IDB WORKING PAPER SERIES Nº IDB-WP-1422

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January 2023

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Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Busso, Matías.
Long-term effects of weather-induced migration on urban labor and housing markets / Matias Busso, Juan Pablo Chauvin.
p. cm. — (IDB Working Paper Series ; 1422)
Includes bibliographic references.
1. Rural-urban migration-Brazil. 2. Climatic changes-Social aspects-Brazil. 3. Climatic changes-Economic aspects-Brazil. 4. Labor market-Brazil. 5. Migrant labor-Brazil. 6. Houssing-Social aspects-Brazil. I. Chauvin, Juan Pablo. II. Inter-American Development Bank. Department of Research and Chief Economist. III. Title. IV. Series.
IDB-WP-1422

Abstract

This paper explores the effects of weather-induced rural-urban migration on urban labor and housing markets in Brazil. In order to identify causal effects, it uses weather shocks to the rural municipalities of origin of migrants. We show that larger migration shocks led to an increase in employment growth and a reduction in wage growth of 4 and 5 percent, respectively. The increased migration flows also affected the housing market in destination cities. On average, it led to 1 percent faster growth of the housing stock, accompanied by 5 percent faster growth in housing rents. These effects vary sharply by housing quality. We find a substantial positive effect on the growth rates of the most precarious housing units (with no effect on rents) and a negative effect on the growth of higher-quality housing units (with a positive effect on rents). This suggests that rural immigration growth slowed down housing-quality upgrading in destination cities.

JEL classifications: J46, J61, O18, R23

Keywords: Weather-induced migration, Rural-urban migration, Urban labor markets, Urban housing markets, Developing countries

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We thank Nicolás Herrera L., Rafael Macedo R., Anna F. Matos, Julio Trecenti, and Haydée Swab for outstanding research assistance. The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its board of directors, or the countries they represent.

1. Introduction

Climate change is expected to increase the frequency and intensity of extreme weather events. Such events are frequently associated with the displacement of rural populations, particularly in developing countries. Distressed lives in rural communities lead workers to pursue better opportunities elsewhere, and a large share of those migration flows are directed to cities. Much of the literature studying the economic effects of weather shocks has emphasized the impact on local labor markets, primarily in affected rural areas (for example, Kleemans and Magruder 2018; Corbi et al. 2021). In this paper we study the long-run effects of weather-induced rural migration to cities on both urban labor markets and urban housing markets in Brazil.

It is important to look at both labor and housing because outcomes in these markets are closely intertwined. Increases in labor supply following migration shocks are likely to increase the local demand for housing, pushing prices up and slowing further migration (Glaeser, 2008). Higher housing demand also can lead to increased local labor demand, not only through growth in the construction sector but also because raising housing prices can lead to substantial increases in the demand for local goods and services by homeowners (Mian and Sufi, 2014; Berger et al., 2018; Stroebel and Vavra, 2019; Howard, 2020). These effects are in turn mediated by the local elasticity of housing supply. Housing supply in developing countries can be more heterogeneous and segmented than in high-income countries, and it includes precarious housing with barely any access to public services (like sewage or running water), low-quality social housing located far from job centers, and more conventional housing. The type of housing that migrants demand and the relative supply of that type of housing shape the ultimate effects on housing prices and labor demand.

To identify the causal effects of weather-induced migration to cities, we follow a recent literature (for example, Kleemans and Magruder 2018; Albert et al. 2021; Corbi et al. 2021; Ibañez et al. 2022) in constructing a city-level instrument using weather variation in rural municipalities of origin interacted with the shares of each rural municipality of origin in the historical rural–urban migration to the city. We validate this approach first by showing that our measure of dryness predicts emigration rates in rural municipalities. We then show that our instrument is a good predictor of rural-urban migration inflows to the cities in our sample.

Our results show that weather-induced migration affects both the urban labor and housing markets in the long run. In the labor market, the influx of rural migrants reduced wage growth by 5 percent and increased employment growth of urban residents by 4 percent, consistent with a downward-sloping long-run demand schedule. We find no effect on local labor force participation. The effects on wages are relatively stronger in the services sector (-7.5 percent), and the effects on employment relatively stronger in the manufacturing sector (15 percent), which may be because manufacturing tends to have higher levels of labor formality and thus higher downward wage rigidity (as in Corbi et al. 2021).

Our housing-market results show that rural-migrant inflows lead to 1 percent faster growth in the quantity of housing available and 6 percent faster growth in average housing rents, consistent with an upward-sloping long-run housing-supply curve. These results, however, mask meaningful heterogeneity. While in the lowest tier of housing quality ("precarious" housing) rural-immigrant inflows have a positive effect on quantities and no significant effect on rents, in higher-housing-quality categories they have a positive effect on rents and a negative effect on quantities. These results suggest that rural-urban migrants are more likely to demand the most basic type of housing, which is also the most affordable, than higher-quality types. If scarce urban land is used for precarious housing, less becomes available for higher-quality units. In a period in which overall housing quality increased across the country, inflows of weather-displaced rural-urban migrants slowed down these improvements. Both the labor-market and housing-market results are robust to alternative specifications and sample definitions.

Our work contributes to the the broader literature on the effects of weather fluctuations on the economy. This large and growing literature has provided credible causal evidence that changes in weather influence multiply economic outcomes (Dell et al., 2014). The documented effects are frequently negative; for example, higher temperatures have led to lower agricultural output and lower economic growth, particularly in poor countries (Dell et al., 2012). A strand of this literature has emphasized the effects of weather changes and extreme weather events on migration, documenting that such events increase emigration out of affected areas, particularly in developing countries (Cattaneo and Peri, 2016; Oliveira and Pereda, 2018). Our paper expands this literature by studying how these weather-driven migrations, in turn, affect the economy of destination urban areas.

Our paper also contributes to a related literature that studies the effects of immigrants—mostly international—on local labor markets. Dustmann et al. (2017), for example, study the effects of shocks to local labor supply induced by an unexpected commuting policy that led to a large inflow of Czech workers along the German-Czech border; they find moderate impacts on wages but large impacts on employment among natives. Calderón-Mejía and Ibáñez (2016) consider internal migration, studying the effects on urban labor markets of inflows of refugees escaping rural armed violence in Colombia, and find that migrant inflows substantially reduce wages among urban unskilled workers. Our study contributes to this literature by studying how weather-induced internal displacement affects not only local labor markets but also local housing markets.

