How Does Emigration Affect Labor Markets? Evidence from Road Construction in Brazil*

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Abstract

We study the impact of emigration on local labor markets, based on the construction of a 1,087-km road in northeastern Brazil. The new road has changed population density substantially, creating new towns along its path and increasing internal migration flows. We first use a reduced-form approach to estimate the effect of emigration on skill groups (defined by education and experience) – a 10 percentage point increase in the proportion of emigrants (which denotes a fall in labor supply) raises wages by 5%. Then, by using a structural approach, we estimate elasticities of substitution across types of labor and between capital and labor. Based on these estimates, we calculate the price elasticities and wage effects among groups – although emigration typically raises wages, complementary effects determine negative impacts on some municipalities. On average, we estimate an overall increase of 50% in local wages due to the construction of the road.

Keywords: Migration, Roads, Labor supply, Competitive local markets, Elasticities of substitution, Wage effects.

JEL Codes: J31, O15, O18.

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1. Introduction

In 1976, the Brazilian government constructed a 1,087-km road from Belém to Teresina that established an important link between the north and the northeast regions of the country. The road construction was followed by concentration of the population and creation of new municipalities.¹ According to the 1980 Demographic Census, the size of migration flows to the municipalities in a radius of 200 km around the road increased by 50% after its construction, with originations predominantly coming from within this radius. Additionally, the number of municipalities along the road increased from 32 in 1976 to 66 in 2000, which is substantially more than the 10% increase observed in the rest of the country.

As documented recently, major roads affect the distribution of the population (Baum-Snow, 2007a,b, Duranton and Turner, 2007, Morten and Oliveira, 2014b,a) and labor markets (Michaels, 2008, Morten and Oliveira, 2013). Here, our focus relies on the emigration flows induced by the new road connecting Belém to Teresina. Proximity to the road is considered as a means of estimating the effect of emigration on wages: an underdeveloped topic in the literature (Mishra, 2007). The analysis is presented in two parts.

In the first part, we consider migration as a labor supply shock that affects different skill groups (defined in terms of schooling and experience), as indicated in Borjas (2003) and Mishra (2007). We also introduce an additional step and consider migration as endogenous² and use road construction as a way of improving the empirical identification of the effects of migration on the labor market: distance to the constructed road is used as an instrument for emigration. This additional step of identification matters because an increase of 10 percentage points in the number of emigrants raises wages from 1.44%, using the OLS estimate, to 5.1%, using the IV estimate. The latter represents a wage elasticity of 0.15%, evaluated at the mean value of outmigration shock (29.30%) in the area of *Belém-Teresina*.

In the second part of the paper, we specify a production function to study not only the direct effect of a particular emigration flow on the wages of the respective group of non-migrant workers, but also the cross effects on the wages of workers in different skill groups. Following Borjas (2003), we estimate the own-factor price and cross-factor price elasticities (across skill groups). Our results suggest that, although the effect of emigration around the Belém-Teresina road on wages was usually positive, in many municipalities, there was a negative effect on wages for the groups with less than one year of schooling due to a complementary effect.

One limitation of our analysis is the fact that the road construction might have additional effects on wages due to changes in labor demand, like the ones described by Morten and Oliveira (2014b,a). The authors find that a 10% increase

¹Municipalities are the smallest political and administrative units in Brazil. In size, they are roughly somewhere between US counties and cities.

²Roy (1951); Sjaastad (1962); Chiswick (1978, 1999); Banerjee and Kanbur (1981); Borjas (1987, 1999b,a); Chiquiar and Hanson (2005); McKenzie and Rapoport (2007).

in paved roads increases the wage premium by 0.8% and the municipal GDP by 0.9% . The changes in transportation costs might affect the demand for the outputs of pre-existing firms, or even change the location of the firms. There are at least two reasons why these effects are not relevant in our case. First, an overall change in the demand for goods in a given municipality would affect all skill groups uniformly, especially if the underlying technology is homothetic, as assumed in our analysis. In this way, variation in emigration across skill groups is more likely to be associated with labor supply rather than with labor demand. Second, we find no evidence that either the levels or the changes in the number of firms or residential capital stock are associated with the distance to the *Belém-Teresina* road.

We believe that our paper contributes to the literature in at least two directions. First, our empirical environment provides a new instrumental variable approach to estimate the elasticity of labor demand. We consider one additional identification step in comparison to Borjas (2003) and Mishra (2007), which we find to be relevant. Second, our results suggest that the construction of a road affects not only the labor markets along its path, as in Michaels (2008), but also the labor markets in municipalities not directly affected by such improvement. In this sense, it is important to note that our paper focuses on markets that lose workers to areas near the road instead of on markets with productivity gains from the new road. We exploit the fall of migration costs as an effect of connecting more places by roads, as described by Morten and Oliveira (2013, 2014b,a).

The remainder of the paper is organized as follows. Section 2 presents the Belém-Teresina road. Section 3 describes the database. Section 4 discusses the impacts of the road on the regional labor market. Section 5 presents a structural approach. Section 6 discusses some limitations and caveats. Section 7 concludes.

2. The Belém-Teresina Road

The Belém-Teresina road was built in the 1970s as a part of the national policy for integration and development of the country as a whole. The highway, which comprises stretches of BR-316 and BR-010, is an important link between the north and northeast regions of the country. It was opened to traffic in 1976, with 1,087 kilometers of paved road. Along with the Belém-Brasília road, the Belém-Teresina road was the main access route to East Amazônia at that time. It also provides access by land from coastal municipalities in the northeast to waterways in the north (Sant'anna, 1988).

