Slum growth in Brazilian Cities

JOB MARKET PAPER

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Abstract

I study slum growth in Brazilian cities between 1991 and 2010 by estimating a spatial equilibrium model. Slums, defined as urban houses without basic water and sanitation, result from households choosing between types of houses, cities, and rural areas. Instrumental variable estimation of the model's structural parameters yields two results: i) households move rapidly to cities when urban wages increase ii) the elasticity of housing rents with respect to demand shocks is higher for serviced relative to unserviced housing. I simulate a set of general equilibrium counterfactuals and show that when wage growth occurs in only a few cities, these cities' unserviced housing share increases. However, when wage growth occurs in all cities, the national urban unserviced housing share declines. I further show that if cities enact a slum repression policy resulting in a 20% increase in unserviced housing costs, urbanization decreases by 0.4% and low income households' welfare declines by 1.1%.

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1 Introduction

One third of urban households in the developing world either live with no adequate water, sanitation, durable construction materials, or experience overcrowding (UN, 2012). With rapid urbanization taking place across the developing world, the number of urban households experiencing these conditions continues to increase, having reached 880 million in 2010 (UN, 2015). Local and national governments invest heavily in policies dealing with slum growth, ranging from strong repression, including evictions, to slum upgrading programs (UN, 2003).[1] In contexts with high spatial mobility of households, both between rural areas and cities and between different cities, slum policies implemented in a few cities may affect slum growth in other cities as well as aggregate urbanization rates. These relocation effects may in turn have significant welfare impacts on different types of households.

This paper estimates a spatial equilibrium model of a system of cities with slum and non-slum houses to examine the effects of changes in slum policies and economic fundamentals on households' spatial distribution and welfare. I estimate the model by looking at the growth in the number of houses with and without basic water and sanitation in Brazilian cities between 1991 and 2010. The basic structure of the model features two elements. First, low and high income households choose between serviced or unserviced houses in a set of cities or living in the countryside. Second, cities provide housing with one supply function for each type of house.

A quick look at the estimated structural elasticities illustrates the basic mechanics of slum growth according to the model. First, as developing world cities become more productive and offer higher wages, low income households move rapidly to these cities, increasing the demand for urban houses (elasticity of 1.6). Second, these increases in housing demand impact serviced housing rents much more (elasticity of 0.4) than unserviced ones (elasticity of 0.1). Third, low income households react to these changes in relative housing rents by increasingly choosing unserviced houses (price elasticity of -0.4) over serviced ones (price elasticity of -0.5). As a result of the interplay of these elasticities, urban economic growth pushes slum incidence

[1] For instance, own processing of Brazil's MUNIC survey indicate that around 50% of Brazilian cities in my sample were implementing some type of slum upgrading program in the mid 1990's.

upwards. However, urban economic growth has another effect operating in the opposite direction, which tends to dominate in the long run as countries become wealthier. I observe a steep positive gradient between serviced housing consumption and household income. As cities grow and countries become richer, this steep gradient implies that households increasingly consume serviced housing over unserviced one, and this pushes slum incidence downwards in the long run.[2]

The impact of urban economic dynamism on slum incidence depends then on the balance between those two forces. In particular, I show that the impact of economic growth on slum growth in any given city depends critically on what happens in other cities. For instance, when I simulate a 20% extra wage growth shock between 1991 and 2010 in a single medium-size city, this city's unserviced housing incidence increases by 1.3% and its number of unserviced houses increases by 28.0%. However, when the same wage shock takes place in all cities, unserviced housing incidence and the number of unserviced houses in that medium-size city go down by 3.3% and 3.5%, respectively. Two reasons explain the different outcomes in the two scenarios. First, in a general equilibrium context, a single growing city attracts more migrants when no other city grows than when all cities grow. Second, when all cities grow, the national share of low income households goes down, and this mechanically reduces the demand for unserviced urban houses given the steep gradient referred to above.

I further use the estimated model to study the reallocation and welfare effects of slum repression and slum upgrading policies. An average city repressing slum growth by making the supply of unserviced houses 20% more expensive reduces slum incidence only by 1.5%. Since the average city size is small, slum repression in one city does not have significant effects outside the city. However, if all cities repress slums by making unserviced urban housing 20% more expensive everywhere, aggregate urbanization in 2010 goes down by 0.4% and low income households' welfare goes down 1.1%. I implement slum upgrading policies as cities targeting to turn 10% of their 1991 stock of unserviced houses into serviced ones.[3] I find that

[2]Several authors have documented how slums were common in today developed countries' cities and slums disappeared as countries developed. See for example World Bank (2009) and Glaeser (2012).

[3]Although I do not know of any systematic international measures of the magnitude of slum upgrading policies, survey evidence I processed for Brazil indicates around 50% of cities in my sample were doing some type of slum upgrading by the end of the 90's.

this improves the welfare of low income households by 4.0% and the welfare of high income households by 3.6%. Also, I find that this policy makes cities more attractive such that the 2010 aggregate urbanization rate becomes 1.1% higher.

This paper's methodological approach follows a recent set of works modeling households' location choices with a discrete choice model and featuring log-linear functions to characterize cities' housing supply side (Diamond, 2016; Serrato & Zidar, 2016). I take this literature a step forward by adding two types of houses and by solving for the general equilibrium of the estimated model for a set of counterfactuals.[4] The paper's empirical strategy uses 1991 and 2010 Census data on wages, housing rents, and population quantities for a set of 272 Brazilian cities. The main goal of this paper's empirical strategy is to identify the set of elasticities mentioned above. Empirically identifying these parameters suffers from the typical simultaneity problem of estimating supply and demand systems. I tackle this problem by building a set of moment conditions based on Bartik (1991) wage shocks and Card (2001) migration shocks, both computed separately for low and high income households. The Bartik wage shock computed for each type of household shifts the respective labor demand and then identifies how households respond to changes in cities' real wages (wages net of housing rents). In terms of identifying the responses of housing rents to housing demand shocks, Bartik wage shocks and Card migration shocks attract more people to cities, thus shifting cities' housing demand and identifying the two housing supply functions.[5]

This paper features several methodological improvements over the relatively scarce literature on the determinants of slum growth (World Bank, 2009; Brueckner & Selod, 2009; Feler & Henderson, 2011; Marx, Stoker & Suri, 2013; Alves, 2014; Castells-Quintana, 2016; Jedwab, Christiaensen & Gindelsky, 2016). First, this paper's empirical strategy exploits census data on housing quantities and rents for the universe of cities in a country with great spatial heterogeneity. This allows me to empirically study slum growth's determinants by looking

[4]For instance, although Diamond (2016) features a full general equilibrium model, her model does not have a closed form solution. Since there is a trade-off between writing down a more complex model and keeping a closed form solution for the model's equilibrium, my model's discrete choice structure is simpler than Diamond's.

[5]The exclusion restriction for these housing demand shifters requires that they affect housing rents only through housing quantities. This might not hold if these instrument affect for instance construction wages. I explicitly test for this and show that the two instruments do not affect local construction wages.

at how the relative evolution of cities' productivities leads to population reallocation across the space and across the housing quality dimension. Second, the paper features a general equilibrium methodology that looks into cities' dual housing markets, links them with what is happening in rural areas and in other cities, and is capable of aggregating city-level outcomes into national level urbanization and slum incidence statistics.

While there is a long tradition of urban studies adopting this spatial equilibrium perspective for the US system of cities (Rosen, 1979; Roback, 1982; Glaeser, 2008; Hsieh & Moretti, 2015; Diamond, 2016), no studies have used this approach to analyze slum growth in developing countries' systems of cities.[6] By looking at the local and national effects of city-level slum policies, this paper also contributes to the literature on the impacts of place based policies (Kline & Moretti, 2014a,b). While there is a broad literature on the effects of slum living conditions on slum residents (Field, 2007, 2005; Galiani & Schargrodsky, 2010; Galiani, Gertler, Undurraga, Cooper, Martínez & Ross, 2016; Kesztenbaum & Rosenthal, 2016), no study has looked at the spatial reallocation effects of slum policies.

The paper starts with a description of the data in Section 2. Section 3 presents evidence on Brazil's general context between 1991 and 2010, studies Brazilian households' spatial mobility, and looks at the empirical relationships between slum growth, wages, and rents. Section 4 introduces the spatial equilibrium model. Section 5 describes the paper's empirical methodology, discussing the main identification concerns and presenting the paper's identification strategy. Section 6 presents the estimation results and Section 7 solves for the general equilibrium of the model for a set of counterfactual scenarios. Section 8 concludes.

2 Data

This paper studies the 1991-2010 changes in the allocation of low and high income households across unserviced and serviced houses in 272 Brazilian cities and the countryside by looking

[6] A few recent studies use a spatial equilibrium approach to study developing countries' system of cities (Harari, 2015; Chauvin et al., 2016). Importantly, Chauvin et al. (2016) have recently provided evidence that using standard Rosen-Roback spatial equilibrium tools seems reasonable for the case of Brazil (not for India for instance).

at three main variables: population quantities, wages, and housing rents. In this section, I describe the construction of these variables. The paper's data come from my own processing of 1991 and 2010 Brazilian censuses' microdata.[7]

I adapt the UN's slum definition to the Brazilian context and data availability and define serviced houses as those with both proper water and sanitation services (UN, 2003). A house has proper water services if it is connected to the local water network, with connection inside the house. A house has proper sanitation services if it is connected to the local sewerage network or has a septic tank. I restrict the paper's relevant population to those households with working household heads between 14 and 70 years old. I compute average wages from household heads' earnings in their main occupation and average rents from self-declared monthly rents by renting households.[8] I express both wages and rents in constant 2010 prices.