Our work is most closely related to two recent papers, both using weather variation to predict migration in the Brazilian context. Albert et al. (2021) study the economic impact of extreme weather events on the economies of the affected areas and on the reallocation of both labor and capital across the national territory, including both urban and rural areas. Corbi et al. (2021) study the effects of weather-induced migrants from the semi-arid region in Brazil on local labor markets in both rural and urban receiving communities. Our study focuses exclusively on urban areas and finds effects on urban labor markets that are broadly consistent with these two studies. Our key contribution consists of incorporating local housing markets into the literature on the effects of weather-induced migration. This is important because housing markets can shape how local labor markets respond to migration shocks and can deter subsequent migration flows by making city living more expensive. Furthermore, it highlights that housing policy can become an important part of policymakers' toolkit to tackle future–potentially growing–inflows of weather-induced migrants.

The rest of the paper proceeds as follows. Section 2 describes our data sources, the computation of our weather shocks, and the empirical specification we use in the analysis. Section 3 provides descriptive facts on the individual characteristics and outcomes of weather-induced rural-urban migrants and on the local labor and housing markets of the urban areas in our sample. Section 4 presents and discusses the main results, and Section 5 concludes.

2. Data and Empirical Strategy

2.1. Geographies and Data

Our analysis focuses on urban areas (or cities). Following Busso et al. (2021), we use *arranjos populacionais* as our definition of "urban areas" in Brazil. These are units similar to US commuting zones, and they consist of urban cores and their surrounding municipalities tied to the cores through commuting links (IBGE, 2016). Each urban area consists of at least one municipality. We consider all municipalities that are not part of one of these cities *rural municipalities*. Each rural area consists of one municipality.

Most of our variables, including migration, demographic, labor-market, and housing-market measures, are based on the microdata of the long-form questionnaire of four rounds of the decennial population census produced by the Brazilian Institute of Geography and Statistics. These are large random samples representative at the municipality level.[1] For 1980 they include 25 percent of the population, and for 1991, 2000, and 2010, they include 10 percent.

Making comparisons across time requires adjustments for changes in administrative boundaries. We follow the approach of Reis et al. (2007) in creating time-consistent municipalities based on the smallest comparable area for the 1980–2010 period[2], and then group them into time-consistent urban areas and time-consistent rural municipalities. We use the microdata of the population censuses to compute area-level measures for these cities and rural areas.

In order to capture weather variation by rural locality, we rely on the average monthly Standardised Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010). This index measures climatic water balance by comparing the observed precipitation with the

[1]Municipalities are typically small units, with average population of 34,500 and area of 1,500 square kilometers in 2010, although they also include a few very populated units, reaching upward of 6 million people in Rio and 11 million in São Paulo in that year. Over the period of study, the number of municipalities increased significantly, going from 3,952 in 1970 to 5,565 in 2010.

[2]The Reis et al. (2007) Minimum Comparable Area (MCA) definitions are readily available on the Institute of Applied Economic Research's website (http://www.ipeadata.gov.br) and have been used in a number of studies of Brazilian local economies (for example, Dix-Carneiro and Kovak 2017; Kovak 2013). However, as noted in Chauvin (2018), the 3,659 Institute of Applied Economic Research MCAs corresponding to our period of interest are more aggregated than needed (for example, they include in the same MCA municipalities that used to be joined at the beginning of the twentieth century but had already been separated by 1970). Thus, we construct the MCAs' 1970–2010 boundaries directly, based on the algorithm from Chauvin (2018).

amount of water required to preserve surface moisture. The precipitation required to preserve moisture, in turn, depends on evapotranspiration, the water lost to the atmosphere through surface evaporation and transpiration. Evapotranspiration varies seasonally and, critically to our research design, varies regionally.[3] This measure depends on various atmospheric factors, especially temperature. It is a better predictor of droughts than measures based only on precipitation data such as the Standardized Precipitation Index, and it has been used in prior studies of weather-induced migration (for example, Kubik and Maurel 2016; Albert et al. 2021). To simplify the discussion of our results, all numbers are reversed (multiplied by -1) so that we can interpret the index as a measure of dryness. Thus, a value of 1 indicates dryness that is a standard deviation higher than the historical average in a given locality, while a value of -1 indicates wetness that is a standard deviation higher.

We complement our main data with selected variables from other sources, including the geographic area of each municipality from the Brazilian Institute of Applied Economic Research and geographical data from the Brazilian Institute of Geography and Statistics. The Appendix provides further details on the sources and computation of the variables we use in the analysis.

2.2. Empirical Strategy

Main Specification

To estimate the effects of the inflow of rural migrants on urban economies, we rely on a city-level regression of the following form:

$$\Delta Y_c = \beta I_c + X_c' \mathbf{\Theta} + \varepsilon_c \tag{1}$$

Here, ΔY_c is the log difference in the outcome of interest Y (for example, log wages or log rents) in city c between 1991 and 2010;[4] I_c is the rural immigration rate in city c between

[3]The SPEI data that we use are provided in a grid with cells of spatial resolution of 0.5° latitude and longitude. To capture moisture variation within the boundaries of each rural MCA, we employ Wiener–Kolmogorov predictions ("kriging") to interpolate the original data using the cell centroids as the origin locality and the MCA's centroid as the target locality.

[4]We use 1991 as our base year in our outcome measures because we are interested in the long-term effects of migration shocks and because the data that we require to study the impact on the local housing markets—in particular, rents—are only available in the 1991 and 2010 rounds of the census.

2001 and 2010,[5] defined as the number of rural immigrants that migrated in this period as a fraction of the 1991 city population; X'_c is a vector of controls, which include a constant term; and $\mathbf{\Theta}$ is a vector of parameters for the controls. ε_c is the city-level residual.

Our main outcomes of interest are prices and quantities both in the local labor market and the local housing market. The key labor-market variables are local average wages and total local employment. The wage measure is adjusted for individual human-capital characteristics (schooling-attainment categories and age). In order to explore whether the effects are driven by adjustments on the extensive margin, we also measure the impact of migration on labor force participation.[6] All labor-market outcome variables are computed for working-age individuals (14 to 64 years old).