Figure 1 depicts an area of 200 kilometers that surrounds the Belém-Teresina road, which is the focus of our analysis. The road crosses a very poor region, where a large percentage of the municipalities was mostly rural until the 1990s; 58% of the population aged over 10 years was living in rural areas in 1980. Note that we excluded the state capitals (Belém, Teresina, and São Luís), and all the municipalities the road passes through, from our sample. This is because we are primarily interested in the effect of emigration.

Figure 1
Area surrounding the *Belém-Teresina* road

Source: Author's elaboration based on IBGE Digital Maps.

The construction of the *Belém-Teresina* road has increased the population density along its path. This change can be seen in two dimensions – creation of new towns and migration flows.

Figure 2 shows the increased urban agglomeration and the creation of new towns after the construction of the *Belém-Teresina* road. Between 1970 and 2000, the number of municipalities in the area surrounding the road increased by 50%, from 218 to 344 towns, compared to an average increase of 10% for the whole country.

There was also a redistribution of the population in the road's area. Figure 3 shows that the number of migrants increased after the road was completed and that most of this flow is internal, coming from municipalities within the referred area. There was an important inflow of migrants to areas near the road. This is the main reason why we focus our analysis on the impact of emigration.

Figures 4 and 5 show the emigration flows of different experience and education groups, respectively, for the years 1980 and 1991, as a function of the distance to the road. Each curve represents locally weighted regressions, with least-squares smoothing and a bandwidth of 0.8, and considers a sample of migration groups within each municipality in the road's area.

The overall pattern is that not only do the levels of the flows decrease with the distance, but that the same is true for the changes between 1980 and 1991.

Figure 2
New towns in the area surrounding the *Belém-Teresina* road in 1970 and 2000

Source: Author's elaboration based on IBGE Digital Maps.

Figure 3
Immigration in the area surrounding the *Belém-Teresina* road in 1980
Internal versus External Migration

Source: Author's elaboration based on IBGE Digital Maps.

Figure 4 shows that individuals with 6 to 15 years of experience are the group with the largest flow of emigrants for both years. There is a positive increase in the number of emigrants for all the experience groups that decreases with the distance to the road and is higher for the two groups with less experience.

Figure 5 shows that the emigration flows for individuals with less than four years of schooling sharply decrease with the distance to the road. The pattern for the most educated is less clear, although the change also decreases with the distance. The changes for the group with less than one year of schooling are negative, although relatively low in comparison with the other levels.

In summary, the construction of the road induced an important change in the location of the population in the 200-km surrounding area. This change is systematically related to the distance to the road. By analyzing a large expansion of road infrastructure in Brazil, Morten and Oliveira (2014b) point out that, after controlling for the Euclidean distance between two locations, reducing the road distance by 50% would increase migration rates by 40%, but the effect of the road infrastructure on migration is reduced by 10% once the general equilibrium effects of migration are computed. In the following sections, we use the construction of the *Belém-Teresina* road as a means of identifying changes in the labor supply determined by emigration.

Figure 4

Emigration and distance to the road per experience groups

Source: Demographic Census of 1980 and 1991.

Emigration and distance to the road per education groups

Source: Demographic Census of 1980 and 1991.

Figure 5

Source: Demographic Census of 1980 and 1991.

Source: Demographic Census of 1980 and 1991.

3. Data

We use data from the 1980 and 1991 demographic censuses, collected by the Brazilian Institute of Geography and Statistics (IBGE). Along with the basic information collected for the Census, IBGE also used an extended questionnaire to obtain more detailed socioeconomic information. This extended questionnaire is applied to a sample of 10 to 15% of the population of each municipality, depending on its size. Our data come from this longer survey.

We work with a subsample of workers with between 1 and 39 years of experience who live in the areas around the *Belém-Teresina* road. The two years of data represent repeated cross-sections, because it is not possible to track individuals across the surveys.

Although we are interested in the area surrounding the *Belém-Teresina* road, we use information from the whole country to account for migration. We have tracked all migrants who have left a municipality in our area of analysis to settle themselves in another municipality within the country. Unfortunately, it is not possible to consider international migration outflows in our analysis. But this is not likely to be a problem because international migration is not quantitatively relevant in Brazil and, moreover, we are considering a very poor region with extremely low levels of international migration flows.

Migrants in our sample are those whose Census records indicate they were settled in another municipality in a 10-year window. Thus, migrants in the 1980 Census are those who migrated in the 1970s, while migrants in 1991 consist of those who moved during the 1980s.

Table 1 presents the distribution of non-migrants, immigrants, and emigrants across many categories for 1980 and 1991, while Table 2 depicts the averages for experience, years of schooling, and earnings in areas surrounding the *Belém-Teresina* road. The comparative analysis between migrants and non-migrants reveals differences in many dimensions. Compared to non-migrants, immigrant flows are comprised of more women, a higher proportion of individuals aged 20-29 years, more educated workers with less experience, people from urban areas, fewer individuals declared as self-employed, and more employees with higher income and hours worked. The same is true for emigrants, although we can see differences between immigrants and emigrants, i.e., the place of residence for emigrants is more frequently in urban areas. The differences are also qualitatively the same across the years.

