

**Residential Wealth and Its Distribution in the
Rio de Janeiro Metropolitan Region**

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Abstract

Given the importance of housing as a component of a household's net worth and of aggregate national wealth, we ask: What variables determine housing value in the Rio de Janeiro Metropolitan Region? What is Rio's aggregate residential wealth (i.e., the sum of the values of all housing units) and its distribution among household income and tenure groups and in space? In other words, what generates residential wealth? How much residential wealth is there? Who holds it? Where is it located? To address these questions, we first calibrate a hedonic residential rent model with microdata from 2010 Population Census. We then use this model to estimate the rents for homeowners, and subsequently transform the actual and imputed rents into housing values by dividing them by the discount rate. Finally, we analyze the distribution of residential wealth by household income and tenure and subregions, and discuss the policy implications of our findings.

Keywords: Brazil, Rio de Janeiro, urban, housing, stock, value, wealth, rent, hedonic model, regression, principal components, access to employment, commute time, neighborhood, location, spatial, equity

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Residential Wealth and Its Distribution in the Rio de Janeiro Metropolitan Region

1. Introduction

Housing is an important component of a household's wealth and of aggregate national wealth. In Brazil, residential structures represent about one third of total net fixed capital (Morandi 2005), about the same as Syz's (2008) estimate for other countries around the world. Residential wealth (i.e., the stock of residential capital) is therefore important for economic and social policy.

Given this importance, we ask: This analysis asks: What variables determine the stock values of residential property? How do location and neighborhood conditions affect these values? What is the aggregate residential wealth in the Rio de Janeiro Metropolitan Region (Metro Rio)? What is its distribution among household income and housing value groups? In other words, what generates residential wealth? How much residential wealth is there? Who holds it? Where is it located?

To address these questions, we calibrate a hedonic rent model using microdata from the 2010 Population Census (hereafter, 2010 Census) and use it to impute the rent of non-rental units, and then convert actual and imputed rents into residential property values using an average monthly discount rate. Finally, we analyze the distribution of residential wealth (i.e., the sum of housing values) among household tenure, income and housing value groups¹ and in space (i.e., among subregions) in Metro Rio. In so doing, we explore the utility of this methodology with census microdata in helping to describe and understand the forces shaping the generation and distribution of residential wealth and household income.

2. How Have Previous Brazilian Studies Estimated Residential Wealth with Microdata?

Brazil's Instituto de Pesquisa Econômica Aplicada (IPEA) employs the hedonic method with microdata to estimate the stock of residential capital for Brazil's municipalities. Using a methodology developed by Cruz and Morais (2000) and Reiff and Barbosa (2005), IPEA first calibrates a hedonic rent model for rental units with microdata from the 1999 household sample survey (PNAD).² Subsequently, it uses this model to impute the monthly rents of non-rental housing units. The underlying assumptions are that the hedonic prices of the characteristics in the model as well as the discount rates are similar for rental and non-rental units. These are strong but necessary assumptions to apply the methodology with the existing census microdata. Finally, it estimates housing values as the present value of perpetual flow of the monthly imputed and actual rents, discounted at the rate of 0.75% per month. The sum of estimated housing values is the measure of residential wealth.

¹ As our measure is not adjusted for the value of the outstanding mortgage, it is of the household's gross rather than net residential wealth.

² The annual household sample survey (Pesquisa Nacional por Amostra de Domicílios—PNAD) covers a sample of all households in Brazil.

They use this same hedonic model with 1999 PNAD data to estimate residential wealth at the municipal level at 1999 prices for 1970, 1980, 1991 and 2000.³ In this way, they estimate the value of the change in the characteristics of the housing stock at 1999 prices. These IPEA estimates show that the total stock of residential capital in 2000 was about equal to Brazil's GDP (US\$1.6 trillion), after increasing by over 56% during the 1991/2000 period.⁴

After a detailed review of alternative methodologies for imputing the value of owner occupied housing, Garner (2004) of the US Bureau of Labor Statistics concludes that: "The primary advantages of the hedonic approach to impute rents for owner occupied shelter consumption [...] are that it is based on accepted economic practice, statistically defensible, and operationally feasible. Possible disadvantages include the massive amount of data that are required and that statistical modeling using regression analysis is required." Fortunately, the necessary data are available in the Brazil's PNADs and the 2010 Census.

In the hedonic price methodology as applied to the housing market, the price of a housing unit is determined by the characteristics of its size and structure and those of its neighborhood, including access to employment and other opportunities, as well as the presence of urban infrastructure and services. In hedonic residential rent models, the dependent variable (R) is a vector of residential rents, and the independent variables are matrices of house characteristics (S), access to employment and other opportunities (A), and neighborhood characteristics (N) that can include indicators of availability of urban infrastructure and services, crime levels, pollution and other factors influencing quality of life. Contract conditions (C), such as who pays the utilities, can also be included, as can the time period (T) when more than one period is involved. So then:

$$R = f(S, A, N, C, T) \quad (1)$$

Where:

R = Rent

S = Matrix of structural characteristics, including size and building materials, and number of bathrooms

A = Matrix of indicators of access to employment, services, etc.

N = Matrix of neighborhood characteristics, such as urban services, amenities, environmental pollution and crime levels

C = Contract conditions or characteristics, such as whether utilities are included in rent

T = Time period, if more than one period is involved.

³ The results are available on IpeaData (IPEA's excellent online database): See *Capital Residencial* in the Regional section on <http://www.ipeadata.gov.br>.

⁴ Morandi (2005) discusses the methods used in measuring the stock and productivity of fixed capital in Brazil's national accounts, including hedonic prices models of housing.