In the housing market, we consider two measures of quantity: the total number of housing units, to capture the extensive margin of housing growth, and the average number of rooms, to capture the intensive margin. We measure price variation using the average rent, adjusted by dwelling characteristics (number of rooms and access to sewage and trash collection, where access is a proxy for neighborhood quality). In addition, we perform subgroup analysis to explore heterogeneous effects by housing quality. We use a set of four housing attributes consistently defined across censuses—access to sewage network, trash collection, brick walls, and access to running water—to create housing-quality categories. We classify a housing unit as *precarious* if it is missing all four of these attributes, as *low quality* if it is missing at least one, and as *quality* if it is not missing any of these attributes.

Weather-Based Instrument for Migration

Immigration rates to cities are endogenous to the conditions of local economies. To identify the effect of migration on urban labor- and housing-market outcomes, we follow the tradition of a large migration-studies literature (starting with Altonji and Card 1991 and Card 2001) by combining historical migration patterns with an exogenous migration push factor (namely, weather shocks) to construct an instrumental variable Z_c, calculated for city c for the 2000–

[5]We can only identify the municipality of origin for the second half or our period of analysis because the 2010 census microdata contain the year of migration and the municipality of prior residence only for migrants who moved between 2001 and 2010.

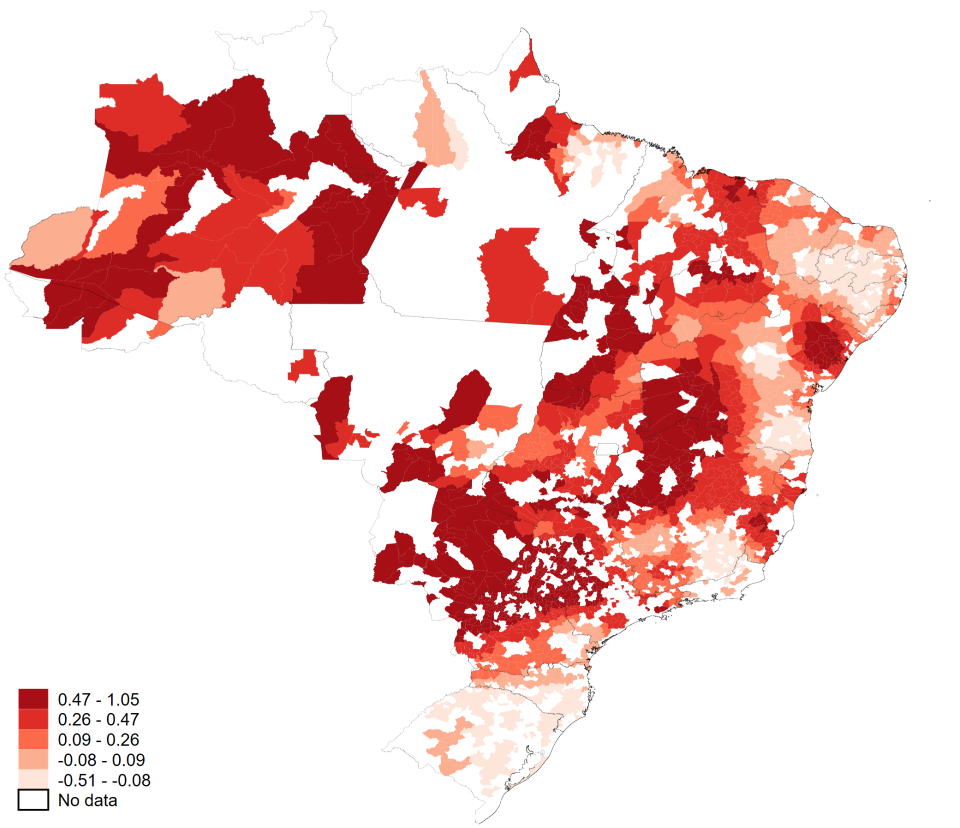
[6]For the labor force participation rate, we use the simple difference in the rate rather than the log difference.

2010 period, which is defined as follows:

$$Z_c = \sum_r s^I_{c,r} D_r \tag{2}$$

Here, $s^I_{c,r}$ is the share of total rural immigrants that arrived in city c from rural area r between 1982 and 1991 and D_r is the average of the monthly reversed SPEI for all months between 2000 and 2009 (that is, the average dryness shock to rural location r). Figure 1 depicts the geographic variation in dryness across rural municipalities in the 2000–2009 period. It shows that, in this time frame, there were rural municipalities with unusually high dryness in most regions of the country, except for the South.

Figure 1: Variation in $-1 \times SPEI$ over the Period of Analysis



Notes: This map shows the geographic distribution of our dryness measure, defined as the monthly average of $-1 \times SPEI$ over the 2000–2009 period. Municipalities that overlap with an urban area in our sample are not included.

To validate our approach, we first assess the impact of our dryness measure on emigration out of rural areas. We use the regional variation in D_r to estimate the following regression at the rural-area level:

$$E_r = \gamma_0 + \gamma_1 D_r + \theta X_r + \mu_r \tag{3}$$

Here, E_r is the emigration rate in rural area r, during the 2001–10 period, measured as the number of working-age individuals that migrated out of municipality r in this period, expressed as a share of the population of municipality r in 2000; D_r is the average of the monthly reversed SPEI index between 2000 and 2009; X_r is a set of controls measured before 2000; and μ_r is a rural-area-level residual term.

Panel A of Table 1 reports the results. Column (1) reports estimates of γ_1 in equation 3 without any controls, and it shows that weather variation, as captured by the SPEI, has a statistically significant effect on emigration out of rural areas. Column (2) adds a set of controls to account for local characteristics that may affect migration and ultimately labor and housing market outcomes and may be correlated with weather variation. Indeed, in Brazil, economically lagging regions (typically more agricultural and less educated) tend to be located in areas that are more prone to negative weather shocks. We control for the economic structure of the local economy (shares of agriculture, services, and government in employment), schooling level (share of college-educated workers in employment), the log of 1991 population, and population growth in the prior decade (1980–91) to account for preexisting migration trends. The point estimate of the impact of dryness on migration changes little and remains significant at the 1 percent level. Last, Column (3) includes fixed effects for the five main macro regions of the country. The macro regions differ markedly on multiple dimensions, including level of development and climate, and the fixed effects allow us to compare the effects of weather in localities that are broadly more homogeneous. In this—our preferred specification—an average dryness one standard deviation higher than the historical average is associated with a 0.72 percentage-point (8.4 percent) statistically significant increase in the emigration rate of rural municipalities. This is in line with various other studies documenting rural-urban migration effects of increasing temperatures and changes in precipitation patterns in middle-income countries (for example, Cattaneo and Peri 2016).