4. A Reduced-Form Approach

Emigration is considered in our framework as a labor supply shifter to estimate wage effects or “wage elasticities” in the municipalities influenced by the *Belém-Teresina* road. We start our analysis with a reduced-form approach, based on a Mincerian wage equation. We first consider an OLS estimation, where emigration

Table 1
Descriptive analysis of migration flows

Variables	Categories	1980			1991		
		Non-migrant	Immigrant	Emigrant	Non-migrant	Immigrant	Emigrant
Sex							
	Male	50.03	48.36***	47.04***	50.36	47.19***	45.81***
	Female	49.97	51.64***	52.96***	49.64	54.51***	54.19***
Residence							
	Rural	69.78	61.15***	42.92***	62.04	54.51***	38.12***
	Urban	30.22	38.85***	57.08***	37.96	45.49***	61.88***
Age							
	10-19 years	44.24	41.47***	39.52***	43.75	39.71***	38.65***
	20-29 years	26.13	30.32***	33.66***	25.63	30.64***	33.73***
	30-39 years	17.94	18.32	17.16***	18.33	19.74***	18.13
	40-49 years	11.34	9.58***	9.22***	11.65	9.38***	8.85***
	50 years or older	0.35	0.31	0.45	0.64	0.53	0.65
Experience							
	1 - 5 years	21.16	20.41***	26.23***	25.54	23.82***	28.82***
	6-15 years	36.02	37.74***	36.74***	34.67	37.89***	37.05***
	16-25 years	20.51	22.11***	20.27***	19.09	21.98***	18.80*
	26-39 years	22.80	19.75***	16.76***	20.70	17.32***	15.32***
Education							
	Less than 1 year	48.43	43.25***	36.73***	32.22	25.77***	25.00***
	1-4 years	38.38	38.17	40.63***	43.30	41.36***	41.39***
	5 years or more	13.19	18.58	14.19	24.47	32.87	20.86
Activity							
	Agriculture/livestock/mining	71.37	57.20***	38.43***	57.26	37.02***	28.40***
	Industry	7.74	11.38***	18.14***	9.56	16.70***	18.24***
	Service	15.63	23.10***	31.83***	24.89	32.66***	37.89***
	Trade	5.26	8.31***	11.60***	8.29	13.61***	15.47***
Occupational Position							
	Employee	25.06	39.30***	54.73***	35.29	51.75***	61.62***
	Employer	0.84	1.17	0.68	1.26	1.99	1.47
	Self-employed	58.44	49.06***	38.05***	49.38	39.12***	32.44***
	Unpaid	15.66	10.47***	6.54***	14.06	7.10***	4.46***
Monthly earnings							
	Unpaid	23.23	15.48***	9.86***	14.31	7.2***	4.53***
	Less than R\$ 50.00	11.33	11.68	9.51***	14.63	10.86***	8.71***
	R\$ 50.00 - R\$ 100.00	15.82	13.47***	11.71***	24.49	22.74***	23.42***
	R\$ 100.00 - R\$ 200.00	26.08	25.60	27.45***	24.27	27.07***	28.34***
	R\$ 200.00 - R\$ 400.00	15.95	20.61***	24.86***	13.79	17.71***	20.22***
	R\$ 400.00 - R\$ 1,200.00	6.38	10.12***	13.93***	6.83	10.85***	11.85***
	More than R\$ 1,200.00	1.21	3.04***	2.72***	1.68	3.56***	2.92***
Hours worked per week (major activity)							
	Less than 15 hours	0.79	0.77	0.75	1.14	1.21	1.21
	15-29 hours	7.94	6.55***	4.95***	14.34	9.66***	7.80***
	30-39 hours	20.32	15.16***	11.76***	13.73	10.07***	9.12***
	40-48 hours	56.62	55.78***	56.99	58.50	57.98	59.47***
	49 hours or more	14.33	21.74***	25.55***	12.29	21.09***	22.41***
Observations		483,516	98,467	131,108	283,253	60,413	71,638

Note: (***) indicates that the difference is significant at 1%; (**) the difference is significant at 5%; and (*) the difference is significant at 10%.

Source: 1980 and 1991 Demographic Censuses.

Table 2
Comparative analysis between migrants and non-migrants

Areas Surrounding the Belém-Teresina Road			
Variables	Group	1980	1991
Average Experience	Non-migrant	14.88	14.14
	Immigrant	14.44***	13.6***
	Emigrant	13.95***	13.26***
Average Years of Schooling	Non-Migrant	2.06	3.17
	Immigrant	2.56***	3.85***
	Emigrant	2.97***	3.87***
Average Monthly Earnings (R\$ 2.000)	Non-Migrant	76.05	177.86
	Immigrant	119.02***	267.68***
	Emigrant	136.09***	257.74***
Average Age	Non-Migrant	23.74	24.02
	Immigrant	23.79***	24.18***
	Emigrant	23.92***	24.13***

Note: (***) indicates that the difference is significant at 1%;

(**) the difference is significant at 5%;

and (*) the difference is significant at 10%.

Source: 1980 and 1991 Demographic Censuses.

is taken as exogenous. We then extend our analysis to introduce the possibility of endogenous migration and consider that road construction is a source of exogenous variation in migration.

4.1 Specification

Following Borjas (2003) and Mishra (2006), we start with a very simple approach of regressing the individual logarithm of wages in source economies on the variable related to emigration that controls for individual and municipality characteristics. The specification is given by:

$$\ln w_{sit}^I = \beta_0 m_{sit} + \beta_1' Z_i + \beta_2' X_{sit}^I + \nu_s + \pi_t + (\nu_s * \pi_t) + \varepsilon_{sit}^I, 1 \quad (1)$$

where w_{sit}^I is the monthly earnings for individual I , in period t , who belongs to skill group s and lives in municipality i ; the m_{sit} is the ratio of emigrants to natives (those who have lived in the municipality for 10 years or more) in skill group s , municipality i , and year t ; the Z_i is a vector of municipality characteristics (distance to state capitals, altitude and distance to the coast);³ and the X_{sit}^I is a vector of individual characteristics (gender, age, experience, education, marital status, occupation, and activity, among others). We also include group fixed effects (ν_s), time fixed effects (π_t), and their interactions ($\nu_s * \pi_t$) to account for unobserved and possible time-varying characteristics of the skill groups. Also, we incorporate the possibility of having the residuals ε_{sit}^I correlated within each cell defined by group, municipality, and year by adjusting the variance for clustering at the group-municipality-year level.