Different functional forms have been used in hedonic housing models (linear, log-linear, log-log) with the log-linear usually showing the best fit.

Following the initial work of Cruz and Morais (2000), Reiff and Barbosa (2005) estimate the residential capital value of Brazil's housing stock using the hedonic rent model with PNAD microdata. Reiff and Barbosa use the median household income of the census sector in which the household is located as their measure of neighborhood quality. In an interesting extension of this previous research, Tafner and Carvalho (2007) analyze the distribution of the stock of residential capital among household income groups and other household characteristics using PNAD microdata. Separate models can be done for any of the other characteristics covered by PNAD or the population census, such as household income groups, tenure, characteristics of the household head (e.g., employment status, age, sex, etc.), household composition (e.g., size and number of children), neighborhood infrastructure and commute to work time. IBGE (2013) uses similar models to impute rents for the Vetter, Beltrão and Massena (2013) use 2009 PNAD microdata to estimate the impact of the sense of security from crime and other variables on monthly rent.

3. How Do We Estimate Residential Wealth?

Our methodology takes advantage of the extraordinarily rich data of the 2010 Census to extend the previous studies that used the annual household survey data (PNAD). For instance, we add the following independent variables to the model used in the Brazilian microdata models discussed above: Commute to work times and conditions on the block where the housing unit is located, including adequate street paving and drainage, as well as the presence of open sewers and garbage on the street. Furthermore, we use the large census sample to estimate the residential wealth, housing characteristics, commute to work times and neighborhood conditions for spatial units within Metro Rio's municipalities. These smaller subregions provide interesting insights in Metro Rio's internal spatial structure. The housing values of household groups or subregions sum to Metro Rio's aggregate residential wealth to generate a system of residential wealth accounts.

Our methodology involves two main steps:

- Calibrate the hedonic residential rent model.
- Use the model to estimate and analyze the residential wealth for different household groups and subregions within the Metro Rio.⁵

3.1 The Hedonic Residential Rent Model: What Variables Generate Housing Value?

We develop the residential rent model in the following steps:

- Estimate and analyze our indicator of commute to work time (A in equation 1).

⁵ Although around 4% of total households in Metro Rio were still in the process of purchasing their housing, we do not adjust household residential wealth for outstanding debt, as we lack the data to do so and our objective is to measure gross rather than net residential wealth, as was the case of the above cited Brazilian studies.

- Use principal components analysis to address the multicollinearity issues of the measures of neighborhood quality (N in equation 1) and analyze the component scores.
- Calibrate a hedonic residential rent model using measures of the housing structure (S), access to employment (A), and the component scores as independent variables.

Our hedonic residential rent model will be similar to those developed by other Brazilian authors⁶ with PNAD microdata and also used by IPEA to estimate the stock of residential capital. In these models, the dependent variable is monthly rent. One advantage of using monthly rent from the PNAD or 2010 Census as the measure of housing value in Brazil is that a national tenant law⁷ provides a common legal framework for all aspects of renting and leasing, including the rights and duties of the renter and the property owner, the length of the rental contract, payment of taxes and other expenses such as condominium fees, eviction, and civil and criminal penalties. Under this law, residential rent contracts are normally done for 30 or more months with clauses that allow for annual rent adjustments for inflation as measured by a specified price index. Given this law and as we know of no incidence of rent control in Brazil, we do not need an independent variable for contract conditions (C in equation 1).

Using rents from the census or a household survey would also seem to compare favorably with two other commonly used methods for estimating residential wealth for the national accounts in other countries (Garner 2004): Asking the homeowner to estimate the selling price or monthly rent of his home and using the asking prices for home sales. Whereas, the renter knows his monthly rent payment, the informant may have little understanding of current trends in the housing prices and rents. Asking prices can be much higher than the final sale price. In Brazil, there are no other reliable sources of data. In the Municipality of Rio de Janeiro, the government uses its own estimates of sale prices in calculating the real estate transfer tax (2.5% of total value) rather than the recorded sale price that it considers unreliable.

We initially test the log-linear functional form and weighted ordinary least squares method used by the other authors cited above. We then review the residuals of this model to find whether we need to test other functional forms. As we are using only one time period (2010), we can also drop T from equation 1. So then, the initial model to be tested is:

$$\text{Log } R = \beta_0 + S\beta_1 + A\beta_3 + N\beta_2 + \varepsilon \quad (2)$$

With regard to methodological issues, Malpezzi (2002) notes that although research shows that “coefficient estimates are not robust with respect to omitted variables,” the correlation “between omitted and included variables that biases individual coefficient estimates can and often does help improved prediction from a “sparse” model. This suggests that hedonic applications that rely on overall predictions—like place-to-place price indexes, or cost-benefit analysis of housing subsidies—can proceed apace, even while papers that rely on interpretation of individual

⁶ Cruz and Morais (2000), Reiff and Barbosa (2005), Tafner and Carvalho (2007) and Vetter, Beltrão and Massena (2013).

⁷ Lei do Inquilinato, Lei nº 8.245, de 18 de outubro de 1991.

coefficients must be interpreted more cautiously.” As our objective is to estimate residential rent for non-rental units, our results will be more robust than those that involve interpretation of individual coefficients.

3.2 A Principal Components Analysis of the Neighborhood (N) Variables

A common problem with the analysis of the matrix of neighborhood indicators (N) in hedonic models is that many of the “independent” variables are in fact correlated (Malpezzi 2002).⁸ Several authors have used factor analysis in seeking to address this multicollinearity problem and also to identify the complex relationships among the indicators of neighborhood quality. For example, Kain and Quigley (1970) used factor analysis in their classic study of the value of housing quality, as have more recently have Day et al. (2003) and Bhattacharjee et al. (2011).