I classify households into low and high income in order to capture Brazil's high income inequality and the stark differences in serviced housing consumption across the income distribution. Figure 1 plots the 1991 gradient between serviced housing consumption and wages and shows how the 75th percentile cutoff defines a rather homogeneous high income group in terms of serviced housing consumption. I then use the 75th percentile of the distribution of wages to classify households into low and high income.[9] The low unserviced housing incidence above the 75th percentile in Figure 1 makes the population share of high income households in unserviced houses in many cities too small to allow for any empirical study of its determinants.[10] I then assume throughout the paper that high income households only live in serviced houses.[11]

[7]The 1991 data is a 25% sample and the 2010 a 10% sample. Although Brazil has censuses approximately every 10 years, I do not use the 2000 census because it does not have data on housing rents.

[8]Because the data are samples of the total population, average rents by type of housing get noisy as the number of renting households with or without services in some small municipalities gets very small. For instance, 34 cities have less than 30 observations of renting households without services in 1991 and 63 in 2010. 36 cities have less than 30 observations of renting households with services in 1991 and 6 in 2010.

[9]This 75th percentile corresponds to a gross monthly wage of 1,140 Reais measured in 2010 prices, approximately 650 US dollars.

[10]For instance, the median share of high income households in unserviced houses in a given city (with respect to the national population of high income households) is 0.0085%.

[11]Besides the empirical reasoning behind this assumption, a more conceptual reason is that, given the high prevailing inequality, those high income households living in unserviced houses probably have ways of effectively dealing with the disamenities of unserviced houses.

My urban universe consists of 272 cities and it is formed by Brazil's 66 official metro areas plus those municipalities that are not part of any metro area but had an urban population of at least 50,000 people in 2010.[12] Figure 2 presents a map with the location of the 272 cities. Throughout the paper, I refer to those 272 cities as Brazil's urban areas and to everything else outside those cities as a homogeneous rural area.[13] Because Brazilian municipalities' borders changed during this period, I use Ipums constant geographies to get spatial definitions which are coherent over time.

I use two additional pieces of data from Brazilian censuses to construct the set of instrumental variables. First, I construct a 1991-2010 compatible classification of 169 industries for household heads' main occupation to build the Bartik instrument (Bartik, 1991). Second, I use household heads' municipality of residence five years before each census to compute the migration instrument based on Card (2001).

3 Background

As noted in the Introduction, this paper uses a spatial equilibrium approach to study slum growth, with cities' wages and housing rents playing a central role in understanding slum dynamics. This section starts by describing the general economic context of Brazil between 1991 and 2010 and then turns to presenting evidence on two key aspects supporting the paper's methodological approach. First, I look at evidence of households' spatial mobility and check if some basic implications of spatial equilibrium theory hold for Brazil's system of cities.[14] Second, I explore the role of wages and housing rents for understanding unserviced housing growth in Brazil.

[12] Metro areas in Brazil are defined as a set of municipalities. I take the 2010 definition of metro areas. Municipalities include rural and urban population. I then further use the censuses' classification of households as urban or rural to identify the urban population within each municipality. The criteria described above yields a total of 278 cities. I lose 6 cities that do not have any observation for serviced housing rents in 1991. I remove those 6 cities from the sample.

[13] For instance, the rural population includes households living in municipalities not included in any official metro area and with an urban population less than 50,000 in 2010 and households living in rural areas within the municipalities belonging to some metro area or having more than 50,000 people in 2010.

[14] This aspect has been recently explored by Chauvin, Glaeser, Ma & Tobio (2016).

3.1 Brazil between 1991 and 2010

Brazil is an early urbanizer by the historical standards of today's developed countries (Chauvin, Glaeser, Ma & Tobio, 2016). This feature, shared by most Latin American countries, is well illustrated by Brazil being today more urbanized than the US, although Brazil has less than half of US per capita GDP. Table 1 presents some basic descriptive statistics for Brazil between 1991 and 2010. The general picture is of moderate but generalized progress: per capita GDP grew 41%, inequality measured by the Gini index went down slightly by 3 points, and typical welfare indicators such as infant mortality and illiteracy improved notably.[15] The number of urban households without basic water and sanitation in Table 1 grew from 5.3 million in 1991 to 5.7 million in 2010. This growth was well below the growth in the total urban population, leading to a reduction in the share of urban unserviced houses, which fell from 32.7% to 23.4%.

The lower half of Table 1 shows population and wage growth rates for low and high income households. Average wages grew more for the low than for the high income group between 1991 and 2010. As a result, many low income households crossed the income threshold and made the high income group grow by 56.9%, compared to 11.8% for the low income group. Given the steep gradient between serviced housing consumption and income in Figure 1, these changes in households' composition by income play a key role in explaining the observed reduction in unserviced housing incidence in Brazil.

Brazil's economy experienced two big productive shocks between 1991 and 2010: trade liberalization in the 1990 and the commodities boom in the 2000.[16] These two shocks impacted the allocation of resources both across industries and across the space, favoring the expansion of cities close to the agricultural frontier in the Midwest and North regions of the

[15] Successful macroeconomic stabilization plans in the 1990 coupled with the expansion of public education, public health, and monetary transfers are usually identified as the main drivers of the improvement in Brazil's welfare indicators in this period (Lustig, Lopez-Calva & Ortiz-Juarez, 2013).

[16] In the early 1990 the Brazilian economy went through a process of commercial liberalization that brought down tariffs differentially for different economic sectors, with manufacturing in particular facing big cuts in commercial protection. A set of works have studied the spatially heterogeneous impacts of this opening process on local economies' wage and employment growth (Kovak, 2013; Dix-Carneiro, 2014; Dix-Carneiro & Kovak, 2015). The commodity boom of the late 2000 reinforced the 'pro-primary sector' impact of 1990 trade liberalization policies.

country, as well as of a few other cities scattered around the country linked to mineral and oil extraction. Figure 2 allows for a full visualization of this spatial variation with a heat map of Brazilian cities' population growth rates. The map shows high growth rates for cities close to the west and northern borders of the country as well as high variation in growth rates within all regions. In order to better appreciate the magnitudes of these growth rates, Figure 3 plots them on a histogram. The histogram shows great heterogeneity in cities' population dynamics, with a few cities keeping their size roughly constant and several cities more than doubling their size. The positive urban growth rates in Figure 3 contrast heavily with the slightly below-zero growth rate in the number of rural working households (vertical red line to the left in the graph).

3.2 Households' spatial mobility

A key element of the paper's methodological approach is to use spatial equilibrium tools to study slum growth in Brazil's system of cities. Chauvin, Glaeser, Ma & Tobio (2016) have recently put together several pieces of data to argue that standard spatial equilibrium tools are relevant for Brazil. A first point these authors make is that Brazil's migration data depicts a country with high internal mobility.[17] Table 2 looks at this by showing that more than half of household heads living in cities in 2010 were not born in the municipality where they currently live.[18] Table 2 also shows that although most migrant household heads were born in rural areas, around 10% of them came from another city. This last fact points to the relevance of population flows between cities to explain cities' growth.

A second sign of spatial equilibrium being relevant is that wage and rent growth are positively correlated. This is a point that Chauvin et al. (2016) also make and refers to the classic Rosen-Roback idea that cities with higher wages must exhibit higher housing rents such that households remain indifferent between cities. Figure 4 plots 1991-2010 average wage and rent growth for the 272 cities and shows a strong positive correlation of 0.54.[19]

[17] In contrast, international migration is relatively limited.

[18] This ratio is a bit higher for households in unserviced houses than for serviced ones.

[19] Chauvin et al (2016) look at this correlation in the cross section. I am looking at it in terms of growth rates.

3.3 Slum growth, wages, and rents

Wages and housing rents are the two main pecuniary incentives that households face when choosing where to live and as such they play a central role in the formal framework of this paper. Figure 5 looks at the empirical relationships between slum growth, wages, and rents by plotting unserviced housing growth rates against average wage and average rent growth. Noteworthy in Figure 5 is that there is great variation in cities' unserviced housing growth rates, wage growth rates, and rent growth rates. This variation is essential for empirically disentangling the determinants of slum growth.

Figure 5 also shows strong positive correlations of unserviced housing growth with both wage and rent growth. I further explore these correlations by running OLS regressions of cities' unserviced housing growth on wage and rent growth. Regression results in Table 3 show that the positive correlations between unserviced housing growth and wage and rent growth are strong and robust to a set of controls. These correlations fit two common narratives in the urbanization literature. First, the strong correlation between wages and slum growth goes in hand with the idea that slum growth takes place in booming cities. When cities grow, they attract low income migrants who put pressure on cities' housing markets, housing becomes more expensive, and migrants end up in slums. This paper's conceptual framework formalizes this narrative by modeling how households' location decisions respond to changes in cities' wages and housing rents and how cities' housing rents respond to housing demand shocks.

The correlation between slum growth and rent growth goes in hand with the narrative on the relevance of housing affordability for households' housing quality choices. In Table 3, the positive correlation between average rents and slum growth goes down in magnitude after conditioning on wages but still remains solid. This suggests that the pattern described in the previous paragraph regarding growing wages causing higher housing demand, higher rents, and higher slum incidence is part but not all of the story. In particular, I show in the paper that policies impacting housing rents by operating on cities' housing supply-side have potential to alter households' housing choices and thus affect slum growth, urbanization, and welfare.