³All distance variables are built based on a geoprocessing software. In the case of the distance between two municipalities, we consider the spherical distance between the seats. The distance from a city to the coast uses as a reference the nearest municipal seat on the coast.

We first consider an OLS estimation of equation (1). However, this strategy can lead to inconsistent estimates if emigration is affected by other wage determinants. In fact, the migration literature stresses that migration flows usually respond to wage differentials, among other factors (Roy, 1951, Sjaastad, 1962, Greenwood, 1975, Borjas, 1987, 1999a, Kanbur and Rapoport, 2005). Under the assumption that individuals living in municipalities with lower wages have a higher probability of emigrating, municipalities with worse labor market conditions for a skill group s might depict a higher proportion of emigrants in that skill group. In this case, the estimated coefficient of m_{sit} will be downward biased.

In order to account for possible endogeneity between migration and wages, we use the construction of the *Belém-Teresina* road as a source of exogenous variation in emigration. The road reduces distances between these municipalities and state capitals (*Belém* and *Teresina*). The evidence regarding the effect of distance on the migration outflows in the region is clear not only in Figures 4 and 5, but also in the migration literature (Sjaastad, 1962, Sahota, 1968, Schwartz, 1973, Fields, 1979, Carrington et al., 1996). In the case of the Brazilian transport infrastructure, Morten and Oliveira (2013, 2014a) find evidence that access to roads is a significant determinant of migration choice and migration destination. Consequently, it increases wages and reduces the relative wage gap. Thus, we consider a first-stage specification where the proportion of emigrants m_{sit} is a function of the distance of municipality i to the *Belém-Teresina* road (represented by d_{it}), as follows:

$$m_{sit} = \gamma_0 d_{it} + \gamma'_1 Z_i + \gamma'_2 X_{sit}^I + \nu_s + \pi_t + (\nu_s * \pi_t) + v_{sit}. \quad (2)$$

4.2 Empirical results

Table 3 presents the estimates of the effect of emigration proportion on wages in the source municipalities in relation to equation (1). The first column shows the OLS estimates and the second column presents the IV estimates, where the emigration proportion is instrumented by the distance to the *Belém-Teresina* road by using (2).

The OLS estimate suggests that an increase of 10 percentage points in the emigration rate increases wages by 1.44% on average in each skill group. This result is substantially lower than the 3.1% reported by Mishra (2007) for Mexico, especially considering the relatively narrow standard deviation. Borjas (2003) shows that it is easier to interpret this coefficient by converting it to an elasticity that gives the percent change in wages associated with a percent change in labor supply. The wage elasticity is 0.04%, evaluated at the mean value of the outmigrant supply decrease (29.3%), which means that a 10% supply shock (an outflow of 2.9%) increases the wages by about 0.4%.

However, when we account for endogeneity and use the distance to the road as an instrument for emigration, the estimated effect of a 10 percentage point increase in the proportion of emigrants raises wages by 5.1% (a wage elasticity of

Table 3
Effect of emigration on wages

	ln (monthly earnings)	
	OLS	IV
Proportion of emigrants in the skill group	0.144*** (0.030)	0.510*** (0.153)
Individual characteristics	yes	yes
Municipality characteristics	yes	yes
Skill fixed effects	yes	yes
Year fixed effects	yes	yes
Interaction of skill and year fixed effects	yes	yes
Observations	284,506	284,506
Distance to the road		First-stage -0.102*** (0.001)
First-stage F-test (instruments)		Prob > F = 0.0000
Observations		284,506

Note: Robust standard errors are in parentheses, clustered by interaction of skills and year and municipality. * indicates significance at 10%, ** significance at 5%, *** significance at 1%. The dependent variable is the log of individual monthly earnings. The proportion of emigrants in the skill group is the endogenous variable in the IV estimation. Independent variables at the individual level (omitted): gender, a dummy indicating migrants, years of schooling, dummies for marital status, a dummy for literacy, age, race, experience, squared experience, a dummy for urban residence, dummies for groups of weekly hours worked, dummies for economic sectors, and dummies for occupational position. Independent variables at the municipality level (omitted): altitude, distance to the coast (in log), and the distances to the three state capitals (in log) – São Luís, Teresina, and Belém. All regressions control for skill and year fixed effects. Observations are at the individual level.
Source: Demographic Censuses (IBGE), 1980/1991.

0.15%). Notice that the coefficient associated with the distance to the road on the first-stage regression is negative and statistically significant at the 1% significance level.

The increase in the coefficient, when comparing the OLS to the IV estimates, is similar to the findings of Mishra (2007). The author uses social networks as functions for emigration, and also finds a downward-biased OLS estimate. After considering the potential endogeneity, emigration has a large and positive effect on wages in the source municipalities.

5. A structural approach

In order to make it possible to estimate not only the impact of a particular emigrant flow on the wages of competing native workers, but also the cross effects on the wages of workers in different groups, we follow the structural approach presented by Card and Lemieux (2001) and Borjas (2003).