Day et al. (2003) note that factor analysis offers a way of identifying the “major dimensions of association between variables such that a smaller set of variables (factors) can be defined that approximate the variation shown in the original data.” Furthermore, as “the factors describe the fundamental dimensions of difference and similarity underlying the original variables,” they “are much easier to interpret in a regression analysis.” As factors generated are orthogonal, collinearity among the resulting factor scores is no problem.

Our approach, then, is to use factor analysis with principal components extraction to analyze the pertinent variables, and then use the resulting component scores as independent variables in our hedonic residential rent model. The component loadings allow us to interpret them as collections of correlated neighborhood characteristics.

3.3 Steps in Estimating Residential Wealth

We then use the hedonic residential rent model to estimate the stock of residential wealth by applying IPEA’s methodology that involves:

- *Using the hedonic rent model to impute the monthly rents of non-rental units:* This would be done just by “plugging in” the values of the independent variables for these non-rental units into the model. These imputed rents and also actual rents are multiplied by the household’s sample weight.
- *Estimate residential property value as the perpetual flow of actual and imputed rents (R/i , where i is the discount rate).* We use two monthly discount rates to estimate residential wealth: The 0.75% used by IPEA (9.38% annual rate) in its estimates of residential wealth, as our conservative estimate of residential wealth, and 0.50% monthly rate (6.17% annual rate). This lower rate may reflect the willingness of households to sacrifice current consumption to gain the benefits of homeownership and also the downward trend in Brazil’s interest rates evident until the 2013. Using the 0.50% monthly discount rate rather than the 0.75% rate increases the housing

⁸ This is to be expected, as the actions of one household can impact his neighbors. In other words, there are externalities (costs and benefits other than those between home buyers or sellers/ landlords and tenants) or “neighborhood effects.”

- value estimates by 50%. See Annex C for a graph showing the evolution of the real interest rates in Brazil. In most cases, we will use the more conservative 0.75% rate.
- *Sum the estimated housing values to estimate the residential wealth for household tenure, income and value groups and subregions.*

4. The Sample and the Variables

Our primary data source is the 2010 Census sample database from IBGE's⁹ website. We selected households living in private permanent housing units, located in urban areas in Metro Rio. Vacant housing units (10.6% of all private housing units) are included only as an initial adjustment in the calculation of the total stock of residential wealth. All of the rest of the analysis is of occupied units. Annex Table B.4 shows the resident population and households in urban or rural areas for the municipalities of Metro Rio in 2010.

4.1 The Universe and the Sample

As with other recent censuses, the 2010 Census involved application of a short questionnaire for all households and a much longer one for a sample of these households. This sample size varied according to the municipality's total population, ranging from 50% for municipalities with only 2,500 inhabitants to 5% for municipalities with over 500,000 inhabitants. Although the census sample database for households is our primary source, we also use some data for smaller spatial units (i.e., subregions) within the municipalities called *Áreas de Ponderação* (hereafter, Census Areas).¹⁰ To permit generation of statistically reliable estimates, these Census Areas combine contiguous census sectors that have a sufficient number of households and are relatively homogenous in terms of population characteristics and infrastructure (Cortez et al. 2012). There are a total of 336 urban Census Areas in Metro Rio.¹¹

Table 1 shows that our total sample is 223,534 for the 3.9 million private permanent urban households in Metro Rio (5.7% sampling proportion). Of these, we use our sample of 41,396 renters to calibrate our hedonic model. As shown in Annex Table B.5, these households are distributed among a total of 19 municipalities and the 336 urban Census Areas in the Metro Rio. The total population in Metro Rio in 2010 was 12.2 million.

⁹ Instituto Brasileiro de Geografia e Estatística—IBGE (Brazilian Institute of Geography and Statistics), Brazil's main government statistical agency.

¹⁰ Although somewhat similar to the Census Tracts of the US Census in that they are subdivisions of a larger entity such as a county, the boundaries of Census Areas change more often and can vary much more in population size.

¹¹ These Census Areas were carefully designed by the municipal authorities in the Municipality of Rio de Janeiro and therefore are of similar population sizes. However, the same does not always apply in the other municipalities of Metro Rio and population sizes can, therefore, vary considerably among them.

Table 1. Metro Rio: Private Permanent Urban Households by Tenure Type, 2010

Tenure Type	Sample	% of total	Sample proportion
Total	223,534	100.0%	5.7%
Owner occupied	171,289	76.6%	5.8%
Renters	41,396	18.5%	5.6%
Rent free (*)	10,849	4.9%	5.9%

Source: Authors' calculations with 2010 Census microdata.

Note: (*) Use granted by employer or other person such as family member.

4.2 Variable Definition

We will use census data of two main types:

- Individual households: The microdata for occupied housing units from the census sample database.
- Census Areas: Neighborhood and access indicators (N and A on equations 1 and 2) generated with the household microdata (including urban services and commute to work time) and also with data on block conditions (*entorno*).

4.2.1 Household Data

For each individual housing unit and household, we generate indicators of the structural characteristics of the housing unit and its urban infrastructure and services.

- Structural Characteristics of the Housing Unit

We will use the following characteristics of the housing units:

- Type of unit: Apartment, single family house, housing in a condominium or closed street (i.e., *vila*¹²).
- Building materials used in the walls: Finished masonry or other. Almost all housing units with durable wall materials in Metro Rio are in some form of masonry.
- Number of private bathrooms: As we found that this variable was highly correlated with both total number of rooms and bedrooms, we decided to use only bathrooms.