Next, we assess the ability of our instrument in equation 2 to predict the inflows of rural migrants into cities (that is, the first stage of our main specification). Specifically, we estimate the following equation:

$$I_c = \alpha + \sigma Z_c + X_c' \boldsymbol{\Sigma} + \nu_c \qquad (4)$$

Here, I_c, Z_c, and X_c are defined as before; α, σ, and $\boldsymbol{\Sigma}$ are parameters; and ν_c is the error term.

Table 1: Effects of Weather Shocks on Migration

	(1)	(2)	(3)
Panel A: effects of precipitation on rural emigration	*Emigration rate from rural areas*		
Average $-1 \times SPEI$	1.101***	0.994***	0.720***
	(0.190)	(0.187)	(0.194)
Observations	2,870	2,868	2,868
Average of dependent variable	8.527	8.520	8.520
Controls	No	Yes	Yes
Macroregions	No	No	Yes
Panel B: Effect of weather-based IV on rural immigration	*Rural immigration rate to cities*		
SPEI-based IV	2.884***	2.089***	2.455***
	(0.592)	(0.556)	(0.609)
F statistic	23.751	14.112	16.247
Observations	454	454	454
Average of dependent variable	5.083	5.083	5.083
Controls	No	Yes	Yes
Macroregion fixed effects	No	No	Yes

Notes: The table reports the results of rural-municipality-level regressions (Panel A) and city-level regressions (Panel B), both calculated with data from the 2010 census. In Panel A, rural emigration is defined as the total number of emigrants who left a rural area in the 2001–10 period as a percentage of the 1991 population, and the drought index is the simple monthly (inverted) SPEI average for the 2000–2009 period. In Panel B, the endogenous independent variable (rural immigration rate) is defined as the number of rural migrants who arrived in a city during the same period as a share of the city's 1991 population. The IV is constructed by interacting the average inverted SPEI (2000–2009) of each rural municipality of origin with the share that migrants from that origin represent in total rural-urban migration to a city from 1982 to 1991 (see equation 2). The vectors of controls include the shares in employment of agriculture, services, and government, the share of workers with college education, the log of 1991 population, and 1980–91 population growth. Robust standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

Our estimates of σ are reported in Panel B of Table 1. Our weather-based instrument

Z_c predicts rural immigration rates in cities. A one-point increase in the weighted average of dryness in the historical municipalities of origin of rural–urban migrants (that is, the instrument defined in equation 2) is associated with an average 2.5 percentage-point increase in cities' immigration rates from rural municipalities of origin. In all specifications, the statistic of the multivariate F-test of excluded instruments is above 10, suggesting that we can rule out that the instrument is weak.

3. Descriptive Facts

We start by exploring to what extent weather-induced migrants are different from other migrants in the country. To this end, Table 2 presents descriptive statistics for three groups of migrants based on their last migration decision: migrants who moved from one city to another in column (1), rural-urban migrants who came from areas with moderate weather shocks (that is, dryness less than one standard deviation away from the historical average in the three years prior to migration) in column (2), and rural–urban migrants who came from severe-weather areas (that is, dryness more than one standard deviation away from the historical average in the three years prior to migration) in column (3).

Over 10.5 million people migrated to cities in Brazil between 2001 and 2010.[7] Roughly two-thirds of them moved from one urban area to another, and a third came from rural areas. Around 155,000 were migrants from rural municipalities that experienced unusually extreme weather during the three years prior to migration. This group included more women and girls (51.3 percent) than men and boys (48.7 percent). Rural-urban migrants were younger and less educated than urban-urban migrants, but weather-induced migrants were very similar to other rural-urban migrants in age and education.[8]

Despite having similar human-capital characteristics to other rural-urban migrants, severe-weather migrants exhibited weaker labor-market performance in their destination cities relative to other migrants and nonmigrant urban residents (Panel B in Table 2). While other migrants' employment rates exceeded that of the urban average by 2 to 3 percentage points, the employment rate of severe-weather migrants was only 0.1 percentage points above the

[7]These estimates do not consider migrants who moved between municipalities within the same urban area.

[8]Albert et al. (2021), in contrast, find that the likelihood of completing high school decreases with the dryness of the municipality of origin.

average.

Table 2: Characteristics of Internal Migrants Who Arrived in Urban Areas in the 2000–2010 Period (national averages)

	Urban–urban	Rural–urban from moderate-weather origins	Rural–urban from severe-weather origins
Panel A: demographic characteristics			
Working-age rural–urban migrants (in 1000s)	6,570	3,840	155
Percent of females	50.8%	51.3%	51.3%
Age at the time of migrating			
Percent 15–30	55.3%	65.0%	65.2%
Percent 31 or older	44.7%	35.0%	34.8%
*Education**			
Percent less than primary	13.4%	20.5%	19.2%
Percent primary but less than high school	33.7%	41.3%	41.8%
Percent high school or higher	52.9%	38.2%	39.0%
Panel B: labor-market performance in destination cities in 2010			
Employment rate	64.9%	65.5%	62.9%
Difference from the urban average (pp.)	2.1	2.7	0.1
Informality rate	37.4%	37.5%	39.8%
Difference from the urban average (pp.)	-1.3	-1.2	1.2
Wages (in 2010 BRL)	1105	756	754
Relative to nonmigrant urban residents	123%	84%	84%
Panel C: housing conditions in destination cities in 2010			
Percentage of households that rent	49%	49%	49%
Difference from the urban average (pp.)	28.90	28.88	28.86
Rent (in 2010 BRL)	386	278	284
Relative to nonmigrant urban residents	125%	90%	92%
Relative to rural municipality of origin	214%	154%	158%

Notes: All values are national averages calculated from the microdata using sampling weights. All variables in Panel A refer to migrants' characteristics at the time of migration. Variables in Panel B are calculated for individuals that were of working age in the 2010 census. Informal workers are defined as those who are without a signed working card or are self-employed. Migrants from moderate-weather origins are defined as those coming from municipalities where the dryness measure was less than one standard deviation away from the historical average in the three years prior to migration. Migrants from severe-weather origins are those coming from municipalities with dryness more than one standard deviation away from the historical average in the three years prior to migration.
* To capture premigration educational attainment, these measures are calculated with the sample restricted to individuals aged 18 or older at the time of migration (that is, the age at which individuals are expected to have finished high school in Brazil).