5.1 Specification

We assume that the aggregate production function for each municipality can be represented in terms of a two-level CES technology: workers with similar skills aggregate to form the workforce in a specific skill group and workers across skill groups then aggregate to form the workforce in each municipality over time. Formally, we have:

$$Q_{it} = [A_i(\lambda_{K_{it}} K_{it}^\nu + \lambda_{L_{it}} L_{it}^\nu)]^{\frac{1}{\nu}}, \quad (3)$$

where Q_{it} is the total production in each municipality over time, the A_i represents the municipality characteristics that shift the total production, and $\nu = 1 - 1/\sigma_{KL}$ with σ_{KL} is the elasticity of substitution between capital K_{it} and labor L_{it} ($-\infty < \nu \leq 1$). The parameters λ_K and λ_L represent the way capital and labor are combined over time, assuming that $\lambda_{K_{mt}} + \lambda_{L_{mt}} = 1$. We adopt a flexible form for λ_K and λ_L that allows them to vary at the micro-region level, indexed by m , which is a set of geographically connected municipalities defined by IBGE.

The composite aggregate workforce L_{it} is a combination of workers from different skill groups, defined as:

$$L_{it} = \left[\sum_s \theta_{st} L_{sit}^\rho \right]^{\frac{1}{\rho}}, \quad (4)$$

where L_{sit} is the number of workers in skill group s , living in the municipality i at time t , and $\rho = 1 - 1/\sigma_s$ with σ_s is the elasticity of substitution across skill groups. The vector (θ_{st}) contains the technology parameters that vary over time and shift the relative productivity of skill groups. For simplicity, we assume that $\sum_s \theta_{st} = 1$ and that these technology parameters are the same for all municipalities, because we are analyzing a relatively homogeneous set of municipalities.

We take the output Q as the numeraire and assume perfectly competitive markets. We then substitute (4) in (3), differentiate with respect to L_{sit} , and take the logarithm. Thus, we have the wage of a worker in skill group s , living in municipality i , at time t , as given by:

$$\begin{aligned} \ln w_{sit} = \ln A_i + \ln \lambda_{L_{mt}} + (1 - \nu) \ln Q_{it} \\ + (\nu - \rho) \ln L_{it} + \ln \theta_{st} + (\rho - 1) \ln L_{sit}. \end{aligned} \quad (5)$$

Substituting $\nu = 1 - 1/\sigma_{KL}$, $\rho = 1 - 1/\sigma_s$, and $\ln A_i = \alpha' Z_i + \varepsilon_i$ (Card and Lemieux, 2001) equation (5) can be rewritten as:

$$\begin{aligned} \ln w_{sit} = -\frac{1}{\sigma_s} \ln L_{sit} + \left(\frac{1}{\sigma_s} - \frac{1}{\sigma_{KL}} \right) \ln L_{it} \\ + \frac{1}{\sigma_{KL}} \ln Q_{it} + \alpha' Z_i + \gamma_{st} + \gamma_{mt} + \varepsilon_i, \end{aligned} \quad (6)$$

where Z_i and ε_i are the observed and unobserved components of A_i , respectively, at the municipality level; $\gamma_{mt} = \ln \lambda_{mt}$ is absorbed by interactions between period and micro-region fixed effects; and $\gamma_{st} = \ln \theta_{st}$ is absorbed by interactions between period and skill fixed effects.

If we assume that individuals in group s , municipality i , and period t have productivity shocks in the form of $\delta' X_{sit}^I + \varepsilon_{sit}^I$, where X_{sit}^I represents observable characteristics of individual I , and ε_{sit}^I is the random and unobserved component

of the productivity shocks, then we have a similar equation (6) for individuals given by:

$$\ln w_{sit}^I = -\frac{1}{\sigma_s} \ln L_{sit} + \left(\frac{1}{\sigma_s} - \frac{1}{\sigma_{KL}}\right) \ln L_{it} + \frac{1}{\sigma_{KL}} \ln Q_{it} + \delta' X_{sit}^I + \alpha' Z_i + \gamma_{st} + \gamma_{mt} + \varepsilon_{sit}^I. \quad (7)$$

5.2 Estimation

We now estimate equation (7) using our sample. We consider the following baseline regression:

$$\ln w_{sit}^I = \beta_1 \ln L_{sit} + \beta_2 \ln L_{it} + \beta_3 \ln Q_{it} + \beta_4' X_{sit}^I + \beta_5' Z_i + \gamma_{st} + \gamma_{mt} + \varepsilon_{sit}^I, \quad (8)$$

where Z_i is a vector containing the distance to state capitals in the area (São Luis, Teresina, and Belém), altitude and distance to the coast, and X_{sit}^I is a vector of the same individual characteristics considered in subsection 3.2.

As in the previous section, we first estimate (8) assuming that L_{sit} is exogenous. We then take the number of workers as endogenous and use the number of emigrants E_{sit} as an instrumental variable for L_{sit} to estimate β_1 . In the IV estimation, the first-stage specification is given by:

$$\ln L_{sit} = \phi_1 \ln E_{sit} + \phi_2 \ln L_{it} + \phi_3 \ln Q_{it} + \phi_4' X_{sit}^I + \phi_5' Z_i + \mu_{st} + \mu_{mt} + v_{sit}, \quad (9)$$

where E_{sit} is the number of emigrants in group s , municipality i , and period t .

Table 4 presents the OLS and IV estimates of β_1 . The OLS estimate is -0.015 , significant at 10%, although the IV estimate is -0.077 , significant at 1%. Again, the results indicate that the OLS is biased towards zero. The implied elasticities of substitution across types of labor for the OLS and IV are 66.67 and 12.99, respectively. These numbers are much higher than those depicted in the literature (Hamermesh, 1993). Borjas (2003) estimates elasticity of substitution across experience groups to be equal to 3.5. Similarly, the Card and Lemieux (2001) estimates for elasticity of substitution between high school and college workers range from 1.1 to 3.1.