See Annex Table A.1 for the operational definitions of the variables. So then, although we don't have space or lot size in square meters, we do have number of rooms by type (bedrooms and bathrooms), and whether the unit is a single family home or an apartment. We also lack the age of the housing unit. However, older units in good condition and well located sometimes command higher prices as they are roomier and have more character. In addition to denoting

¹² A *vila* consists of housing units on a street with restricted access.

housing size, the number of bathrooms also serves to indicate age to some extent, as newer units tend to have more (albeit smaller) bathrooms.

- Level of Urban Infrastructure and Services

We also include a number of indicators of the level of urban infrastructure and services, including connection to the public water and sewer system, and garbage collection. Car ownership is, of course, correlated with household income and also with the availability of parking space for the unit. Many households lack access to a phone line that allows adequate internet use. See Table A.1 for the definition of these binary variables.

4.2.2 Census Areas

For the Census Areas, the indicators include variables generated with the sample census data:

- Average commute to work time of employed commuters in the Census Areas.
- % of the housing units with finished masonry walls and also access to adequate sewer and water and solid waste collection systems.

In addition, we will use the census block data to calculate the percentage of households on blocks in the Census Area with street lighting, sidewalks, etc.

In summary, for each household, we will have indicators for the household per se (e.g., number of bathrooms and urban infrastructure and block characteristics) and also for the Census Area in which it is located (e.g., % of households with water from the public system, average commute to work time and block conditions). Annex Table A.1 shows all of the indicators used in the principal component analysis and the hedonic model.

- Commute to Work Time

The 2010 Census provides the data on commute to work time for household members who commute and were employed during the reference week of the Census¹³ (i.e., employed commuters) for the following time groups:¹⁴ 5 minutes or less; 6 thru 30 minutes; 31 thru 60 minutes; 61 minutes thru 2 hours; and more than 2 hours. Annex Table B.1 shows the distribution of employed commuters by these commute time groups. Nearly 28.7% of household members have commutes to work of over one hour and 5.5% have commutes of over two hours (over 20 hours per week in commuting).

¹³ The week of 25th to the 31st of July 2010.

¹⁴ The following question was asked only of persons employed during the census week who work outside the home and commute every day: How long does the trip from your home to the place where you work take?

- Block Conditions

The 2010 Census collected data on the conditions on the block on which the housing units were located for urban areas with regular street layout (i.e., *áreas com ordenamento urbano regular*). Using these data, we calculate indicators of block conditions within the Census Area in which the housing unit is located. These indicators are the percentage of households in the Census Area with the following positive and negative block conditions for areas with regular street layout:¹⁵ Street lighting, street paving, sidewalks, street curbs, storm water inlets or drains, street trees, street signs, wheelchair ramp, accumulated garbage on street and open sewers. In Metro Rio, 92.1%¹⁶ of the households lived in areas with such regular street patterns and 7.9% in areas with irregular patterns.¹⁷ Annex Table B.2 shows that for households living in urban areas with regular street patterns, coverage was highest for street lighting (85.9%) followed by street paving (75.0%). As in the case for the Census Area indicators generated with the microdata for individual households, the block level indicators would be the same for all of the individual households located in each Census Area.

4.2.3 The Definition of Six Subregions

As housing markets are local and diverse, metropolitan housing market are often composed of several different housing submarkets (i.e., are segmented). Malpezzi (2002) notes that many hedonic housing studies test this market segmentation hypothesis. To test this hypothesis and to facilitate the presentation of our residential wealth results, we grouped the Census Areas into six subregions¹⁸ for Metro Rio that are relatively homogeneous with regard to the variables used in our model and also based on previous studies (Lago 2010):

1. *Center and other central areas in Municipality of Rio de Janeiro (Muni Rio) and the Municipality of Niteroi*: Includes both the area around the Tijuca and Vila Isabel and the Administrative Regions (ARs) and also the Municipality of Niteroi on the far side of the bay (although it is quite socio-economically diverse)
2. *Older higher income neighborhoods along the bay and coast in Muni Rio*: Covers the ARs of Botafogo, Copacabana, and Lagoa
3. *Higher income expansion area along the coast in Muni Rio*: The Barra da Tijuca AR
4. *Suburbs in Muni Rio*: Includes the ARs of the North Zone and Jacarepaguá AR.
5. *Large Squatter Settlements in Muni Rio*: Includes only the *favelas* classified as ARs in Muni Rio (Complexo do Alemão, Jacarezinho, Maré and Rocinha).¹⁹

¹⁵ There is no sector code on the microdata that would enable us to match the sector and microdata files, so we must use the data at the Census Area level for which there is a code on the microdata file.

¹⁶ Of this total, the data for 1.7% of the households was missing.

¹⁷ Some Squatter Settlements may have regular street patterns.