Furthermore, while for both urban-urban migrants and migrants from moderate-weather municipalities informality rates were below the urban average, severe-weather migrants had an informality rate 1.2 percentage points above the average in their urban destinations.

Last, the average wage of rural-urban migrants was only 84 percent of the urban average. Albert et al. (2021), by comparison, look at how labor-market outcomes vary with the level of dryness in the origin municipality of migrants, and they find that migrants from drier municipalities tend to have a higher likelihood of employment and lower total labor income than other migrants.

Panel C in Table 2 looks at the housing situation of migrants in their destination cities. It shows that about half of all migrants, regardless of their origin, were renters. Their propensity to rent was 28 percentage points above the urban average. Migrants coming from other urban areas paid, on average, rents that were 25 percent higher than the urban average and more than twice as high as the average rents in their cities of origin. In contrast, rural-urban migrants lived in more affordable housing, with rents that were between 90 and 92 percent of the urban average but still over 50 percent higher than the average rents in their municipalities of origin.

We turn now to the main focus of our study: the local labor and housing markets of the 454 Brazilian urban areas in our sample during the 1991–2010 period. Table 3 presents cross-city averages of key characteristics of these markets. Over these two decades, labor-market conditions in Brazilian cities (Panel A) improved noticeably. Employment rates increased, informality rates dropped, and both labor force participation and wages rose. These improvements were experienced bamong both urban residents and rural-urban migrants to cities. However, labor-market outcomes remained weaker for rural-urban migrants throughout. Both at the beginning and end of the period, while these migrants had on average higher employment and labor force participation rates than urban residents, they also experienced higher rates of labor informality and lower wages.

Urban housing markets, meanwhile, experienced substantial growth over these two decades (Table 3, Panel B). The number of housing units in our sample of urban areas went from 25 million in 1991 to 42 million in 2010, and the number of rooms in these units from 135 million to 240 million. Average housing rents also increased. Expressed in 2010 Brazilian reais (worth around 0.6 US dollars at the 2010 exchange rate), average rents went from 168 to 260 reais. This rise was accompanied by an average upgrading in housing quality. The number of precarious housing units decreased by 49 percent, and the number of rooms in these units by 38 percent.

Table 3: Labor and Housing Markets in Destination Cities (cross-city averages)

	1991	2010
Panel A: local labor markets		
Employment rate (employed / working age)	58.04	61.03
Among rural migrants (rural migrants employed / migrants w.a.)	60.20	62.57
Among local residents (residents employed / residents w.a.)	57.52	60.93
Informality rate (informally employed / employed)	49.67	45.82
Among rural migrants	49.75	43.13
Among local residents	50.02	46.28
Labor force participation rate (employed + unemployed / working age)	60.52	66.10
Among rural migrants	62.41	68.09
Among local residents	60.03	65.81
Wages (in 2010 BRL, geometric mean)	469	752
Among rural migrants	417	718
Among local residents	466	740
Panel B: local housing markets		
Housing units (local stock, in millions)	24.75	41.85
Precarious housing	1.37	0.69
Low-quality housing	13.60	17.63
Quality housing	9.78	23.52
Number of rooms (local stock, in millions)	134.62	239.26
in precarious housing	4.79	2.98
in low-quality housing	69.73	96.70
in quality housing	60.10	139.59
Monthly housing rent (in 2010 BRL, geometric mean)	168	260
in precarious housing	58	178
in low-quality housing	134	228
in quality housing	281	303

Notes: All values are cross-city averages of the corresponding variables. Each city-level statistic is constructed directly from census microdata using sampling weights. All labor-market variables are calculated over the working-age population (aged 15 through 64). Informal workers are defined as those that lack a signed working card or are self-employed. We define housing quality using a vector of four housing attributes that are consistently observable across censuses: sewage network, trash collection, brick walls, and water network. If a house is missing all four of these attributes, it is classified as precarious, and if it is missing at least one, it is called low-quality. Houses that are not missing any of these attributes are classified as quality housing.

In contrast, the stock of low-quality housing increased by 30 percent (38 percent for number of rooms), and the stock of quality housing rose by a striking 140 percent (132 percent for number of rooms). Housing rents, expressed in constant 2010 reais, increased 55 percent over these two decades on average. The increase was more pronounced in housing categories in which the stock became relatively more scarce. While for quality housing units rents rose by 8 percent, for low-quality housing the increase was 70 percent, and for precarious housing rents increased by a striking 200 percent. Despite these changes, rents for precarious housing remained, in 2010, 22 percent lower than for low-quality housing on average.

4. Results

4.1. Labor-market Effects

Table 4 reports estimates of the effect of rural immigration to cities (β in equation 1) on urban labor-market outcomes. Column (1) reports, as a benchmark reference, OLS estimates of these coefficients, and columns (2) through (4) report 2SLS estimates using our weather-based IV (equation 2). Column (2) reports estimates generated without using controls. Column (3) adds the same set of controls as in Panel B of Table 1, and column (4) adds macroregion fixed effects.

The overall results, reported in Panel A, are in line with what we would expect from a local labor-supply shock in the presence of a downward-sloping long-run labor-demand schedule. All 2SLS specifications show that inflows of rural migrants lead to slower wage growth among urban residents, and all results are statistically significant at conventional levels. In our preferred specification (column (4)), we estimate that a one-percentage-point increase in the rural immigration rate leads to 5 percent slower wage growth among residents. The positive point estimate in the OLS specification is consistent with rural-urban migrants' tendency to choose higher-wage destinations (Busso et al., 2021) and suggests that our instrumentation strategy is effectively addressing this source of endogeneity. The negative effects on wages also suggest that, in this context, rural-urban migration does not have a substantial positive effect on labor demand, contrary to the findings of Berger et al. (2018) and Howard (2020). These results are consistent with those of Albert et al. (2021), who show that climate migrants tend to earn lower income than other migrants. Calderón-Mejía and Ibáñez (2016) also find negative effects on urban native wages of influxes of forced migrants to Colombian cities.