We can interpret these results in two ways. First, it is suggested that the technology available for the municipalities in the road area is such that workers with different levels of education and experience can be easily substituted with other workers. Second, it might be possible that the estimates of β_1 presented in Table 4 are biased. This bias can happen, for instance, if the migration flows are endogenous to the economic activity.

We then take one step further for the identification of the parameter β_1 that takes into account that E_{sit} is endogenous and considers the road construction as

Table 4
Effects of Skill Groups' Labor Supply on Earnings

	log (monthly earnings)	
	OLS	IV
log(labor force in the skill group (L_{sit}))	-0.015* (0.008)	-0.077*** (0.020)
log(labor force in the municipality (L_{it}))	-0.056*** (0.019)	0.004 (0.026)
log(GDP in the municipality (Q_i))	0.124*** (0.014)	0.126*** (0.014)
Individual characteristics	yes	yes
Municipality characteristics	yes	yes
Interaction of skill and year fixed effect	yes	yes
Interaction of micro region and year fixed effect	yes	yes
Observations	284,509	284,509
log(total number of outmigrants)		First-stage 0.370*** (0.002)
First-stage F-test (instruments)		Prob > F = 0.0000
Observations		284,509

Note: Robust standard errors are in parentheses, clustered by interaction of skills and year and municipality. * indicates significance at 10%, ** significance at 5%, *** significance at 1%. The dependent variable is individual monthly earnings (ln). The endogenous variable in the IV estimation is the labor force in each skill group. Independent variables at the individual level (omitted): gender, a dummy indicating migrants, years of schooling, dummies for marital status, a dummy for literacy, age, race, experience, squared experience, a dummy for urban residence, dummies for groups of weekly hours worked, dummies for economic sectors, and dummies for occupational position. Independent variables at the municipality level (omitted): altitude, distance to the coast (in log), and the distances to the three state capitals (in log) – São Luís, Teresina, and Belém. All regressions control for skill and year fixed effects. Observations are at the individual level.

Source: Demographic Censuses (IBGE), 1980/1991.

an additional source of identification. We specify another equation for E_{sit} given by:

$$\ln E_{sit} = \delta_1 \ln D_i + \delta_2 \ln L_{it} + \delta_3 \ln Q_{it} + \delta'_4 X_{sit}^I + \delta'_5 Z_i + \varphi_{st} + \varphi_{mt} + v_{sit}, \quad (10)$$

where D_i is the linear distance between the administration center of the municipality and the nearest point on the road.

Table 5 presents the estimates obtained from a three-step estimation procedure that uses equations (8), (9), and (10). Again, results suggest that endogeneity potentially biases the estimation towards zero. The β_1 estimate changes substantially to -2.863 , significant at 5%, which indicates a lower elasticity of substitution across skill groups (or types of labor) of 0.35. This number is quite different from the other estimates available in the literature (Hamermesh, 1993). However, it is important to keep in mind that our sample is comprised of individuals with extremely low levels of education. According to Table 1, only 13% of non-migrants have five or more years of education. The estimated elasticity of substitution across groups might reflect the difficulty in substituting individuals across education and experience groups in this less educated population.

The elasticity of substitution between capital and labor, σ_{KL} , can be obtained from β_2 (based on β_1) or β_3 . In Table 5, both ways of computing σ_{KL} lead

Table 5
Estimated elasticity of substitution across skill groups

	log (earnings)	log (labor force)	log (outmigrants)
log(labor force in each skill group)	-2.863** (1.348)		
log(emigrants in each skill group)		0.067*** (0.026)	
Distance to the Belém-Teresina road			-0.222*** (0.007)
log(labor force in each municipality)	2.701** (1.304)	0.918*** (0.019)	0.727*** (0.004)
log(GDP in each municipality)	0.189*** (0.032)	0.002 (0.008)	0.314*** (0.003)
Individual characteristics	yes	yes	yes
Municipality characteristics	yes	yes	yes
Interaction of skill and year fixed effects	yes	yes	yes
Interaction of microregion and year fixed effects	yes	yes	yes
Observations	284,509	284,509	284,509

Note: Robust standard errors are in parentheses. * indicates significance at 10%, ** significance at 5%, *** significance at 1%. Independent variables at the individual level (omitted): gender, a dummy indicating migrants, years of schooling, dummies for marital status, a dummy for literacy, age, race, experience, and squared experience, a dummy for urban residence, dummies for groups of weekly hours worked, dummies for economic sectors, and dummies for occupational position. Independent variables at the municipality level (omitted): altitude, distance to the coast (in log), and the distances to the three state capitals (in log) – São Luís, Teresina, and Belém. All regressions also control for skill and year fixed effects. Observations are at the individual level.
Source: Demographic Censuses (IBGE), 1980/1991.

to statistically equal values. Considering the computation from β_3 , we see that $\hat{\sigma}_{KL} = 5.3$. It is a high value when compared to the empirical evidence found in the international literature, which ranges from 0 to 1.5. Among the results reported by Hamermesh (1993), only Hall et al. (1990) estimate a value with the same order of magnitude –6.86 for the United Kingdom. Again, we can explain the high elasticity of substitution between labor and capital by the labor market conditions in the region around the *Belém-Teresina* road, where workers have low levels of education and are therefore easily substituted with capital (Cahuc and Zylberberg, 2004).