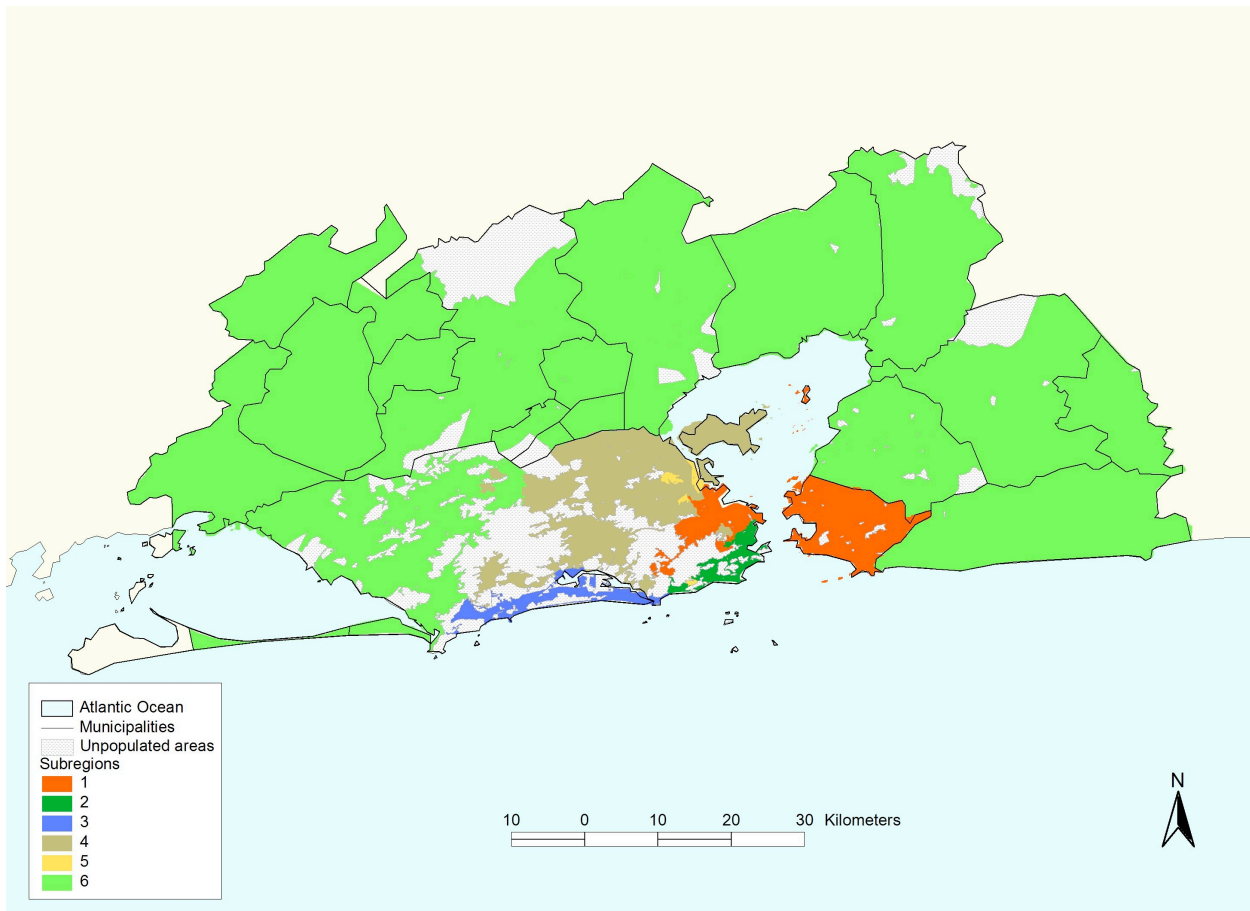
¹⁸ Annex Table C.1 shows the distribution of the ARs of Muni Rio and the other municipalities in these six subregions.

¹⁹ Although there are data for all Squatter Settlements, the 2010 Census sample dataset available to the public do not provide the Census Sector code that would enable us to identify them in our analysis.

6. *Periphery*: West Zone of Muni Rio and municipalities of the Baixada Fluminense and the east side of the bay except for Niterói.

Map 1 shows these six subregions. The areas in white are uninhabited mountains, bodies of water, etc. Except for the large *favelas* classified ARs included in Zone 5, all other squatter settlements are included within the five other subregions.²⁰

Map 1. Metro Rio: The Six Subregions Defined for This Study



A regression of the 336 Census Areas with average monthly rent as the dependent variable and binary variables denoting these subregions as the independent variables yielded an R^2 of 0.77 with all coefficients significant at greater than the 0.001 level. See Annex Table D.2.

In the rent model, we introduce a binary variable for the higher income subregions 2 and 3 into the regression model to test the hypothesis that it would raise the regression's constant, and also multiply this binary variable by other key variables to see if it impacts their slope.

²⁰ See Annex A for a discussion of IBGE's operational definition of squatter settlements.

4.2.4 Minimum Salary and Exchange Rate

IBGE used the value of the monthly minimum salary in the reference month of the 2010 Census (July 2010): R\$510 (R\$6,120 per year). The exchange rate used is the average of the commercial buy and sell rates for 2010: US\$1=R\$1.76. Using this exchange rate, the value of the monthly minimum salary would be us\$290 (US\$3,480 per year)

The following sections present the results of the hedonic rent model (Section 5), the estimates of residential wealth for household tenure, income and housing value groups (Section 6), as well as for spatial units (Section 7), and also the distribution of household income (Section 8).