Table 4: Effects of Weather-Induced Immigration on Labor-market Outcomes of Residents

	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)
Panel A: all industries				
Wages (residuals at national level)	0.007***	-0.061***	-0.075***	-0.050**
	(0.001)	(0.017)	(0.026)	(0.020)
Employment	0.022***	0.054***	0.045***	0.038***
	(0.006)	(0.014)	(0.014)	(0.012)
Labor force participation rate	0.003***	-0.000	-0.001	0.002
	(0.001)	(0.003)	(0.004)	(0.004)
Panel B: by industry				
Services				
Wages (residuals at national level)	0.003**	-0.080***	-0.099***	-0.075***
	(0.001)	(0.019)	(0.030)	(0.023)
Employment	0.017***	0.040**	0.030*	0.029*
	(0.005)	(0.018)	(0.018)	(0.016)
Manufacturing				
Wages (residuals at national level)	0.008***	-0.052***	-0.062**	-0.042**
	(0.003)	(0.018)	(0.025)	(0.021)
Employment	0.046***	0.132***	0.138***	0.149***
	(0.012)	(0.026)	(0.037)	(0.039)
Observations	454	454	454	454
Controls	Yes	No	Yes	Yes
Macroregion fixed effects	Yes	No	No	Yes

Notes: The table reports the results of city-level regressions. City aggregates are computed directly from the census microdata, restricted to observations of residents (people who were already living in the city at the beginning of the period and did not migrate). The endogenous independent variable (rural immigration rate) is defined as the number of rural migrants who arrived in a city during the same period, as a share of the city's 1991 population. The IV is constructed by interacting the average inverted SPEI (2000–2009) of each rural municipality of origin with the share of migrants from that municipality in total rural-urban migration to a city from 1982 to 1991 (see equation 2). The vectors of controls include the shares in employment of agriculture, services, and government, the share of workers with college education, the log of 1991 population, and 1980–91 population growth. Robust standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

We also find that rural-migrant inflows exert a positive and significant effect on residents' employment. Our preferred specification suggests that a one-percentage-point higher rural immigration rate leads to a 3.8 percent increase in local employment. We find no significant effects on local labor force participation, suggesting that the effects are not driven by changes in the labor supply of residents. Corbi et al. (2021) also find positive effects on native employment in the informal sector, but they find negative effects in the formal sector. Kleemans and Magruder (2018) also find negative formal-sector employment effects.

Panel B in Table 4 explores differential effects by economic sector. In both services and manufacturing we find negative effects on residents' wages and positive effects on employment. The relative size of these coefficients varies by sector. In the services sector, the negative effect on wages is more pronounced and the effect on employment weaker. The opposite is true in manufacturing, where the average positive effect on employment is larger and the average negative effect on wages is smaller than for the local economy as a whole. These patterns are consistent with the findings of Kleemans and Magruder (2018) and Corbi et al. (2021), who find that weather-induced migrant inflows have negative wage effects on informal workers. Because the services sector tends to have more informal employment, the minimum wage is less likely to be binding, making downward wage adjustments more feasible.

4.2. Housing-market Effects

Table 5 presents the results for housing-market outcomes for the same specification used in our labor-market results (Table 4). Panel A reports reports effects on prices and quantities for all urban housing units in the sample. The results show that migrant inflows increase local housing demand, pushing prices up. A one-percentage-point higher rural immigration rate leads, in our preferred specification, to a 5.7 percent increase in housing rents (adjusted for housing characteristics). In a related study—looking at the impact of war-driven Syrian refugees in Jordan—Rozo and Sviatschi (2021) also find a positive effect of forced immigration on rents. Our point estimates of the quantity effects are also positive; the effect on the number of housing units is not statistically significant, while the effect on the total number of rooms is statistically significant at the 10 percent level.

Panel B of Table 5 shows that these aggregate effects mask important heterogeneity. The influx of rural migrants appears to have led to disproportionate growth in demand for precarious housing to the detriment of demand growth for low-quality and quality housing. This amounted to an overall downgrading of housing quality in urban areas receiving migrants—more precisely, to a slower improvement in housing quality over the 1991–2010 period.

Specifically, our preferred specification shows that a one-percentage-point increase in rural immigration led to a 35 percent and significant increase in housing units and a 37 percent and significant increase in the number of rooms, with no effect on housing rents in the precarious housing category. These effects are large in percentage terms. However, it should be noted that they are based on a relatively small initial quantity (1.37 million housing units, equivalent to 5.5 percent of all housing units in 1991). These effects are consistent with very elastic supply for the most basic housing category. Indeed, in many cities in developing countries, rural-urban migrants frequently take low-quality housing, including in slums and through land invasions, sometimes building dwellings—often informally—on land for which other city dwellers have little demand (among other reasons, because of terrain that is steeply sloped, has high risk of landslides, or requires long distances from urban job centers). Consistent with this explanation, in Brazil, Hidalgo et al. (2010) show that weather shocks lead to more land invasions and Cavalcanti et al. (2019) show that rural-urban migration is one of the key determinants of slum formation.

In contrast, we observe in the next-higher housing category (low quality) that rural migration leads to faster growth in housing rents and slower growth in housing quantities. Our preferred specification shows that, in this category, a one-percentage-point increase in the rural immigration rate leads to a 6.4 percent larger increase in housing rents, accompanied by a 12.3 percent slower increase in the number of housing units and a 9.5 percent slower increase in the number of rooms. All these effects are significant at conventional levels. Similar point estimates are observed in the quality housing category—positive effects on rents and negative, larger effects on quantities—although these estimates are not statistically significant in our preferred specification. These results are consistent with an increase in housing demand in the presence of relatively inelastic housing supply.

Taken together, these results suggest that rural-urban migrants disproportionately demand the most precarious (and most affordable) type of housing and have relatively smaller demand for higher-quality housing. When land—a particularly scarce resource in many urban settings—is used for precarious housing, it is no longer available for other uses, restricting the supply of better-quality housing units.