5.3 Simulations of the Effects of Emigration on Wages

Following Borjas (2003), we estimate the impact of the migration outflows on wages in the municipalities of the *Belém-Teresina* road area by keeping capital stock constant. In this case, the total effect is a combination of the own-factor price elasticity, $\varepsilon_{si,si}$, and the cross-factor price elasticity, $\varepsilon_{si,s'i}$, given by:

$$\Delta \ln w_{si} = \varepsilon_{si,si}(-m_{si}) + \sum_{s' \neq s} \varepsilon_{si,s'i}(-m_{s'i}), \quad (11)$$

where m_{si} is the average emigration rate for the years 1980 and 1991 of the skill group s in municipality i . The negative sign stands for the reduction in the labor supply induced by emigration.

Hamermesh (1993) and Borjas (2003) point out that the factor price elasticity keeps marginal cost and quantities of other factors constant. Thus, the own-factor price elasticity can be obtained by deriving equation (5) from the logarithm of total labor in skill group s , in municipality i ($\ln L_{si}$), which gives us:

$$\varepsilon_{si,si} = (1 - \nu) \frac{d \ln Q_i}{d \ln L_{si}} + (\nu - \rho) \frac{d \ln L_i}{d \ln L_{si}} + (\rho - 1). \quad (12)$$

We can rewrite the equation (12) as a function of the estimated elasticities of substitution and the shares of income assigned to each group:

$$\varepsilon_{si,si} = \frac{1}{\sigma_{KL}} s_{si} + \left(\frac{1}{\sigma_s} - \frac{1}{\sigma_{KL}} \right) \frac{s_{si}}{s_L} - \frac{1}{\sigma_s}, \quad (13)$$

where $s_{si} = \frac{d \ln Q_i}{d \ln L_{si}}$ is the share of income assigned to group s , in municipality i , and $s_L = \frac{d \ln Q_i}{d \ln L_i}$ gives the labor's share of income in municipality i .

Similarly, the cross-factor price elasticity is given by:

$$\varepsilon_{si,s'i} = \frac{1}{\sigma_{KL}} s_{si} + \left(\frac{1}{\sigma_s} - \frac{1}{\sigma_{KL}} \right) \frac{s_{s'i}}{s_L}. \quad (14)$$

Notice that both the own-factor price and the cross-factor price elasticities vary across skill groups and municipalities. The income shares s_{si} and s_L were obtained from the earnings reported in the 1991 Census and from the GDP information used above.

Table 6 reports the mean, the minimum, and the maximum of the own-factor and cross-factor price elasticities estimated for each municipality. The overall average of the own-price elasticity is -2.62 , and indicates that a reduction of 10% in the labor force increases wages by 26.2%. Numbers across groups are quite homogeneous. It seems that most of the variation occurs between municipalities.

The estimated cross-factor elasticities, or elasticities across types of labor, are much lower and positive, similar to those found by Borjas (2003). The overall average cross elasticity is 0.2428 and suggests that a reduction in the number of workers in one group implies an average increase in wages of 2.4%. The variation across groups is high. Groups of individuals with less experience have systematically lower cross-factor price elasticities. The same is true for education, although with less intensity.

Table 7 describes the emigration shocks, m_{si} , and the total wage effects determined by (11). Emigration is quite intensive for groups with one to five years of experience and less than one, one to four, or five or more years of schooling, with averages of 86%, 123%, and 110%, respectively.

The estimated average wage effect indicates that the migration outflows induced by the road construction increased wages in the source municipalities by 51.5%. This is a very high effect in absolute terms, but has the same magnitude

Table 6
Price elasticities according to skill groups

Groups of Skills	Own Elasticity			Cross Elasticity		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Less than 1 Year of Schooling and 1-5 Years of Experience	-2.8578	-2.863	-2.8257	0.0052	0	0.0373
Less than 1 Year of Schooling and 6-15 Years of Experience	-2.7576	-2.8547	-2.4974	0.1054	0.0083	0.3656
Less than 1 Year of Schooling and 16-25 Years of Experience	-2.6671	-2.8418	-2.4292	0.1959	0.0212	0.4338
Less than 1 Year of Schooling and 26-39 Years of Experience	-2.5586	-2.8173	-2.2752	0.3044	0.0457	0.5878
1-4 Years of Schooling and 1-5 Years of Experience	-2.8476	-2.863	-2.7821	0.0154	0	0.0809
1-4 Years of Schooling and 6-15 Years of Experience	-2.6703	-2.7958	-1.5654	0.1927	0.0672	1.2976
1-4 Years of Schooling and 16-25 Years of Experience	-2.5989	-2.7808	-2.2925	0.2641	0.0822	0.5705
5 or more Years of Schooling and 1-5 Years of Experience	-2.4883	-2.7522	-2.0044	0.3747	0.1108	0.8586
5 or more Years of Schooling and 6-15 Years of Experience	-2.7727	-2.8596	-2.4592	0.0903	0.0034	0.4038
5 or more Years of Schooling and 16-25 Years of Experience	-2.4738	-2.7958	-1.5362	0.3892	0.0672	1.3268
5 or more Years of Schooling and 26-39 Years of Experience	-2.545	-2.8388	-2.1859	0.318	0.0242	0.6771
Total	-2.6202	-2.8630	-1.5362	0.1378	0.001	0.5525
				0.2428	0	1.3268

*Values are weighted by total number of persons in each group in each municipality.

Source: Demographic Censuses, 1980/1991.