5. Results for the Hedonic Rent Model

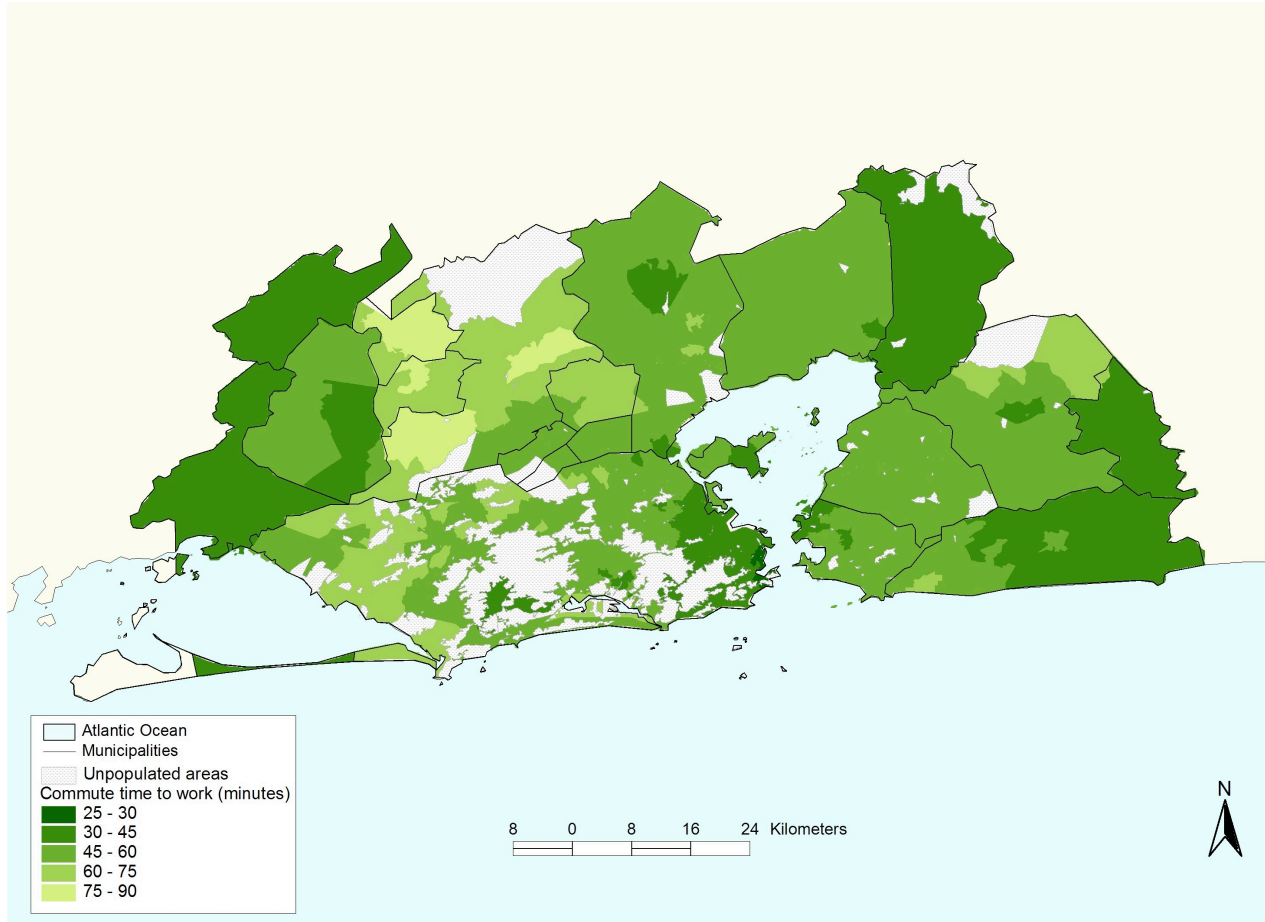
In this section, we first calculate our indicator of access to employment (A), and then use principal components analysis to generate the Neighborhood (N) component scores for the 336 Census Areas, and subsequently use these scores as independent variables in our residential rent model. We used SPSS (version 16) for the principal components and regression analysis.

5.1 Access to Employment

As our measure of **access to employment**, we use the weighted average commute to work time for each of the Census Areas calculated at the midpoint of each of the employed commuter time groups.²¹ Map 2 shows that this indicator is interesting in itself, as it shows that the average commute time increases with distance from the center, but not by as much that one might expect, partly because Metro Rio is polycentric with many subordinate centers (with those in the outlying areas working within them) and also due to increases in traffic congestion in all areas.

²¹ For the open group of more than two hours (5.5% of employed commuters), we estimated the value at 182 minutes using linear regression.

Map 2. Metro Rio: Average Commute Times for Census Areas, 2010



Source: Authors' calculations with 2010 Census microdata.

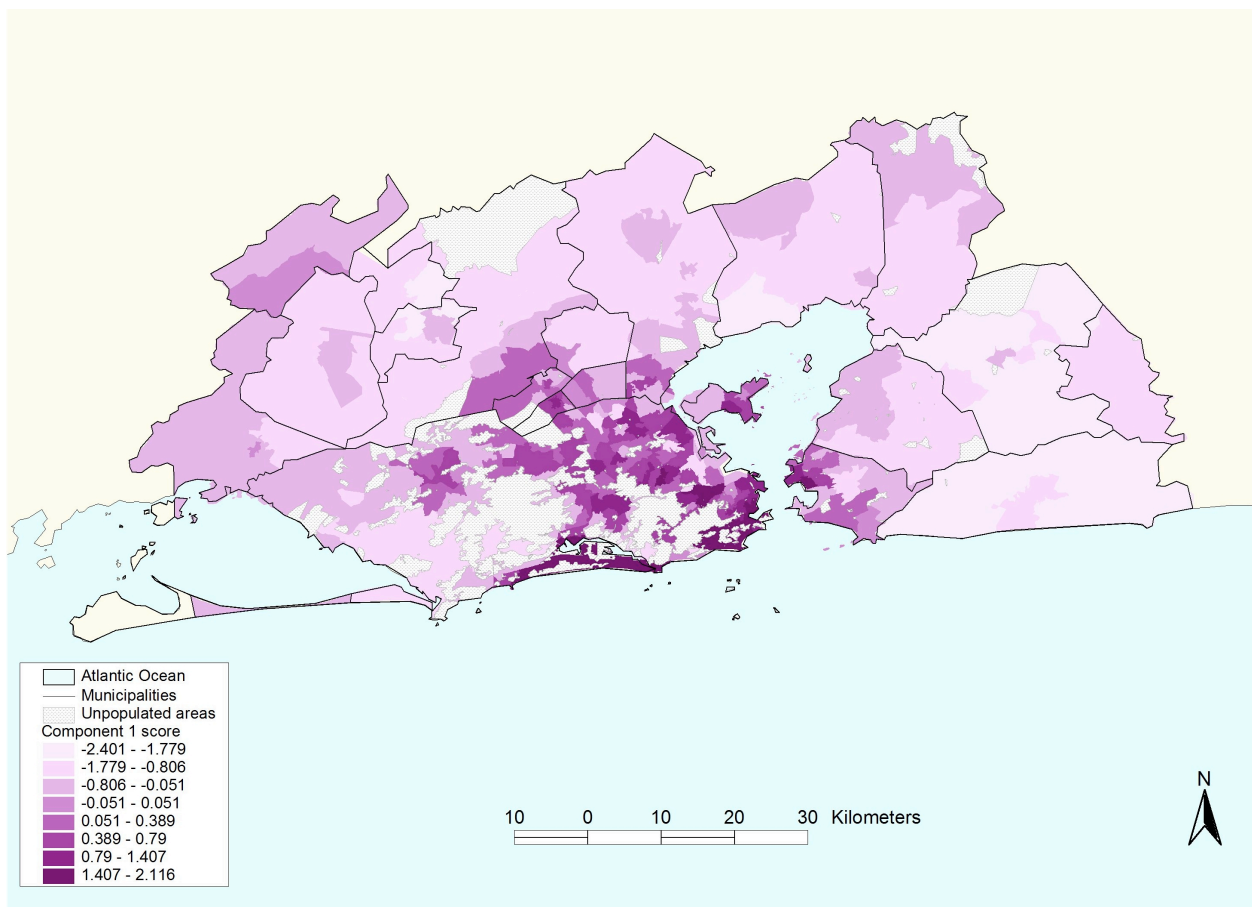
5.2 Principal Components Analysis of the Census Area Indicators of Neighborhood Quality