Table 5: Effects of Weather-Induced Immigration on the Local Housing Market

	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)
Panel A: all housing units				
Housing rents (adjusted by unit characteristics)	-0.002	0.055**	0.094***	0.057**
	(0.003)	(0.022)	(0.036)	(0.025)
Number of housing units (local stock)	0.024***	0.031***	0.023**	0.011
	(0.004)	(0.010)	(0.011)	(0.011)
Number of rooms (local stock)	0.022***	0.034***	0.026**	0.017*
	(0.004)	(0.011)	(0.012)	(0.010)
Panel B: by housing quality				
Precarious housing				
Housing rents (adjusted by unit characteristics)	-0.000	0.077	0.087	-0.002
	(0.022)	(0.091)	(0.100)	(0.087)
Number of housing units (local stock)	-0.024	0.145**	0.199**	0.350***
	(0.015)	(0.074)	(0.097)	(0.109)
Number of rooms (local stock)	-0.023*	0.156**	0.212**	0.373***
	(0.014)	(0.078)	(0.103)	(0.115)
Low-quality housing				
Housing rents (adjusted by unit characteristics)	-0.004	0.084***	0.121***	0.064**
	(0.004)	(0.028)	(0.045)	(0.029)
Number of housing units (local stock)	0.015***	-0.090**	-0.141**	-0.123***
	(0.005)	(0.041)	(0.057)	(0.045)
Number of rooms (local stock)	0.012**	-0.051	-0.088*	-0.095**
	(0.005)	(0.036)	(0.046)	(0.040)
Quality housing				
Housing rents (adjusted by unit characteristics)	-0.000	0.035	0.092	0.056
	(0.003)	(0.037)	(0.072)	(0.068)
Number of housing units (local stock)	0.013	-0.595***	-0.910**	-0.277
	(0.015)	(0.196)	(0.434)	(0.191)
Number of rooms (local stock)	0.010	-0.570***	-0.872**	-0.268
	(0.015)	(0.191)	(0.418)	(0.190)
Observations	454	454	454	454
Controls	Yes	No	Yes	Yes
Macroregion fixed effects	Yes	No	No	Yes

Notes: The table reports the results of city-level regressions. City aggregates are computed directly from the census microdata as averages across households. The endogenous independent variable (rural immigration rate) is defined as the number of rural migrants who arrived in a city during the same period, as a share of the city's 1991 population. The IV is constructed by interacting the average inverted SPEI (2000–2009) of each rural municipality of origin with the share that migrants from that municipality represent in total rural–urban migration to a city from 1982 to 1991 (see equation 2). We define housing quality using a vector of four housing attributes that are consistently observable across censuses: sewage network, trash collection, brick walls, and water network. If a house is missing all four of these attributes, it is classified as precarious, and if it is missing at least one, low-quality. Houses that are not missing any of these attributes are classified as quality housing. The vectors of controls include agriculture's share of employment, services' share of employment, government's share of employment, share of employed individuals who have at least a college education, log of population in 1991, and population growth from 1980 to 1991. Robust standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

4.3. Robustness

Our results are robust to a number of alternative specifications and sample definitions. Table 6 reports these tests for our main labor-market and housing-market results. Column (1) reproduces, as a reference, the results of our preferred specification from Tables 4 and 5.

A potential concern is that spatial autocorrelation may affect the significance of our results. In particular, urban areas that are located close to each other might be exposed to similar weather-induced migration shocks, violating the independence assumption. To address this concern, we cluster the standard errors of our regressions at the mesoregion level. Mesoregions are geographic units smaller than macroregions but larger than our urban areas (*arranjos populacionais*). As in our other analyses, we adjust mesoregion boundaries to make them time consistent, resulting in a total of 122 clusters. As shown in column (2), the statistical significance of our key results is unaffected.

Column (3) focuses on the effects of recent migrants. In this case, we redefine the endogenous variable—the rural immigration rate—as the ratio of rural immigrants who arrived in the city over the last five years (in the 2005–10 period), instead of over the last decade. It might take some time for local economies to fully accommodate an increase in population. Recent migrants need to search for jobs, rebuild their networks, or find clients and suppliers. Similarly, recent migrants need to find a place to live, and they take some time to settle in. Column (3) shows that the effects on both the labor and housing markets seem to be somewhat larger for recent migrants vis-à-vis the effects of longer-term migrants.

While in our main specification we use weather variation in both directions—excess dryness and excess wetness relative to historical averages—other studies have only focused on the effects of excess dryness (droughts). In column (4) we replicate our analysis using only the variation in dryness—that is, inputting zeros when the average $(SPEI * -1)$ in rural municipalities of origin during our period of analysis is smaller than zero. Droughts may have short-run effects on farmers by reducing crop yields and total production. If farmers rely on current crops to finance investment in future production, then droughts, especially persistent ones, may permanently hinder farmers' ability to produce, thus increasing the probability they will migrate from rural locations to cities. Column (4) shows very similar point estimates to the baseline results, suggesting that the effects captured by our main specification are driven primarily by drought-induced migration.

Table 6: Robustness Tests of Effects of Weather-Induced Rural Migration on Urban Economies

