45, *max*)	−0.0016	0.0046	−0.0173 ***	0.0048
Elementary, incomplete	−0.0301 ***	0.0042	0.0294 ***	0.0043
High school, incomplete	−0.0156 ***	0.0047	0.0048	0.0049
Higher education, incomplete	−0.0081 ***	0.0031	−0.0323 ***	0.0032
Higher education, complete	−0.0072	0.0067	−0.0836 ***	0.0070
Experience (0, 2)	−0.0178 ***	0.0033	−0.0047	0.0034
Experience (2, 10)	−0.0188 ***	0.0033	−0.0133 ***	0.0034
Experience (10, *max*)	0.0257 ***	0.0061	−0.0618 ***	0.0063
Private sector	−0.0143 ***	0.0023	−0.0051**	0.0024
Public sector	0.0047	0.0056	−0.0248 ***	0.0058
Whites	−0.0270 ***	0.0034	−0.0175 ***	0.0035
Non-whites	−0.0109 ***	0.0029	−0.0115 ***	0.0030
Rural sector	−0.0149 ***	0.0024	−0.0200 ***	0.0025
Urban sector	−0.0208 ***	0.0056	0.0096**	0.0057
Formal	−0.0118 ***	0.0024	−0.0065 ***	0.0025
Informal	−0.0398 ***	0.0050	−0.0310 ***	0.0052

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$, se(.) stands for the standard error of the estimate

Our estimates based on our best spatial regression model (FE2SLS—Table 3) indicate that a high unemployment level in a worker's area and surrounding areas exerts a statistically significant downward pressure on local individual real wages. Yet, as previously pointed out by Fingleton and Palombi (2013) and Baltagi and Rokicki (2014), local real wages are more sensitive to the unemployment rates in the surrounding areas than in their local counterparts.

We interpret this finding as meaning that a large share of workers are commuting, or that many firms set the wage level according to the situation in the broader regional labour market. This result supports the view that labour mobility and regional aspects, the diffusion of information in the economy, and the wage policy of businesses are essential drivers for understanding Brazil's labour market mechanisms.

In comparison with the works of Baltagi and Rokicki (2014), Baltagi et al. (2012), and Longhi et al. (2006), it is worth noting that in contrast to the cited papers, the negative sign (and significance) of spatial spillovers in the Brazilian labour market is consistent with theoretical expectations. The existence of a positive spillover may cause the wage curve to disappear (Blanchflower and Oswald 1995, p. 160). The consistency between the theoretical expectation and the results may indicate that the spatial regression model chosen describes the Brazilian microdata reasonably well.

Based on the above findings, we can draw the following general conclusions. First, in comparison with other studies, our findings indicate that Brazil's labour market is more competitive for men than for women. Card (1995) obtains the same result for the United States, and Baltagi and Rokicki (2014) do so for Poland. Thus, the Brazilian labour market tends to follow the pattern of other countries in this respect.

Second, as Longhi et al. (2006) suggest, we find a substantial difference between rural and urban sector workers: while the wage elasticity for the rural sector wage is −0.0328, the elasticity of the urban sector does not differ statistically from zero (concerning local unemployment). Workers experience less bargaining power when working in more isolated and difficult-to-access regions (less dense areas). This piece of evidence confirms the theoretical hypothesis of Longhi et al. (2006).

Third, when wage elasticities are compared by level of education as an approximate measure of qualifications, the results are quite different from the initial estimates obtained by Reis (2006), based on annual PNAD data for the 1990s in Brazil. In the present study, the workers with the highest educational level (higher education) face the most substantial reduction in real hourly wages (−0.061) in response to rising unemployment in neighbouring states. This result may indicate that the recent expansion of higher education in Brazil is not being accompanied (at the same speed) by the absorption of these new professionals arriving in the labour market year after year. This feature is not present in other studies of Brazil.