4 Conceptual framework

This section presents the paper's formal structure to study slum growth in a system of cities. The model serves three main purposes. First, it provides a set of estimatable equations characterizing households' location decisions and cities' housing supply capacities. Second, it allows for a formal discussion of those equations' main identification concerns and how the paper's identification strategy deals with them. Third, the model features a closed form solution, which allows to study the general equilibrium effects of a set of counterfactuals on changes in households' spatial allocation and welfare between 1991 and 2010.

The basic structure of the model follows the recent work by Diamond (2016) with the key extension of allowing for general equilibrium computation. In the model, households' location decisions follow a discrete choice multinomial logit formulation in the spirit of McFadden (1973).[20] These decisions depend on observed wages and rents and on unobserved type-of-house and city amenities. The model's housing supply side features a specific housing supply function for each type of house. Cities' production sector features two infinitely elastic housing demands with low and high income households' wages following city-specific productivity shocks. The model is static and I interpret it as capturing the long run equilibrium of Brazil's system of cities. In particular, I take the model to the data by assuming that 1991 and 2010 are two different long run equilibria of the model.

4.1 Households' location decisions

Each household i is either of low L or high H income. In order to simplify the exposition, I first present the location decision problem for a generic household and then indicate which aspects of that problem differ between low and high income households.

At each time t, a fixed number of households $\overline{N}_t$ choose to live in serviced or unserviced housing $m \in \{u, s\}$ at some city j or in the countryside c. Denote this set of alternatives as O. At each specific location choice, households maximize a Cobb Douglas utility defined over

[20] A series of recent works have used discrete choice multinomial structures to model households' location choices in system of cities Serrato & Zidar (2016); Morten & Oliveira (2016); Diamond (2016).

a composite non-housing good X, housing Z_m, and a city and type of house specific amenity A_{imjt}. Households face a budget constraint given by wages W_{jt}, housing rents P_{mjt}, and by the price of the non-housing good being normalized to 1. The maximization problem for each location is then:

$$\begin{aligned} \max_{Z_m, X} \quad & \alpha_m \ln Z_m + (1 - \alpha_m) \ln X + \ln A_{imjt} \\ s.t. \; & P_{mjt} Z_m + X = W_{jt} \end{aligned} \tag{1}$$

With lower case denoting variables in logarithms, the log-indirect utility function v_{imjt} for a household i from location choice m, j is:

$$v_{imjt} = w_{jt} - \alpha_m p_{mjt} + a_{imjt} \tag{2}$$

Households choose the type of house and city with the highest indirect utility. Since only differences in indirect utility between alternatives matter for households' location choices, I normalize indirect utility in the countryside to zero.

City and type of house amenities a_{imjt} have a component common to all households $\bar{a}_{mjt}$ and a household-specific shock ε_{imjt} such that $a_{imjt} = \bar{a}_{mjt} + \varepsilon_{imjt}$. The ε_{imjt} term is distributed iid type I Extreme Value with dispersion parameter σ. This dispersion parameter measures how much real wages and amenities matter for households' location decisions. For instance, high dispersion in idiosyncratic preferences implies that households do not react much to changes in wages and housing rents.

Define the component of the indirect utility that is common to all households as $\bar{v}_{mjt}$, such that $v_{imjt} = \bar{v}_{mjt} + \varepsilon_{imjt}$. Then, the number of households N_{mjt} in type of house m and city j at time t is:

$$N_{mjt} = P(v_{imjt} = \max_O \{v_{imjt}\}) = \sum_{i \in \overline{N}_t} \frac{exp(\bar{v}_{mjt}/\sigma)}{\sum_O exp(\bar{v}_{mjt}/\sigma)} \tag{3}$$

Low and high income households largely share this common choice structure but differ in two things. First, as explained in Section 3, I assume that high income households do not live in unserviced houses. Then, their choice set O^H consists only of urban serviced houses or the countryside. Second, low and high income households may have different population sizes $\overline{N}^L, \overline{N}^H$, taste parameters $\alpha_m^L, \alpha_s^H, \sigma^L, \sigma^H$, earn different wages w_{jt}^L, w_{jt}^H, and have different values for type of house and city amenities $\bar{a}_{mjt}^L, \bar{a}_{sjt}^H$.

4.2 Production

I model cities' labor demand side following Moretti (2011). Two types of firms operate in perfectly competitive factor and output markets. Their production technology is characterized by a constant return to scale Cobb-Douglas production function, with a city-specific productivity term and labor and capital as inputs. One type of firm uses only low income labor and the other type of firm uses only high income labor. The Cobb-Douglas' labor shares for each of the two types of firms are β^L, β^H and the city-specific productivities are $\theta_{jt}^L, \theta_{jt}^H$. The supply of capital is infinitely elastic at a national interest rate i_t and the output prices P_t^L, P_t^H are exogenous and set at the national level.

Under those assumptions, profit maximization yields a perfectly elastic labor demand for each type of household in each city such that wages are a function of city-specific productivities and a constant C_t. This constant term captures national level factors, including the national interest rate and output prices. The labor demand expressed in logarithms is:

$$w_{jt}^L = C_t^L + \frac{1}{\beta^L}\theta_{jt}^L \tag{4}$$

$$w_{jt}^H = C_t^H + \frac{1}{\beta^H}\theta_{jt}^H \tag{5}$$

The assumptions above then imply that L and H types face completely separate labor markets. This rather extreme assumption could be reasonable for the context of extreme inequality of Brazilian cities. For instance, the correlation between both types of households' wage growth between 1991 and 2010 is -0.05.

4.3 Housing Market

Competitive firms produce the two types of housing such that the price of each type of house equals its marginal cost. Housing costs have two components: land and construction costs. Land costs LC_{mjt} increase with the amount of each type of housing being supplied Z^S_{mjt}. I allow the land cost gradient dLC_{mjt}/dZ^S_{mjt} to differ between serviced and unserviced houses and assume that all housing rents go to absentee landlords. Construction costs C_{mjt} might also differ between types of houses. I parametrize the corresponding inverse housing supply function for each type of house as:

$$\ln P_{mjt} = \gamma_h \ln Z^S_{mjt} + \ln C_{mjt} \tag{6}$$

The demand for each type of housing in each city Z^D_{mjt} depends on how many households decide to live in each city and type of house (extensive margin), and on how much housing each household consumes (intensive margin). The extensive margin is given by the number of households choosing each city and type of house (Equation 3), and the intensive margin comes from households' Cobb-Douglas optimization problem above. Therefore, the two housing demands are:

$$Z^D_{ujt} = N^L_{ujt} \frac{\alpha^L_u W^L_{jt}}{P_{ujt}} \tag{7}$$

$$Z^D_{sjt} = N^L_{sjt} \frac{\alpha^L_s W^L_{jt}}{P_{sjt}} + N^H_{sjt} \frac{\alpha^H_s W^H_{jt}}{P_{sjt}} \tag{8}$$

4.4 Equilibrium

The system of cities' equilibrium is an allocation of the country's population between types of houses in cities and the countryside $(N^{*L}_{mjt}, N^{*L}_{ct}, N^{*H}_{sjt}, N^{*H}_{ct})$ and a vector of housing rents and wages $(P^*_{ujt}, P^*_{sjt}, W^{*L}_{jt}, W^{*H}_{jt})$, such that each city's labor and housing markets are in equilibrium and all households live somewhere.

Formally, the labor supply by each type of household is given by Equation 3. These labor supplies must equal the respective labor demands defined by Equations 4 and 5 in each city:

$$N_{mjt}^{*L} = \sum_{i \in \overline{N}_t^L} \frac{exp((w_{jt}^{*L} - \alpha_m^L p_{mjt}^* + \bar{a}_{mjt}^L)/\sigma^L)}{\sum_{O^L} exp((w_{jt}^{*L} - \alpha_m^L p_{mjt}^* + \bar{a}_{mjt}^L)/\sigma^L)} \tag{9}$$

$$N_{sjt}^{*H} = \sum_{i \in \overline{N}_t^H} \frac{exp((w_{jt}^{*H} - \alpha_s^H p_{sjt}^* + \bar{a}_{sjt}^H)/\sigma^H)}{\sum_{O^H} exp((w_{jt}^{*H} - \alpha_s^H p_{sjt}^* + \bar{a}_{sjt}^H)/\sigma^H)} \tag{10}$$

$$w_{jt}^{*L} = C_t^L + \frac{1}{\beta^L}\theta_{jt}^L \tag{11}$$

$$w_{jt}^{*H} = C_t^H + \frac{1}{\beta^H}\theta_{jt}^H \tag{12}$$

Also, the housing supplies for each type of house and city must equal the respective housing demands:

$$\ln P_{mjt}^* = \gamma_m \ln Z_{mjt}^{*D} + \ln C_{mjt}, \tag{13}$$

$$Z_{ujt}^{*D} = N_{ujt}^{*L} \frac{\alpha_u^L W_{jt}^{*L}}{P_{ujt}^*} \tag{14}$$

$$Z_{sjt}^{*D} = N_{sjt}^{*L} \frac{\alpha_s^L W_{jt}^{*L}}{P_{sjt}^*} + N_{sjt}^{*H} \frac{\alpha_s^H W_{jt}^{*H}}{P_{sjt}^*} \tag{15}$$

Finally, all households must live somewhere:

$$N_{ct}^{*L} + \sum_{O^L} N_{mjt}^{*L} = \overline{N}_t^L \tag{16}$$

$$N_{ct}^{*H} + \sum_{O^H} N_{sjt}^{*H} = \overline{N}_t^H \tag{17}$$

The equilibrium defined by Equations 9 to 17 is non-linear and does not feature a closed form solution. In order to study the general equilibrium effects of changes in slum policies and economic fundamentals, in Section 7, I solve for a first differences' version of the model, which does feature a closed form solution.