	Baseline results (1)	Clustered SE Mesoregion (2)	Only recent rural migrants (3)	Droughts only (4)	Excluding largest cities (5)*
Panel A: Labor-market outcomes					
Wages (adjusted by education and experience)	-0.050**	-0.050*	-0.070**	-0.053**	-0.051**
	(0.020)	(0.029)	(0.027)	(0.027)	(0.025)
Employment	0.038***	0.038***	0.054***	0.034**	0.033**
	(0.012)	(0.015)	(0.017)	(0.015)	(0.014)
Labor force participation rate	0.002	0.002	0.003	0.002	0.002
	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
Panel B: Housing-market outcomes					
Precarious housing					
Housing rents (adjusted by unit characteristics)	-0.002	-0.002	-0.004	0.054	0.050
	(0.087)	(0.079)	(0.127)	(0.139)	(0.130)
Number of housing units (local stock)	0.350***	0.350**	0.499***	0.385**	0.373***
	(0.109)	(0.166)	(0.151)	(0.154)	(0.144)
Number of rooms (local stock)	0.373***	0.373**	0.532***	0.399**	0.385***
	(0.115)	(0.175)	(0.159)	(0.160)	(0.149)
Low-quality housing					
Housing rents (adjusted by unit characteristics)	0.064**	0.064*	0.090**	0.064	0.061*
	(0.029)	(0.037)	(0.041)	(0.039)	(0.036)
Number of housing units (local stock)	-0.123***	-0.123**	-0.172***	-0.173**	-0.162***
	(0.045)	(0.052)	(0.060)	(0.070)	(0.062)
Number of rooms (local stock)	-0.095**	-0.095**	-0.133**	-0.143**	-0.133**
	(0.040)	(0.046)	(0.054)	(0.061)	(0.055)
Quality housing					
Housing rents (adjusted by unit characteristics)	0.056	0.056	0.078	0.073	0.069
	(0.068)	(0.060)	(0.096)	(0.090)	(0.082)
Number of housing units (local stock)	-0.277	-0.277	-0.390	-0.325	-0.281
	(0.191)	(0.232)	(0.268)	(0.254)	(0.219)
Number of rooms (local stock)	-0.268	-0.268	-0.378	-0.312	-0.270
	(0.190)	(0.228)	(0.266)	(0.249)	(0.216)
Controls	Yes	Yes	Yes	Yes	Yes
Macroregion fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: The table reports the results of city-level regressions. City aggregates are computed directly from the census microdata. Labor-market outcomes are computed for residents (people who were already living in a city at the beginning of the period and did not migrate). Housing-market outcomes are computed as averages across households using all households in the microdata. The endogenous independent variable (rural immigration rate) is defined as the number of rural migrants who arrived in a city during the same period, as a share of the city's 1991 population. The IV is constructed by interacting the average inverted SPEI (2000–2009) of each rural municipality of origin with the share that migrants from that municipality represent in total rural-urban migration to a city from 1982 to 1991 (see equation 2). We define housing quality using a vector of four housing attributes that are consistently observable across censuses: sewage network, trash collection, brick walls, and water network. If a house is missing all four of these attributes, it is classified as precarious, and if it is missing at least one, low-quality. Houses that are not missing any of these attributes are classified as quality housing. The vectors of controls include agriculture's share of employment, services' share of employment, government's share of employment, share of employed individuals that have at least a college education, log of population in 1991, and population growth from 1980 to 1991. Robust standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.
* Large cities are removed from the sample: São Paulo, Rio de Janeiro, Brasília, Salvador, Fortaleza, and Belo Horizonte.

Given that an important share of the rural-urban migration flows are directed to the largest cities, we might worry that the migration to small- and midsize cities is not substantial enough to have a detectable effect on labor- and housing-market outcomes. In column (5) we exclude the six largest cities of the country (São Paulo, Rio de Janeiro, Brasília, Salvador, Fortaleza, and Belo Horizonte) from the analysis sample. Results are unaffected, suggesting that they capture the effects on a wide range of city sizes.

5. Conclusions

Climate change is likely to increase the severity and frequency of weather-related shocks. From droughts, to hurricanes, to wildfires, these events can harm the livelihoods of rural households (especially those who are the most vulnerable), causing them to migrate to other destinations. In this paper, we studied the impact that these migrants have in their destination cities.

We found that these newcomers increase the labor supply, causing wages to grow at a slower rate (especially in services) and employment to increase (especially in manufacturing). We also showed that the increased population leads to changes in the housing market. On average, both quantities and prices grow faster in destination cities. However, these averages mask substantial heterogeneity. We observed much faster growth in the quantity of precarious housing units and much slower growth of units of higher-quality types. In contrast with the rest of the housing market, rents of precarious housing are unaffected, suggesting highly elastic supply in this market segment.

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Appendix

Table 1: Description of Measures

Variables	Description/comments
Working-age population	Population between 15 and 64 years old, inclusive
Employed	Individuals who answered being employed, regardless of formal registry status, in the census
Informal worker	People who answered not having formal work registry in a work card or declared being self-employed, in the census. This question is for individuals who answered being employed.
Severe-weather-driven rural migrant	Migrants who came from regions where the monthly drought-score average of the 36 preceding months prior to migrating is below -1 or above 1.
Moderate-weather-driven rural migrant	Migrants who came from regions where the monthly drought-score average of the 36 preceding months prior to migrating is between -1 and 1.
Resident	Individuals who lived in the reported place of residency for 10 years of more, or people who had not reported a previous place of residence.
Time-consistent urban areas	Similar to IBGE *arranjos*, time-consistent urban areas are urban conurbations that maintain the same boundaries for a selected period. In this study, all geographic unities are time consistent between 1980 and 2010.
Time-consistent rural areas	Non-*arranjo* municipalities, with municipal boundaries consistent between 1980 and 2010.
Rural migrant	Individuals whose previous location of residency was a rural time-consistent rural areas (up to 9 years before the census).

Table 2: Definitions of Variables

Variables	Description/comments
Panel A: Rural variables	
SPEI	Standardised Precipitation-Evapotranspiration Index developed by the Spanish National Research Council (Consejo Superior de Investigaciones Cientficas). In this study, all SPEI scores were reversed (multiplied by -1). This was employed in order to represent positive values as droughts.
Rural emigration rate (2010-2001)	Total number of people who emigrated up to 9 years before the 2010 Census over the total rural population in the 1991 Census, per rural MCA.
Panel B: Urban variables	
Labor market outcomes	
Wages (adjusted by education and experience)	Reported values in the Census deflated to 2010 BRL values.
Employment	People who reported in the census as being employed, restricted by working age.
Labor force participation rate	Rate of the employed and unemployed people in working age population, as previously defined.
Housing market outcomes	
Housing rents (adjusted by unit characteristics)	Rents adjusted for house amenities: log number of rooms, access to the main sewage system and trash collection service.
Number of housing units (local stock)	Unique household observations in the Census
Number of rooms (local stock)	Sum of reported number of rooms in the Census, per unique household.
Controls	
Share of employment in large industries	Workers who reported working in four categories: agriculture, manufactures, services and government.
Share of college-educated in employment	Share of college educated in working age over all people employed in working age.
Population	Total respondents of the Census
Population growth 1980-1991	Difference of log of total population from 1991 Census and 1980 Census.