Fourth, Brazil's wage curve represents approximately one-quarter of the coefficient initially estimated for the United States and the United Kingdom for the whole sample. Compared to other studies of the Brazilian labour market, our findings indicate an overestimation of the real wage elasticity when the regression model neglects significant spatial autocorrelation, as pointed out by Baltagi and Rokicki (2014).

However, the estimate for different categories shows that wage rigidity is heterogeneous among the various worker categories, exhibiting varying nuances according to the group's characteristics. As Card (1995) suggests, this heterogeneity may reflect the existence of hierarchies between classes in terms of bargaining power.

We conclude that individual real wages in Brazil are less flexible (relative to unemployment at the worker's location) than the mean estimates available for other economies with a similar degree of development. This feature may indicate that the present economic crisis has higher costs than the previous one.

5 Conclusions

The present study aimed to verify the existence of a spatial wage curve for the whole sample and 20 different worker categories in Brazil. We find evidence for the spatial wage curve based on Brazilian microdata. Data reject the null of $\beta = 0$ against $\beta < 0$ for the whole sample and 16 out of 20 different worker categories at the 5% level. Besides, we find that the data reject the null of $\chi = 0$ against $\chi < 0$ for the whole sample and 13 out of the 20 different worker categories at the 5% level. The findings consistently indicate a negative sign for both parameters, distinct from previously reported studies.

Accounting for significant spatial spillovers and considering the whole sample, a 100% increase in local unemployment reduces the individual real hourly wage in

Brazil by 2.61%, while the same increase in unemployment in contiguous states leads to a reduction of 1.00% in real wages. The same increase in local unemployment reduces men's hourly wage by 2.45% and women's hourly wage by 2.29%.

A noticeable difference between men and women workers is the statistical significance of spatial spillovers for men: a 100% increase in unemployment in neighbouring states leads to an additional reduction of 2.44% in their real wages. In contrast, competitive conditions in contiguous states do not affect female workers.

These findings highlight two related aspects for a better understanding of Brazil's functioning of the labour market. In essence, there are clear signs that most workers exhibit mobility significantly (or high commuting) between interconnected areas in the search for job opportunities. Lastly, companies seem to carefully analyse the workers' economic scenario when negotiating wage readjustment rules, accounting for unemployment in neighbouring regions.

We speculate that these aspects will become more critical as labour mobility, information dissemination, and commuting between the labour markets of different states and regions of Brazil increase due to the decrease in transport costs, advances in communications, and lower housing prices.

The spatial spillovers' significance and magnitude imply that the consequences of state policy decisions that affect a given state's performance will not be limited locally but may broaden or alleviate the unfavourable conditions in interconnected areas. This finding calls for attention to a more coordinated economic policy among the federative units of the country.

Appendix

See Tables 5, 6, 7 and 8.

Table 5 Variables used in the regression models

Description	PNAD code	Category
Typical monthly income	VD4016	Continuous (R$ from 08/2019)
Hours typically worked	V4039	Continuous (hours)
Sex	V2007	Man = 0, Woman = 1
Age	V2009	Continuous (years)
Race	V2010	White, Asian = 0; Black, Mixed, Indigenous = 1
Education	VD3005	Continuous (years)
Household location	V1022	Urban = 0, Rural = 1
Type of area	V1023	Metropolitan region = 0, Rest of the federative unit/state = 1
Length of employment	V40401, V40402, V40403	Continuous (years)
Employment status	VD4009	Formal = 0, Informal = 1
Occupation	V4010	See Table 6
Activity of the company	V4013	See Table 7

Table 6 Grouping of occupations

Description	Selection
Directors and managers	$1111 \leq V4010 \leq 1439$
Science professionals and intellectuals	$2111 \leq V4010 \leq 2659$
Technicians and mid-level professionals	$3111 \leq V4010 \leq 3522$
Administrative support workers	$4110 \leq V4010 \leq 4419$
Service workers, trade and market vendors	$5111 \leq V4010 \leq 5419$
Skilled farm, forestry, hunting, and fishing workers	$6111 \leq V4010 \leq 6225$
Skilled workers, labourers and artisans in construction and mechanical arts, plant and machine operators, and assemblers	$7111 \leq V4010 \leq 8350$
Elementary occupations	$0110 \leq V4010 \leq 0512$
Members of the armed forces, police, and military firefighters	$9111 \leq V4010 \leq 9629$