5 Estimation strategy

In this section I describe how I estimate the set of structural parameters $(\sigma^H, \sigma^L, \gamma_U, \gamma_S)$. This estimation, together with calibration of the housing expenditure shares' parameters (α_m^L, α_s^H), fully characterize the model's parameters.

Divide the set of estimating equations in two groups. The first group of equations estimates σ^L and σ^H by running linear regressions of cities' population growth rates for each type of house and type of household on changes in cities' real wages. I follow Berry (1994) to derive these regression equations from the discrete choice problem above. The second group of equations estimates the parameters γ_U and γ_S by regressing, for each type of house, changes in housing rents on changes in the respective housing demands.

Estimating the set of parameters above suffers from the typical simultaneity problem of estimating supply and demand systems. I start this section by deriving the estimating equations and discussing the endogeneity concerns. In the second part of the section, I present the set of instrumental variables dealing with those concerns and discuss the corresponding identification assumptions.

5.1 Location decision equations

The estimation strategy to identify the σ^L and σ^H parameters follows Berry (1994). Berry showed how to estimate the discrete choice problem above with linear regressions of cities' population quantities on all the components of the log indirect utility function except for the extreme value term, which is integrated out. In order to see how Berry's procedure works, start by taking logs on both sides of Equation 3:

$$\ln N_{mjt} = \bar{v}_{mjt}/\sigma - \ln \sum_{O} exp(\bar{v}_{mjt}/\sigma) \tag{18}$$

By noting that the indirect utility of the outside option c has been normalized to zero and by doing some simple algebra, the difference between the log population of mj and c is:

$$\ln N_{mjt} - \ln N_{ct} = \bar{v}_{mjt}/\sigma \tag{19}$$

The next step consists in applying the first time differences operator Δ to both sides of Equation 19 and substituting the $\bar{v}_{mjt}$ term by its components, which differ between L and H types. Taking the Δn_c term to the RHS yields the following two linear regression equations, one for each type of household:

$$\Delta n^L_{mj} = \Delta n^L_c + \frac{1}{\sigma^L}(\Delta w^L_j - \alpha^L_m \Delta p_{mj} + \Delta \bar{a}^L_{mj}) \tag{20}$$

$$\Delta n^H_{sj} = \Delta n^H_c + \frac{1}{\sigma^H}(\Delta w^H_j - \alpha^H_s \Delta p_{sj} + \Delta \bar{a}^H_{sj}) \tag{21}$$

In these two equations, I observe population quantities, wages, and housing rents, and I do not observe amenities.[21] As I said above, I calibrate the housing expenditure parameters α^L_m, α^H_m. Then, estimating the two equations consists in regressing population growth on real

[21]Note that the first RHS term is population growth in rural areas. This term does not vary across observations and thus is part of the regressions' constant.

wage growth, with unobserved amenities being the error term.[22]

Because changes in unobserved amenities affect equilibrium housing rents in the model, any OLS estimate of σ^L and σ^H in Equations 20 and 21 would be biased.[23] In order to get consistent estimates, I need an instrument which impacts each type of household's real wages and is not correlated with changes in unobserved amenities.

5.2 Housing Supply equations

The two regression equations for estimating γ_U, γ_S come from expressing in first time differences the housing market equilibrium Equation 13 for each type of house $m \in \{u, s\}$:

$$\Delta p_{uj} = \gamma_u \Delta z_{uj} + \Delta c_{uj}, \tag{22}$$

$$\Delta p_{sj} = \gamma_s \Delta z_{sj} + \Delta c_{sj}, \tag{23}$$

In these two equations I observe growth in rents and all the components of housing demand growth.[24] The growth in construction costs is unobserved and makes the residual of the two regression equations. The simultaneity problem in Equations 22 and 23 is given by construction costs affecting equilibrium housing demand according to the model.[25] Then, any OLS estimates of γ_U and γ_S would be biased. Consistent estimation of these two (inverse) housing supply equations needs housing demand shifters to overcome the simultaneity problem. I need an instrument affecting cities' housing demands and this instrument must be uncorrelated with unobserved changes in construction costs.

[22]Note that the unit of observation in both equation is the location alternative. These are type of house-city combinations for low income households and cities for high income households.

[23]Intuitively, changes in amenities affect the extensive margin of housing demand, and higher demand causes higher housing rents (assuming the housing supplies are not perfectly elastic).

[24]See Equations 14 and 15 for the definition of cities' housing demands for each type of house.

[25]Intuitively, higher construction costs mean higher housing rents, and higher housing rents imply lower housing demand.

5.3 Instruments

5.3.1 Bartik Wage Instruments

Bartik (1991) wage instruments predict cities' wage growth by interacting 1991-2010 national wage growth rates by industry with cities' 1991 industrial employment composition. I compute three versions of this instrument: one for low income workers ΔB_j^L, one for high income workers ΔB_j^H, and one considering all workers in each city ΔB_j. These Bartik wage instruments fit the conceptual framework outlined in Section 4 by acting as proxies for changes in the local productivity shocks $\theta_{jt}^L, \theta_{jt}^H$ in Equations 4 and 5 (Bartik, 1991; Bound & Holzer, 2000; Notowidigdo, 2011; Diamond, 2016).

Formally, let $W_{ind,j,t}$ denote the average wage paid by industry ind in city j at time t and $W_{ind,-j,t}$ denote the average wage paid by that industry in all other cities except j. With these definitions in mind, the three Bartik instruments are:

$$\Delta B_j = \sum_{ind} (\ln W_{ind,-j,2010} - \ln W_{ind,-j,1991}) \frac{N_{ind,j,1991}}{N_{j,1991}} \tag{24}$$

$$\Delta B_j^L = \sum_{ind} (\ln W_{ind,-j,2010}^L - \ln W_{ind,-j,1991}^L) \frac{N_{ind,j,1991}^L}{N_{j,1991}^L} \tag{25}$$

$$\Delta B_j^H = \sum_{ind} (\ln W_{ind,-j,2010}^H - \ln W_{ind,-j,1991}^H) \frac{N_{ind,j,1991}^H}{N_{j,1991}^H} \tag{26}$$

Note that when computing the Bartik wage for a given city, national average wage growth rates by industry do not include wage growth in that city. Otherwise, local shocks affecting labor supply in a city could trivially affect the instruments and invalidate their interpretation as proxies for changes in local labor demand.

In Table 4, I regress actual wage growth on Bartik wages for each type of household. The first two columns show that each type of household's Bartik wage does a good job predicting actual wage growth for the same type of household but not for the other type of household.

This is additional evidence in favor of the assumption on labor markets for low and high types being fairly independent.

I first use the Bartik wages to instrument for changes in real wages in Equations 20 and 21. Specifically, I use low income households' Bartik wage to instrument for changes in low income households' real wages and high income households' Bartik wage to instrument for changes in high income households' real wages.[26] The identification assumption is that Bartik shocks are uncorrelated with changes in local amenities and then the corresponding moment conditions are:

$$E(\Delta B_j^L \Delta \bar{a}_{mj}^L) = 0$$

$$E(\Delta B_j^H \Delta \bar{a}_{sj}^H) = 0,$$

In the spatial equilibrium model above, changes in cities' productivities increase wages and wages bring more people to cities. Then, if Bartik instruments are good proxies for changes in cities' productivities, they affect cities' housing demands by bringing more people into cities. Based on these analytical relationships implied by the model, I specifically use the average Bartik wage shock as a housing demand shifter to identify the unserviced supply Equation 22.[27] The corresponding exclusion restriction states that the average Bartik instrument must be uncorrelated with the growth in unobserved construction costs:

$$E(\Delta B_j \Delta c_{uj}) = 0$$

A natural concern about using the Bartik instrument to identify a housing supply equation is that any instrument affecting wages might affect construction costs through its impact on construction wages. If this happened, then the exclusion restriction for the instrument would

[26]As I discussed before, I associate the Bartik shocks with the productivity shocks $(\Delta\theta_j^L, \Delta\theta_j^H)$ and then the first stage for this instrument is defined by first time differences versions of Equations 4 and 5.

[27]In principle, I could use Bartik instruments to identify the serviced housing equation also. The specific choice has to do with the empirical relevance of each instrument for predicting changes in housing demand.

be violated. I do two things to deal with this concern. First, when using the average Bartik shock to identify the unserviced housing supply equation, I compute the instrument without considering construction workers' wages. Second, in Table 5, I show that the Bartik shock computed without considering construction workers does not affect construction wages.

5.3.2 Migration Instruments

The migration instrument proposed by Card (2001) is based on the evidence that migration networks matter for migration decisions and thus previous migration flows can be used to predict future flows.[28]

Denote the number of migrants from origin k to destiny j at time t as $M_{k,j,t}$ and the number of migrants from origin k to destinies other than j as $M_{k,-j,t}$. Then, the idea behind the instrument is that $M_{k,j,t}$ is affected by migration influxes from k to j which occurred before t. For instance, if a given city j had a big share of migrants from a given origin k in 1991 and that origin is, for whatever reason, generating substantial out-migration between 1991 and 2010, then the city j will get a positive migration shock.

Analytically, defining the set of all possible origins as K and the set of all possible destinies as J (i.e. the 272 cities in the sample), the pair of instruments $(\Delta M_j^L, \Delta M_j^H)$ is:[29]

$$\Delta M_j^L = \ln\left(\sum_{k\in K} M^L_{k,-j,2010}\frac{M_{k,j,1991}}{\sum_{j\in J} M_{k,j,1991}}\right) - \ln\sum_{k\in K} M^L_{k,j,1991} \tag{27}$$

$$\Delta M_j^H = \ln\left(\sum_{k\in K} M^H_{k,-j,2010}\frac{M_{k,j,1991}}{\sum_{j\in J} M_{k,j,1991}}\right) - \ln\sum_{k\in K} M^H_{k,j,1991} \tag{28}$$

The instrument then uses the 1991 distribution of migrants by place of origin and destiny

[28] See for example Munshi (2003).