Table 2 shows the component loadings generated using factor analysis with principal components extraction for the Census Area indicators defined using the population of each Census Area as weights. Annex Table B.3 shows the values of the averages and standard deviations of the variables used in the principal components analysis. Table 2 shows the loadings higher than 0.30 in green and those less than -0.30 in brown. Although we experimented with component rotation and different numbers of components, we decided that three unrotated components provided the most pertinent summary of the data. The scores of these three components are used as independent variables in the hedonic residential rent model.

The three components explain nearly 74% of total variance. The first component (Component 1) explains 46.6% of the variance and shows high positive loadings on adequate block conditions and infrastructure, percentage of apartments and household income, and high negative on inadequate block conditions. In this way, we interpret Component 1 as high level of attractiveness or desirability of the Census Area due to the availability of urban infrastructure and services, housing types and income level. We therefore interpret Component 1 as a

composite indicator for a high level of attractiveness or desirability of the Census Area. Map 3 shows the average Component 1 score for the Census Areas indicating their attractiveness in terms of level of urban services. Although the lowest scores are clearly concentrated in the outlying areas, the patterns of attractiveness vary considerably with some areas showing relatively high scores. As with commute times, the spatial patterns of the scores reveal the complexity of Metro Rio’s spatial structure.

Map 3. Metro Rio: Census Area Scores for Component 1—High Neighborhood Attractiveness, 2010



Source: Authors’ calculations with 2010 Census microdata.

The second component (Component 2, Lower Income with Single Family Homes) explains 15.8% of the variance with high loadings for single family homes with some basic infrastructure, and low loadings for renters that would characterize outlying, lower income neighborhoods. We expect a negative coefficient on Component 2 score in our regression analysis. Component 3 (Higher Income with Low Access to Public Infrastructure) explains 11.5% of the variance with high loadings for household income and also on water from wells and septic tanks indicating higher income outlying areas. We expect a positive coefficient in our residential rent model for Component 3 in the model.

Table 2. Metro Rio: Variable Loadings from the Principal Components Analysis of the Census Area Data (*)

Variables	Variable Loadings for the Components		
	1. Overall Attractiveness	2. Lower Income with Single Family Homes	3. Higher Income with Low Access to Public Infrastructure
% with street signs	.770	.244	.149
% with street lighting	.424	.792	.082
% with street paving	.833	.349	-.269
% with sidewalks	.873	.324	-.248
% with street curbs	.852	.375	-.244
% with storm water inlets or drains	.874	.247	-.159
% with ramps for wheelchairs	.560	-.145	.497
% with street trees	.737	.216	.326
% with open sewer	-.688	.096	.286
% with accumulated garbage on street	-.512	.162	.188
% single family homes	-.827	.324	-.371
% homes in condominiums	.157	.049	-.252
% apartments	.811	-.308	.423
% renters	.485	-.527	.075
% with finished masonry walls	.881	-.078	.011
% with public sewer system	.760	-.242	-.484
% with septic tank	-.589	.312	.525
% with water from public system	.621	-.392	-.479
% with water from well or spring	-.584	.398	.473
% with direct garbage collection	.255	.858	-.121
% with indirect garbage collection	-.053	-.903	.051
% with PC with internet connection	.889	-.182	.328
% with car	.691	.158	.509
Average household income	.712	-.139	.559
Extraction Sums of Squared Loadings			
% of Variance	46.6	15.8	11.5
Cumulative %	46.6	62.4	73.9

Note (*): Loadings +0.30 or more shown in green, and those of -0.30 shown in brown.

Source: Authors' calculations with 2010 Census block conditions and sample data.

5.3 The Hedonic Residential Rent Model

We calibrated our hedonic residential model using weighted ordinary least squares (as in the Brazilian hedonic studies discussed above). After testing the alternatives, we settled on using the logs of the dependent variable and independent variables except for component scores and, of

course, the binary variables. Annex Table B.4 shows the averages²² and standard deviations of the variables used in our rent model.