Table 7 Grouping of activities

Description	Selection
Agriculture, animal husbandry, forestry production, fishing and aquaculture	$01101 \leq V4013 \leq 03002$
General manufacturing	$05000 \leq V4013 \leq 39000$
Construction	$41000 \leq V4013 \leq 43000$
Commerce; repair of automotive vehicles and motorcycles	$45010 \leq V4013 \leq 48100$
Transport, storage, and mail/courier services	$49010 \leq V4013 \leq 53002$
Accommodation and food	$55000 \leq V4013 \leq 56020$
Information, communication, and financial, real estate, professional, and administrative activities	$58000 \leq V4013 \leq 82009$
Public administration, defence and social security, education, human health, and social services	$84011 \leq V4013 \leq 88000$
Domestic services	$V4013 = 97000$
Other services	$90000 \leq V4013 \leq 9609$ or $V4013 = 99000$

Table 8 Tests for weak instruments and the exogeneity of regressors: Results

Type of test	Statistic	*p*-value
Based on $\chi = 0$		
Weak instruments	6588779***	0.0000
Wu-Hausman	141***	0.0000
Based on $\chi \neq 0$		
Weak instruments	448331***	0.0000
Wu-Hausman	187***	0.0000

***= significance level

Funding This research article has not received any funding support.

Data Availability The data that support the findings of this study are openly available in the Instituto Brasileiro de Geografia e Estatística at http://www.ibge.gov.br/.

Code Availability This paper uses R, a free software environment for statistical computing and graphics. R is freely available at http://www.r-project.org/, and the codes used are available upon request.

Declarations

Conflict of interest Guilherme Cemin de Paula and André M. Marques declare that they have no relevant or material financial interests that relate to the research described in this paper.

References

Amadeo, E.J., Horton, S. 1997. Labour Flexibility and Productivity: An Overview, Palgrave Macmillan UK, London, pp 1–35. https://doi.org/10.1007/978-1-349-25977-9_1.

Anselin, L., and S. Rey. 1991. Properties of tests for spatial dependence in linear regression models. *Geographical Analysis* 23 (2): 112–131. https://doi.org/10.1111/j.1538-4632.1991.tb00228.x.

Baltagi, B., and U. Blien. 1998. The German wage curve: Evidence from the IAB employment sample. *Economics Letters* 61 (2): 135–142.

Baltagi, B., and B. Rokicki. 2014. The spatial polish wage curve with gender effects: Evidence from the polish labor survey. *Regional Science and Urban Economics* 49: 36–47. https://doi.org/10.1016/j.regsciurbeco.2014.08.001.

Baltagi, B., U. Blien, and K. Wolf. 2012. A dynamic spatial panel data approach to the German wage curve. *Economic Modelling* 29 (1): 12–21. https://doi.org/10.1016/j.econmod.2010.08.019.

Baltagi, B.H., B. Rokicki, and K.B. de Souza. 2017. The Brazilian wage curve: New evidence from the national household survey. *Empirical Economics* 53: 267–286.

Barufi, A.M.B., Haddad, E.A., Nijkamp, P. 2016. New evidence on the wage curve: Non-linearities, urban size, and spatial scale in Brazil. Anais do 44° Encontro Nacional de Economia.

Blanchflower, D., Oswald, A. 2005. The wage curve reloaded (w11338), https://ssrn.com/abstract=723307.

Blanchflower, D.G., and A.J. Oswald. 1995. An introduction to the wage curve. *Journal of Economic Perspectives* 9 (3): 153–167. https://doi.org/10.1257/jep.9.3.153.