[29] Following Card (2001) the relevant migrant share is not skill specific (note that the quotient does not have L, H notation) based on the intuition that migration networks matter across income groups.

and the total outflow of migrants by place of origin in 2010 to predict the 2010 number of migrants for each destiny j.[30] Note that this procedure excludes flows from k to j when computing the total out-migration flows used to predict the 2010 number of migrants in j. I do this to prevent local labor market conditions from affecting the instrument.

In terms of the identification strategy of the paper, these migration shocks bring more people to cities and thus increase the demand for houses. Specifically, I use the migration shock for high income households ΔM_j^H to predict growth in serviced housing demand and identify Equation 23. Column 4 of Table 4 regresses serviced houses' growth on ΔM_j^H and shows a positive first stage relationship. The corresponding moment restriction states that these migration shocks are uncorrelated with unobserved changes in construction costs of serviced houses:

$$E(\Delta M_j^H \Delta c_{sj}) = 0$$

As I discussed for Bartik shocks, a natural concern about the exclusion restriction for this instrument is that migration shocks might affect wages and wages affect construction costs. To check that this is not the case, in Table 5, I run changes in construction wages against migration shocks and show that there is no correlation.

5.4 Estimation summary

Summarizing the discussion above, the estimation strategy consists in running IV regressions for Equations 20, 21, 22, and 23 in order to obtain consistent estimates for the set of structural parameters $(\sigma^L, \sigma^H, \gamma_u, \gamma_s)$. All the estimating equations feature one endogenous variable and one instrument and are thus exactly identified. Note that all the regression errors have a structural interpretation in the context of the model. Then, regression errors are also inputs for the general equilibrium computation in Section 7.

[30] Based on the available migration data in the 1991 and 2010 Brazilian censuses, I define the set of origins K as the municipality of residence 5 years before each census.

6 Estimates

Table 6 presents the 2SLS regression results for the four estimating equations. The first column estimates Equation 20 by running low income households' population growth on real wage growth and identifies the parameter σ^L. The point estimate $1/\hat{\sigma}^L = 1.67$ gives a picture of highly mobile households, which goes in hand with the evidence on households' spatial mobility in Section 3.[31]

Multiplying $1/\hat{\sigma}^L$ by the calibrated housing expenditure shares ($\alpha_U^L, \alpha_S^L = 0.25, 0.30$) yields low income households' elasticity with respect to housing rents for each type of house.[32] The coefficients obtained by that procedure imply that a 1% increase in unserviced housing rents reduces the number of low income households demanding unserviced houses by 0.4%, and a 1% increase in serviced housing rents reduces the number of low income households demanding serviced houses by 0.5%.

High income households' reaction to real wages, given by $1/\hat{\sigma}^H$ in Column 2, is much noisier and seems smaller in magnitude. The small magnitude of the point estimate is coherent with high income households' urbanization rate being very high already (83% compared to 64% for low income households), which limits their rural-urban migration margin. The calibrated housing consumption share for high income households α_S^H is 0.16. Therefore, high income households' response to housing rents' shocks given by $\alpha_S^H/\hat{\sigma}^H$ is very small.

Columns 3 and 4 in Table 6 show estimates for $\hat{\gamma}^U$ and $\hat{\gamma}^S$. 2SLS regression estimates show two positively sloped housing supplies, with unserviced housing rents reacting much less to housing demand shocks than serviced housing ones. For instance, a 1% increase in the demand for unserviced housing leads to less than 0.1% higher unserviced housing rents. The same increase in the demand for serviced housing leads to 0.4% higher serviced housing rents.

In terms of external validation of these housing supply-side estimates, my serviced housing

[31] Note that this estimate does not give yet the equilibrium effect of higher wages because it does not account for the effect of increased housing demand on housing rents and for the impact of changing housing rents on households' housing demand.

[32] Although I will be referring generically to estimated parameters as 'elasticities', keep in mind that in the context of the underlying multinomial logit, parameters should be interpreted as elasticities for "small" cities. For instance, given the log-linear indirect utility function, the wage elasticity for choice mj is $(1-N_{mj})*1/\sigma^L$.

(inverse) supply elasticity is similar to the 0.47 elasticity reported by Saiz (2010) for (serviced) housing in the US.[33] Moreover, the fact on unserviced housing supply being relatively more elastic than serviced one has been one of the usual suspects in the urbanization literature when trying to explain why economic dynamism leads to slum growth (UN, 2003). This is, to my best knowledge, the first empirical study confirming this hypothesis.

7 General Equilibrium and Counterfactuals

In this section, I solve for the 1991-2010 changes in the general equilibrium of Brazil's system of cities for a set of different scenarios. This exercise will yield the population reallocation and welfare effects of changes in slum policies and economic fundamentals. In particular, the general equilibrium framework will allow me to compare the effects of these changes when they take place in only a few cities versus when they take place in all cities.

7.1 Benchmark General Equilibrium

Solving for the 1991-2010 changes in the general equilibrium of the model implies finding the population and rent growth rates in each type of house and city such that two conditions hold. First, the growth in housing supply must equal the growth in housing demand in all housing markets. Second, for each type of household, the weighted sum of population growth rates in all cities and the countryside must add up to the national population growth rate.

The general equilibrium computation takes as inputs the point estimates for the set of structural parameters $(\sigma^L, \sigma^H, \gamma_u, \gamma_s)$, the calibrated structural parameters $(\alpha_u^L, \alpha_s^L, \alpha_s^H)$, the set of regression residuals $(\Delta\bar{a}_{uj}^L, \Delta\bar{a}_{sj}^L, \Delta\bar{a}_{sj}^H, \Delta c_{uj}, \Delta c_{sj})$, and a set of exogenous variables from the data $(\Delta w_j^L, \Delta w_j^H, \Delta\overline{n}^L, \Delta\overline{n}^H)$. These elements fully characterize the set of linear equations of the model expressed in first time differences. The set of linear equilibrium

[33] The unserviced housing estimate could be interpreted as coherent with the recent finding by Henderson, Venables, Regan & Samsonov (2016) that slum housing rents in Nairobi do not decreasing with distance from the central business district. This gradient is the typical microfoundation for upward sloping housing supplies in the Alonso-Mills-Muth urban model (Fujita, 1989).

equations are the four equations estimated above plus two equations guaranteeing that the weighted sum of local population growth rates adds up to national exogenous population growth.[34] The resulting system of equations is fully linear and has the same number of equations as endogenous variables. The system's endogenous variables are the population growth rates $\Delta n^L_{mj}, \Delta n^L_c, \Delta n^H_{sj}, \Delta n^H_c$ and the housing rent growth rates Δp_{mjt}.

Table 7 presents some aggregate statistics for the system of cities for the actual data and for a set of simulated equilibrium scenarios. The table summarizes the system's endogenous variables by showing Brazil's aggregate urbanization rate and unserviced urban housing share in 2010 as well as the unserviced and serviced average rent growth between 1991 and 2010.[35] Columns 1 and 2 display the actual values of those variables in the data for 1991 and 2010, Column 3 shows how well the model's equilibrium replicates the data for 2010, and the remaining columns show the statistics for 2010 for a few counterfactual scenarios. The upper part of Table 7 describes which are the exogenous drivers of the model characterizing each of the counterfactual scenarios.

A quick look at Table 7 gives some insights on the reasons behind the changes observed between 1991 and 2010 in Brazil's urbanization and unserviced housing incidence. A first thing to note is that despite Brazil's relatively high level of urbanization, almost half of low income households lived outside of the sample of 272 cities in 1991. This leaves ample space for substantial reallocations of households across the system of cities. Given low income households' highly elastic responses to urban wage growth estimated above, growing urban wages are then part of the explanation for the growth in urbanization observed between 1991 and 2010.

Section 3 established that this was a period of "pro-poor" economic growth in Brazil, with incomes improving both for low and high income households but much more for the former

[34] Note that the linear decomposition of a growth rate into a weighted sum of its components is exact for the exponential growth rates but not for log-growth rates. I then rely on the approximation between log and exponential growth rates to linearize the two national-level equations as well as each serviced housing market equation.

[35] Here I define urbanization as the share of households in my sample of 272 cities. These urbanization rates differ from the official ones which I reported in Table 1. This discrepancy results from official urbanization rates considering small towns as urban and this paper considering urban only those municipalities with at least 50,000 people in 2010.

than for the latter. This trend in the level and dispersion of incomes led to changes in the composition of the population between low and high income households. Specifically, there was a ten point shift in the national population share of high income households. In the context of the model above, this population change mechanically reduces the share of urban residents in unserviced houses.

Column 3, in Table 7, presents the model's general equilibrium computed for the actual values of the exogenous parameters. The model does well in matching the four (endogenous) aggregate statistics in Table 7. The goodness of fit of the model is further illustrated by Figure 6, which plots the actual versus the predicted values for the three endogenous population growth variables: low income households in urban unserviced houses, low income households in serviced houses, and high income households in serviced houses.