Table 7
Outmigration shocks in the 1970s/1980s and effects on wages according to skill groups

Groups of Skills	Emigration shock			Wage effect		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Less than 1 Year of Schooling and 1-5 Years of Experience	0.8582	0.1125	1.6941	1.2967	-0.1636	4.2606
Less than 1 Year of Schooling and 6-15 Years of Experience	0.4706	0.0952	1.2044	0.1405	-0.5593	2.033
Less than 1 Year of Schooling and 16-25 Years of Experience	0.4488	0.1217	1.0706	0.074	-0.5987	1.3043
Less than 1 Year of Schooling and 26-39 Years of Experience	0.4246	0.1508	0.9789	0.0015	-0.6377	1.5623
1-4 Years of Schooling and 1-5 Years of Experience	1.2386	0.4623	1.8343	2.3938	0.9697	4.1821
1-4 Years of Schooling and 6-15 Years of Experience	0.6633	0.1951	1.3032	0.7191	-0.1163	2.3456
1-4 Years of Schooling and 16-25 Years of Experience	0.5546	0.1354	1.0717	0.4081	-0.2212	1.7249
1-4 Years of Schooling and 16-39 Years of Experience	0.4488	0.0859	0.8908	0.1022	-0.4553	1.3824
5 or more Years of Schooling and 1-5 Years of Experience	1.1013	0.2846	1.7907	1.9826	0.5034	3.7803
5 or more Years of Schooling and 6-15 Years of Experience	0.8303	0.1613	1.4321	1.2071	0.1433	3.3763
5 or more Years of Schooling and 16-25 Years of Experience	0.5598	0.0863	1.2596	0.4207	-0.3832	2.781
5 or more Years of Schooling and 26-39 Years of Experience	0.5047	0.1033	1.3249	0.1818	-1.0509	2.6952
Total	0.5955	0.0859	1.8343	0.5149	-1.0509	4.2606

*Values are weighted by total number of persons in each group in each municipality.

Source: Demographic Censuses, 1980/1991.

of the average emigration rate of 60%. We must emphasize that this high mobility could be explained by the age structure of the regional population – a very young workforce; on average, the workers in the municipalities located near the road were 23-24 years old (Table 2).

On the other hand, the wage effect is highly heterogeneous, ranging from –105% to 426%. The heterogeneity of the emigration shocks and of the wage effects is also depicted in Figure 6. In most of the cases, the wage effect is positive, indicating that the substitution effect is larger than the complementary one. However, the wage effect is negative for some skill groups in some municipalities in which the complementary effect is large. This is especially true for the groups with 26 to 39 years of experience, which face a relatively low migration outflow and are affected by the changes in other groups.

When we average the wage effects by municipalities, all the negative effects disappear. The distribution of the effects is presented in Figure 7. At the municipality level, the average wage effects range from 15.6% to 143.6%, with a large concentration around the mean 56%. Figure 8 shows how the wage effect varies with the distance to the Belém-Teresina road, at the municipality level. The magnitude of the final effect varies significantly with respect to the distance to the road. Municipalities closer to the road experience a higher migration shock, as shown by Figures 4 and 5 and, consequently, a higher wage effect.

6. Caveats and Limitations

The analysis of the previous sections is based on the assumptions that the road construction has affected the labor supply in the municipalities in a 200-km radius through a migration outflow of workers, and that there is no other relevant link between the road construction and wages. One of the potential pitfalls in these assumptions is related to the impact of the new road on business and on the location of firms. It might be the case that the pattern depicted in Figure 8, in which the wage effect declines with the distance to the Belém-Teresina road, is determined by an improvement in the labor demand in the areas closest to the road.

Although we cannot assure that the exclusion condition stated above is valid for our case, we do have some evidence that the road construction has affected the labor supply more intensely than the labor demand. The underlying assumption is that labor is more mobile than capital. Figure 9 shows how the number of firms and the value of the residential capital stock varies with the distance to the Belém-Teresina road.

Neither the levels nor the changes in the number of firms or the stock of residential capital seem to decline with the distance to the road. The number of firms has a flat pattern that has remained the same throughout the years. Thus, if the wage effects estimated in the previous sections are generated by changes in labor demand, then they are generated by other mechanisms which are not

Figure 6
Emigration shocks, wage effects, and skill groups

Source: Author's estimates based on Demographic Census of 1980 and 1991.

Figure 7
Distribution of the wage effects across municipalities

Source: Author's estimates based on Demographic Census of 1980 and 1991.

Figure 8
Wage effect and distance to the Belém-Teresina road

Source: Demographic Census of 1980 and 1991.

related to the number of firms. The pattern of the residential capital points in a similar direction.

7. Conclusion

This paper investigates the impact of road construction on labor markets in municipalities located within an area of a 200-km radius from the Belem-Teresina road. We have shown that the road construction has changed the population distribution in the area – many towns were created along the road and there was an increase in migration flows within the area.

Following a structural model approach, we use migration outflows as a source of variation in labor supply in order to estimate elasticity of substitution across skill groups (or types of labor) and elasticity of substitution between capital and labor. We also consider the distance to the road as an instrument for emigration. Then, based on the estimates of elasticities of substitution across types of labor and between capital and labor, we calculate the own-factor and cross-factor price elasticities of labor demand across skill groups. Finally, by considering these factor price elasticities and the observed emigration shocks, we show the wage effects of the *Belém-Teresina* road construction.

The results suggest that the migration outflows determined by the road construction have important consequences for the municipalities that lose workers. The episode has produced an overall increase of 50% in wages, although we also document a reduction in wages in some skill groups in some municipalities due to complementary effects.

Figure 9

Number of firms, residential capital, and distance to the *Belém-Teresina* road

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