Boushey, H. 2002. Reworking the wage curve: Exploring the consistency of the model across time, space and demographic group. *Review of Political Economy* 14 (3): 293–311. https://doi.org/10.1080/09538250220147859.

Buettner, T. 1999. The effect of unemployment, aggregate wages, and spatial contiguity on local wages: An investigation with German district level data. *Papers in Regional Science* 78: 47–67. https://doi.org/10.1007/s101100050011.

Card, D. 1995. The wage curve: A review. *Journal of Economic Literature* 33 (2): 285–299.

de Carvalho Filho, I., Estevão, M. 2012. Institutions, informality, and wage flexibility: Evidence from Brazil. IMF Working Paper WP/12/84 2012:84.

Elhorst, J.P. 2010. Applied spatial econometrics: Raising the bar. *Spatial Economic Analysis* 5 (1): 9–28. https://doi.org/10.1080/17421770903541772.

Elhorst, J.P., U. Blien, and K. Wolf. 2007. New evidence on the wage curve: A spatial panel approach. *International Regional Science Review* 30 (2): 173–191. https://doi.org/10.1177/0160017606298426.

Fingleton, B., S. Palombi, et al. 2013. The wage curve reconsidered: Is it truly an empirical law of economics''. *Région et développement* 38: 49–92.

Greene, W.H. 2003. Econometric Analysis, 5th edn. Pearson Education, http://pages.stern.nyu.edu/~wgreene/Text/econometricanalysis.htm.
Halleck Vega, S., and J.P. Elhorst. 2015. The slx model. *Journal of Regional Science* 55 (3): 339–363. https://doi.org/10.1111/jors.12188.
Holland, M. 2019. Fiscal crisis in Brazil: Causes and remedy. *Brazilian Journal of Political Economy* 39 (1): 88–107.
Janssens, S., and J. Konings. 1998. One more wage curve: The case of Belgium. *Economics Letters* 60 (2): 223–227.
Kennedy, S., and J. Borland. 2000. A wage curve for Australia? *Oxford Economic Papers* 52 (4): 774–803. https://doi.org/10.1093/oep/52.4.774.
LeSage, J., and R.K. Pace. 2009. *Introduction to spatial econometrics*. Boca Raton, FL: CRC Press.
LeSage, J.P. 2014. What regional scientists need to know about spatial econometrics. *Review of Regional Studies* 44 (1): 13–32.
Longhi, S., P. Nijkamp, and J. Poot. 2006. Spatial heterogeneity and the wage curve revisited. *Journal of Regional Science* 46 (4): 707–731. https://doi.org/10.1111/j.1467-9787.2006.00474.x.
Manning, N. 1994. Earnings, unemployment and contiguity: Evidence from British counties 1976–1992. *Scottish Journal of Political Economy* 41 (1): 43–68. https://doi.org/10.1111/j.1467-9485.1994.tb01109.x.
Mincer, J. 1975. Education, experience, and the distribution of earnings and employment: an overview. In: Education, income, and human behavior, NBER, pp 71–94.
Palombi, S., R. Perman, and C. Tavéra. 2017. Commuting effects in Okun's law among British areas: Evidence from spatial panel econometrics. *Papers in Regional Science* 96 (1): 191–209. https://doi.org/10.1111/pirs.12166.
Reis, M.C. 2006 Os impactos das mudanças na demanda por trabalho qualificado sobre o desemprego por nível de qualificação durante os anos noventa no Brasil. Revista Brasileira de Economia 60:297–319, http://www.scielo.br/scielo.php?script=sci_arttext &pid=S0034-71402006000300006 &nrm=iso.
Silva, A., Monsueto, S., Porsse, A. 2015 Flexibilidade do mercado de trabalho: uma análise comparativa entre segmentos socioeconômicos no Brasil (2002-2009). Pesquisa e planejamento econômico 45.
Staiger, D., and J.H. Stock. 1997. Instrumental variables regression with weak instruments. *Econometrica* 65 (3): 557–586.