7.2 Slum Growth and Cities' Economic Dynamism

The first counterfactual exercise looks at the mechanics of urban economic growth and slum growth in developing countries' system of cities. By looking at the long-run historical trajectories of today's developed countries' cities, a series of authors have noted that slum incidence disappears in the long run as countries become richer (World Bank, 2009; Glaeser, 2012). This seems to hold true for Brazil between 1991 and 2010. As noted in Section 3, in this period Brazil's per capita GDP grew by 41% and unserviced housing incidence went down from 28% to 18% (Table 7).

In order to see how cities' economic growth affects slum incidence in the context of the model, I simulate an extra wage increase of 20% for both types of households in all cities. This type of shock has two main effects in the context of the model. First, higher wages bring more low income households to cities (elasticity of 1.7). These migration flows imply higher housing demand and thus make both housing rents grow. In particular, given the elasticities estimated above, serviced rents grow much more (0.4) than unserviced ones (0.1). Also, because serviced houses are more expensive, changes in serviced housing rents impact low income households' housing demand more than changes in unserviced housing rents. These housing demand and supply mechanics define a first effect of higher wages, which pushes unserviced housing incidence upwards. The second effect operates in the opposite direction. When all wages grow by an extra 20%, the 2010 share of high income households goes up 35.4% to 45.5%. Since high income households' unserviced housing incidence is very low, this change in the population's composition mechanically pushes slum incidence downwards.

In order to quantify the role of each of these two opposite effects of urban led economic growth on slum incidence, Column 2 in Table 7 shows the set of summary statistics for 2010 without changing the population composition. When population composition does not adjust, both housing rents increase, reflecting higher housing demand for both types of houses. Under this scenario, the equilibrium unserviced share is slightly higher and the number of households in unserviced houses (not shown in the Table) is 7% higher compared to the benchmark of Column 1. Column 3 shows the full effect of higher urban wages on the system of cities by including the changes in population composition implied by the extra 20% wage shock. Urbanization in Column 3 goes up by 7.8% and unserviced housing goes down by 2% with respect to the benchmark.

The exercise in the previous paragraph shows how national income increases are key in explaining long run reductions in slum incidence. Another way to look at this is to contrast the effect of generalized economic growth with the effects of spatially unbalanced growth (i.e. some cities growing much faster than others). A common phenomenon identified in the slum growth and urbanization literature is that rapidly growing cities experience enormous growth in the number of slum households in periods of two or three decades. In order to evaluate this idea for the case of Brazil between 1991 and 2010, Table 8 regresses unserviced housing growth (Columns 1 and 2) and changes in unserviced housing incidence (Columns 3 and 4) on exogenous local economic shocks captured by the average Bartik instrument. Regression coefficients show reduced-form evidence on how economic dynamism leads to increases both in the number of unserviced houses (Column 1) and in unserviced housing incidence (Column 3). This relationship is robust to controlling for cities' initial population size and income levels (Columns 2 and 4).

This paper's general equilibrium approach helps to understand why unbalanced economic growth might lead to higher slum growth and slum incidence in economically dynamic cites. First, when balanced urban economic growth takes place, all cities attract rural households at the same time and this decreases the housing demand that any single city faces. In contrast, when a few cities grow, they become the focus of all rural migrants and they also attract households from other, less dynamic cities. Second, when balanced urban economic growth takes place, it activates the composition effect by which households become wealthier and switch to serviced housing in all cities. In order to illustrate this process using the structure of the model, I consider what happens to an average city of around 100,000 people when all cities' wages grow by 20% versus when only that city's wages grow by 20%. First, when economic growth takes place in all cities, unserviced housing incidence in that city goes down by 3.3% and the number of unserviced households goes down by 3.6%. Second, when only this city grows, unserviced housing incidence in the city grows by 1.2% and the number of unserviced households grows by 26.6%.

7.3 Slum Policies

Turning to the role of policies, I model slum repression and slum upgrading as exogenous shifts in the supply of each type of housing. In particular, I analyze what happens to households' spatial allocation and welfare if a few cities, versus all cities, implement these policies.

Starting with slum repression, this policy may take the form of evictions once houses have been already built but it can also operate ex-ante by making it harder for households to build in land without services (UN, 2003). In any of these cases, slum repression substantially increases the cost of producing unserviced housing. Therefore, I model it as a generic backwards shift in the supply for unserviced houses. Specifically, I implement a supply shift increasing the Δc_{uj} term by 20 points.[36]

When a single medium-size city implements slum repression, the model indicates that this city reduces its number of unserviced houses by 7.4%. The mechanism in place involves rent

[36] This shock would increase Δp_{uj} by 20 points if housing quantity were fixed. Note that given that the estimated inverse housing supply elasticity is almost horizontal, this shock will translate to almost 20 points higher equilibrium unserviced housing rents.

elastic low income households reacting to higher housing costs by moving to unserviced houses in other cities where there is no repression. However, if this policy generalizes to all cities, unserviced housing becomes more expensive everywhere and the reduction in the number of unserviced households in that single medium city goes down to 6.3%. The generalization of slum repression to all cities also brings in significant nation-wide changes. Column 4 in Table 7 shows the national summary statistics for the counterfactual scenario in which all cities repress slum formation. Slum repression in all cities shows up as a huge spike in equilibrium unserviced rents in Column 4. Households react to this price shock by moving both to serviced houses and rural areas. The first movement shows up as higher serviced housing rents, which grow 1.2% more than in the baseline due to increased demand from those households leaving unserviced houses. The second movement, from unserviced houses to rural areas, shows up as a lower equilibrium urbanization rate. In Column 4 of Table 7 urbanization in 2010 goes down by 0.4%. These reallocation effects have welfare consequences since households are moving away from what was their best location choice in terms of wages, housing rents, and amenities. Specifically, low income households' welfare is 1.1% lower with respect to the benchmark after this policy.[37] Slum repression's impact on high income households' welfare and spatial allocation is negligible.

Slum upgrading consists in bringing services and other amenities to previously unserviced houses. In terms of the two housing markets in the model, slum upgrading can be thought of as withdrawing substantial numbers of unserviced houses and simultaneously adding an equivalent number of serviced houses. I then model this policy as a shift of the unserviced supply backwards and a simultaneous shift of the serviced supply forward. The magnitudes of the housing supply shifts are such that the equilibrium number of withdrawn unserviced houses equals the number of added serviced houses. Specifically, I simulate a scenario in which cities target to reduce the 1991 stock of unserviced houses by 10%.[38]

In the context of the model, the subsidy in favor of serviced houses and against unserviced ones

[37] See Appendix A.2 welfare calculation's details.

[38] Exactly targeting that 10% reduction is a hard problem for cities since it involves a general equilibrium calculation. I assume the policy shifts both supply functions in opposite directions in order to achieve a 10% reduction under a partial equilibrium scenario. In any case, the exact magnitude of the policy is not meaningful.

impacts serviced rents downwards and unserviced rents upwards and this makes households switch from one type of housing to the other one. The effects of this policy on any single city depend on whether this city is the only one implementing this policy or not. For instance, when a single medium-size city does slum upgrading, it reduces its number of unserviced houses by 2.3% and increases the number of serviced houses by 1.7% in comparison with when all cities implement it.

Column 5 in Table 7 shows aggregate statistics for the counterfactual scenario when all cities do slum upgrading. Although this policy reallocates households away from their benchmark location choices and thus could potentially hurt low income households' welfare, I find that welfare improves for both types of households when all cities implement slum upgrading policies. This contrasts with what I find for slum repression and has to do with households attaching a higher amenity value to serviced houses in comparison to unserviced ones. Specifically, welfare improves 4.0% for low income households and 3.6% for high income households with respect to the benchmark.

8 Concluding Remarks

This paper contributes to a better understanding of developing world's contemporary urbanization processes with a particular focus on the housing quality dimension. I do this by modeling households' location decisions and cities' housing production capacities in reaction to housing demand shocks. I use the model to study the effects of changes in economic fundamentals and common slum policies on the allocation of households across housing types, cities, and the countryside. This methodology explains how unbalanced urban economic growth leads to slum growth in dynamic cities and how this is not inconsistent with long run slum incidence going down as countries become richer. I show how the two main paradigms in terms of slum policy, slum repression and slum upgrading, have opposite effects on households' welfare. Also, I show how the reallocation effects of these slum policies on any given city depend on what other cities are doing.

I conclude the paper with a few remarks on some directions for future work. The provision of water and sanitation services in cities features huge economies of scale and thus involves collective action problems. This paper abstracts from those specific aspects of providing services to keep the problem tractable, but the economics of providing these and other urban amenities should be further explored. In another paper (Alves, 2014), I explore the local political economy of the problem and show that local governments' political sign matter for which slum policies are implemented and for the local dynamics of slum incidence. A second issue to be further explored is the efficiency implications of slums' location in the internal structures of cities. This "within-city" approach is motivated by slums being usually built in land that could have more efficient uses. This aspect has been recently studied by Henderson, Venables, Regan & Samsonov (2016) for the case of Nairobi.

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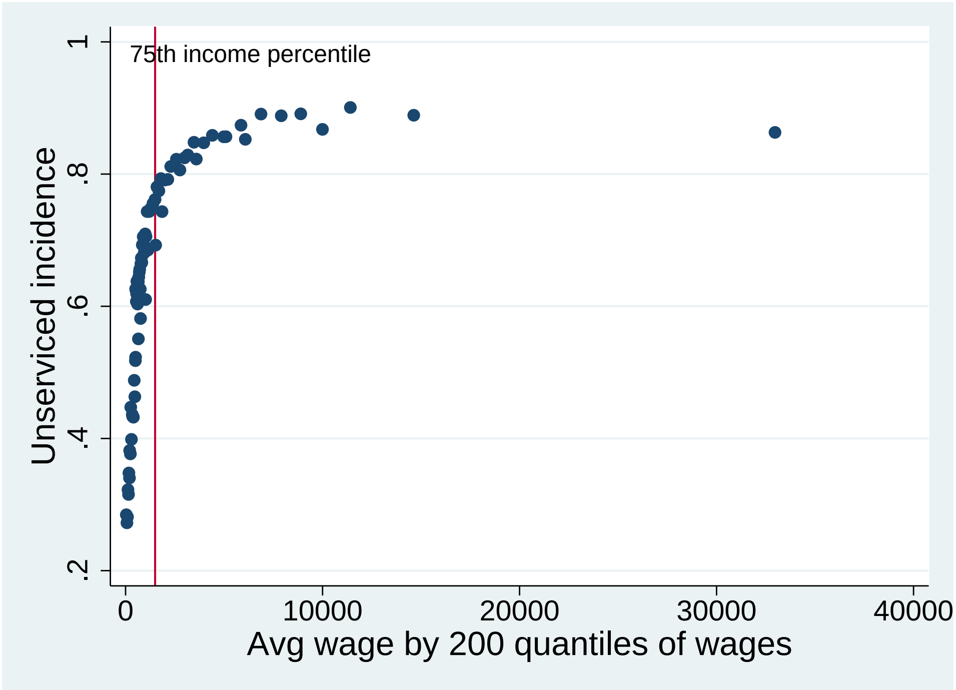
A Appendix

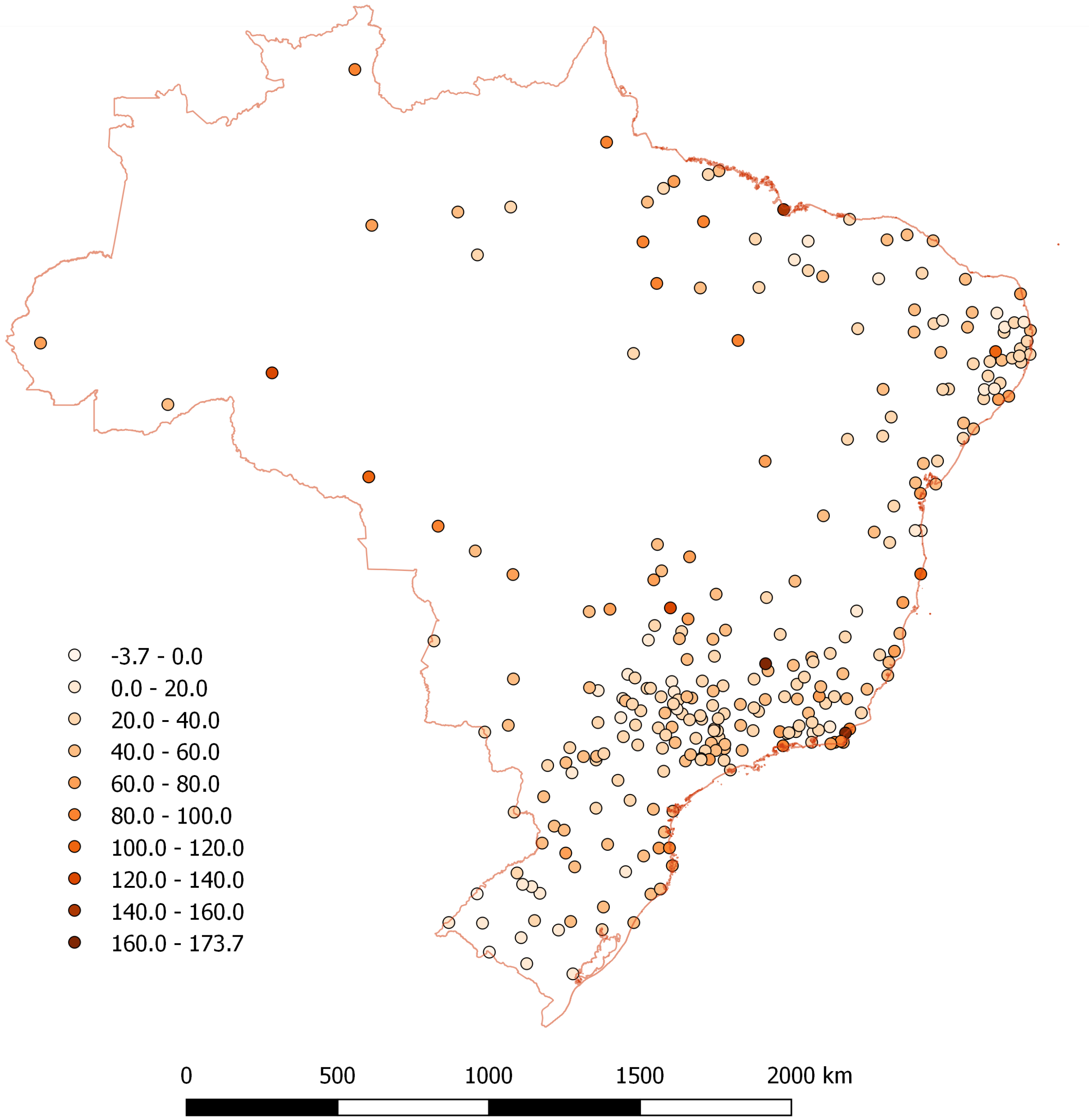
A.1 Graphs and Tables

Figure 1: Serviced housing and wages



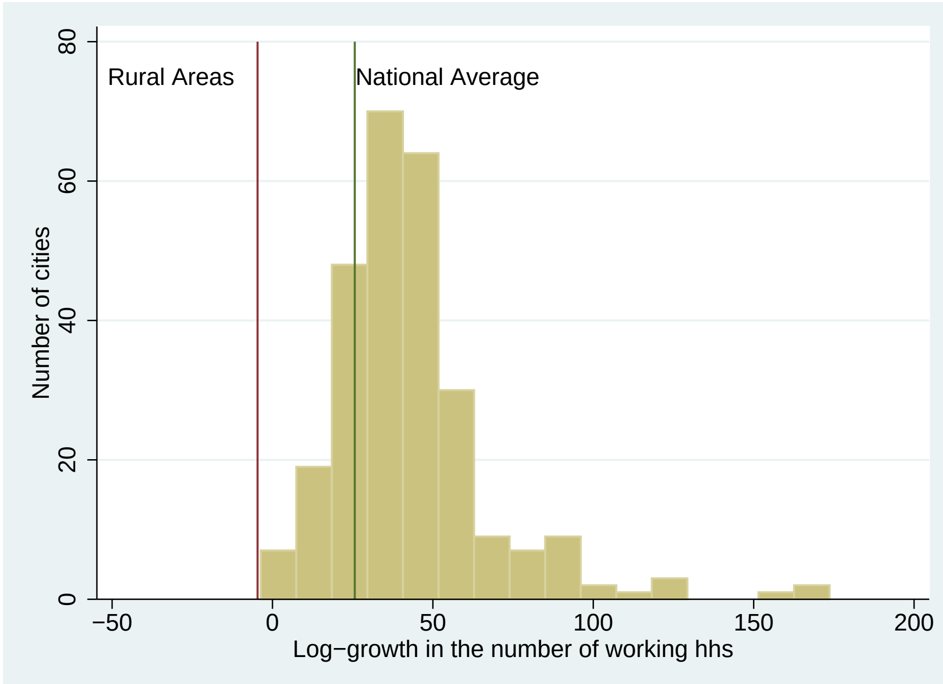
Each dot represents averages of serviced housing and wages by 200 quantiles of wages. Wages measured in Brazilian currency (Reais) and expressed in 2010 prices. Own processing of Brazilian Census data. See data section for details.

Figure 2: Map of Cities' Population Growth



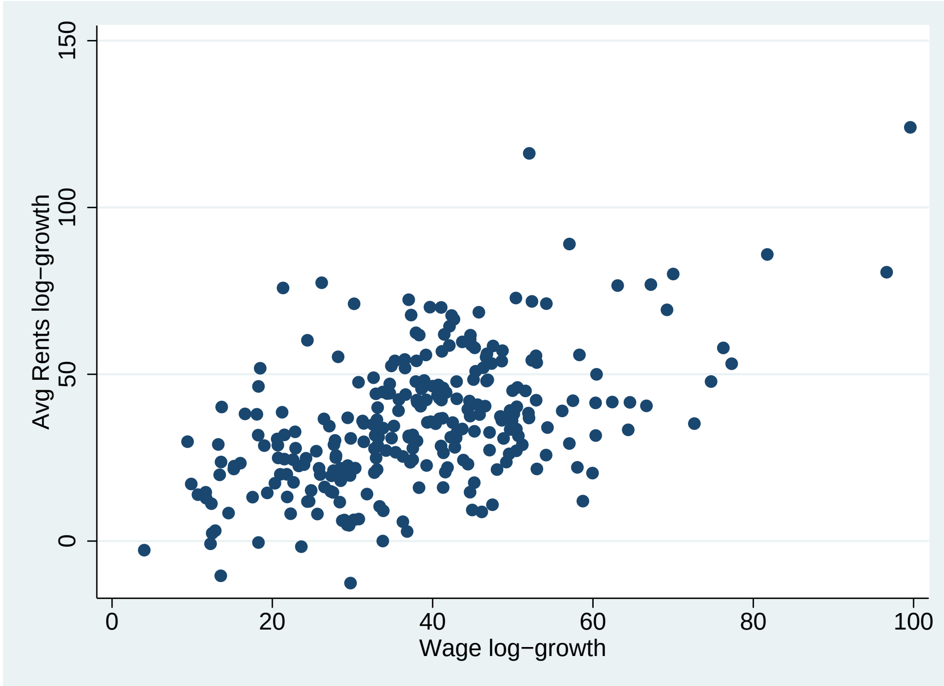
272 cities. Growth in the number of working households. Own processing of Brazilian Census data. See data section for details.

Figure 3: Histogram of Cities' Population Growth between 1991 and 2010



272 cities. Growth in the number of working households. Own processing of Brazilian Census data. See data section for details.

Figure 4: Wages and Rents growth



Each dot represents one of 272 cities. Own processing of Brazilian Census data. See data section for details.

Figure 5: Unserviced Housing growth, Wages and Rents

272 cities. Growth in the number of working households. Own processing of Brazilian Census data. See data section for details.

Figure 6: Model's Fit

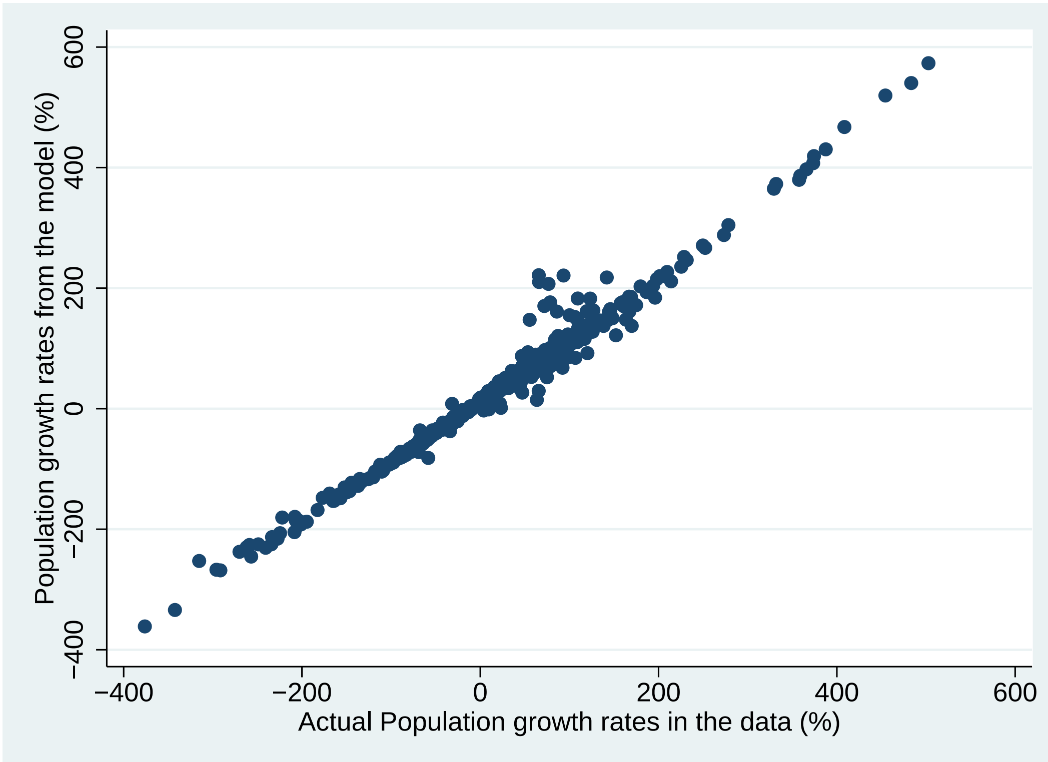


Table 1: National statistics for Brazil between 1991 and 2010

	1991	2010
Per Capita GDP (2005 US$ PPP)	10,263	14,409
Gini Index	0.64	0.61
Total Population (millions)	145.7	181.9
Urbanization (%)	74.7	84.3
Working Households (millions)	26.5	34.2
Living in the 272 cities	16.2	24.4
In houses without services	5.3	5.7
Wage growth (%)		
Low income	29.4	
High income	16.3	
Population growth (%)		
Low income	11.8	
High income	56.9	

Source: World Bank (for GDP and Urbanization), IBGE for Gini Index, and own processing of Census data for the rest.

Table 2: Share of urban households' heads not born in the city where they currently live (2010 census)

	Unserviced	Serviced
Born rural area	48.5	45.9
Born in other cities	10.7	8.7
Born elsewhere	59.2	54.6

Source: own processing of Census data.

Table 3: Unserviced housing growth, wages and rents

	(1)	(2)	(3)	(4)	(5)
	Unserviced housing growth				
Dwage	1.43***		1.07***	0.97***	1.16***
	(0.33)		(0.38)	(0.37)	(0.39)
Drentavg		0.92***	0.49*	0.55**	0.58**
		(0.23)	(0.26)	(0.28)	(0.28)
Dgini				0.59	0.09
				(0.66)	(0.71)
lnhhs_1					10.55**
					(4.08)
Constant	-88.53***	-66.78***	-92.34***	-84.96***	-202.49***
	(14.52)	(10.82)	(14.95)	(15.81)	(52.12)
Observations	272	272	272	272	272
R-squared	0.07	0.05	0.08	0.08	0.10

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Source: own processing of Census data.

Table 4: Instruments' First Stages

	(1)	(2)	(3)	(4)
VARIABLES	DW_L	DW_H	DN_U	DN_S
Bartik_L	2.06***	-0.04		
	(0.26)	(0.35)		
Bartik_H	0.22	0.96***		
	(0.16)	(0.16)		
Bartik_avg			3.17***	
			(0.76)	
Migration_H				0.17***
				(0.06)
Constant	-35.60***	1.68	-111.53***	103.92***
	(9.03)	(11.77)	(19.76)	(9.88)
Observations	272	272	272	272
R-squared	0.19	0.11	0.05	0.03
F	31.77	18.10	17.62	8.715

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The average Bartik shock is computed without construction workers.

Table 5: Instruments and construction wages

	(1)	(2)
VARIABLES	Dwage_c	Dwage_c
B_nc	-0.31	
	(0.26)	
M_H		0.05
		(0.05)
Constant	63.23***	55.82***
	(6.19)	(1.44)
Observations	272	272
R-squared	0.01	0.00

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Dependent variable is cities' wage growth for construction workers. B_nc is the average Bartik shock computed without construction workers.

Table 6: 2SLS estimates

	(1)	(2)	(3)	(4)
	Δn^L	Δn^H	Δp_u	Δp_s
$\Delta w^L - \alpha_m * \Delta p_m$	1.67*			
	(0.88)			
$\Delta w^H - \alpha_s * \Delta p_s$		0.46		
		(0.54)		
Δz_u^D			0.07	
			(0.11)	
Δz_s^D				0.37*
				(0.22)
Observations	544	272	272	272
1st stage F	61.9	30.9	19.0	15.6

Robust s.e. in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
See Section 5 for details on moment conditions.

Table 7: General Equilibrium and Counterfactuals

	Data		Counterfactuals				
	1991	2010	(1)	(2)	(3)	(4)	(5)
Exogenous changes							
Wage growth L's	29.4		29.4	49.4	49.4	29.4	29.4
Wage growth H's	16.3		16.3	36.3	36.3	16.3	16.3
Share of H types	25.0	35.4	35.4	35.4	45.5	35.4	35.4
Slum Repression	-	-	No	No	No	Yes	No
Slum Upgrading	-	-	No	No	No	No	Yes
Endogenous outcomes							
Urbanization	60.6	71.1	70.4	75.0	78.2	70.0	71.0
Share Unserviced Urban	28.4	17.5	15.2	15.4	13.4	14.4	13.4
Unserviced Rent Growth	47.6		48.7	49.5	48.3	68.3	72.5
Serviced Rent Growth	18.7		22.1	24.0	29.3	22.3	-1.8

1 - Benchmark. 2 - Extra 20% urban wage growth without changing population composition. 3 - Extra 20% urban wage growth changing population composition 4 - "Slum repression": 20% higher cost of supplying unserviced housing (all cities). 5 - "Slum upgrading" : Turn unserviced houses into serviced ones (All cities. See Section 7 for details).

Rent growth rates are national averages weighted by city population.

Table 8: Productivity shocks and unserviced housing growth

	(1)	(2)	(3)	(4)
	Unserviced housing growth		Change in unserviced incidence	
Bartik	4.5***	3.2***	0.2	1.0***
	(0.9)	(1.1)	(0.2)	(0.2)
Constant	-169.6***	664.9*	-21.5***	-209.8***
	(27.8)	(356.8)	(5.8)	(73.9)
Observations	272	272	272	272
R-squared	0.1	0.1	0.0	0.2
Controls	No	Yes	No	Yes

Robust s.e. in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Controls are logs of 1991 number of households in the city, low income wages, and high income wages.

A.2 Welfare Calculation

The logit structure features a closed form solution for the welfare associated to a set of alternatives. Since the full indirect utility is not observed, one must calculate an expected consumer surplus by integrating over the known probability of the extreme value idiosyncratic error. Following Train (2009), define the expected consumer surplus CS_i for a generic household i from the set of location choices O as:

$$E(CS_i) = \sigma E[\max(\bar{v}_{mjt}/\sigma + \epsilon_{imjt})]$$

The expectation term yields the expected utility from the discrete choice problem and pre-multiplying the inverse of the marginal utility of wages σ express expected utility in monetary terms. Given the extreme value distribution assumption, the last expression simplifies to:

$$E(CS_i) = \sigma \ln \left(\sum_{O} \bar{v}_{mjt}/\sigma \right) + C,$$

where C is a constant capturing the absolute level of utility which is not identified in the discrete choice model. This constant drops when I look at the difference in welfare before and after changes in policies.