Analysis of the residuals of the first regression runs revealed a number of cases where the rents fell significantly below the values predicted by the model. This problem was especially evident for higher income households (e.g., two of which showed rents of only one Real and several others showed rents of less than 1% of total income). Probable causes for this include rents provided at concessionary levels by employers, family members or others and perhaps coding errors. To address this problem, we cut the outliers in which the rent was over two standard errors below the predicted value in subsequent runs. Total outliers and missing values of all the variables was 3.1% of the full sample, leaving a total sample of 40,099. Table 3 shows the results of the regression, including the variable type (binary, log, etc.) and to which matrix of explanatory variable to which they belong from equations 1 and 2: Structural (S) characteristics of the housing unit, Accessibility (A) to employment and Neighborhood (N) conditions. Both the R2 and adjusted R2 for the model are 0.73, about 10 percentage points higher than the Brazilian microdata models discussed above. The Variance Inflation Factors (VIF) of all of the independent variables is below 2.5 (indicating relatively low collinearity), except for the variables related to market segmentation (as one would expect). All of the coefficients are statistically significant at above the 0.05 level, except for Housing in a Condominium or Closed Street (*vila*). The results show that the Metro Rio's market is segmented, as location in subregions 2 or 3 impacts the model's constant and the slope of the log of number of bathrooms and of Component 1. All of the variables show the expected signs, including Components 1, 2 and 3.

²² The antilog of the mean of a log transformed variable is, of course, the geometric mean.

Table 3. Metro Rio: Regression Results—Hedonic Residential Rent Model—Natural Log of Monthly Rent as the Dependent Variable, 2010

Variables	Type	Matrix	Coefficients	t	Sig.
(Constant)			5.9496	141.69	0.002
Household: House in a condominium or vila	binary	S	0.0134	2.28	0.131
Household: Apartment	binary	S	0.1411	29.56	0.011
Household: Finished masonry walls	binary	S	0.1625	21.08	0.015
Household: Number of private bathrooms	log	S	0.4884	69.56	0.005
Census Area: Log of average commute to work time	log	A	-0.1910	-18.46	0.017
Household: Public sewer system	binary	N	0.1257	16.75	0.019
Household: Septic Tank	binary	N	0.1106	11.08	0.029
Household: Public water system	binary	N	0.0861	11.24	0.028
Household: Direct garbage connection	binary	N	0.1654	38.86	0.008
Household: PC with access to internet	binary	N	0.4884	69.56	0.005
Household: Car ownership	binary	N	0.1654	38.86	0.008
Component 1. Overall Attractiveness	Score	N	0.1584	54.83	0.006
Component 2. Lower income single family homes	Score	N	-0.0197	-9.64	0.033
Component 3. Higher income poor infrastructure	Score	N	0.1210	46.53	0.007
Segmentation: Higher income subregions 2 and 3	binary	N	0.1035	8.31	0.038
Segmentation: Higher income binary * log bathrooms	slope	N	0.2359	18.40	0.017
Segmentation: Higher income binary * Component 1	slope	N	0.0603	8.34	0.038
R2			0.73		
Adjusted R2			0.73		
N			40,099		

Source: Authors' calculations with 2010 Census block conditions and sample data.

As we noted above, we are most interested in using the model to measure residential wealth than to focus on the individual coefficients that may be biased due to missing variables, collinearity or other problems. Nonetheless, we use the product measures proposed by Pratt (1987) to estimate the percentage of variance explained by the variables of the three matrices (S, A and N). Together, Accessibility and Neighborhood variables account for about two thirds of the total variance explained by the model (i.e., explain two thirds of the R2). In other words, location related variables influenced by government actions (including connection to urban infrastructure and access to employment) explain about two thirds of the variation of residential rents. For example, access to employment depends on public actions, including transportations investments (e.g., construction and maintenance of roads and metros), licensing of public transport, and policing of traffic. Other urban services such as schools, fire protection, street lighting, parks, solid waste collection and disposal, water and sewerage, and storm sewers depend on public sector infrastructure investments or direct service provision or contracting.

6. What Is the Total Residential Wealth and Its Distribution Among Households?

In this section, we estimate total residential wealth and analyze its distribution among households by tenure, household income and housing value groups.

6.1 What Is Metro Rio's Aggregate Residential Wealth?

Table 4 shows that Metro Rio's total residential wealth of occupied and vacant units estimated at the 0.75% and 0.50% monthly discount rates in 2010. To estimate the value of the vacant units, we multiplied total residential wealth of the occupied units by the percentage of vacant units (10.6%) in the total private housing stock. At the more conservative 0.75% monthly discount rate, our estimate of Metro Rio's **aggregate residential wealth** of both occupied and unoccupied units in 2010 is US\$155.1 billion (94.2% of Metro Rio's 2010 GDP of US\$164.4 billion) and US\$140.2 billion for occupied units (85.2% of Metro Rio's GDP). The rest of our analysis excludes the vacant housing units. At the 0.50% monthly discount rate, aggregate residential wealth for occupied units would be 50% higher at US\$210.3 billion (127.8% of Metro Rio's GDP).

Table 4. Metro Rio: Total Estimated Residential Wealth of Occupied and Vacant Housing Units at the Two Different Monthly Discount Rates (US\$ billions), 2010

Monthly discount rates	Total	Occupied units			Total vacant units	
		Total	Home-owners	Renters		Rent free
0.75%	155.1	140.2	105.4	29.0	5.8	14.9
0.50%	232.6	210.3	158.0	43.6	8.7	22.3

Source: Authors' calculations with 2010 Census block conditions and sample data.

6.2 What Is the Distribution of Residential Wealth Between Homeowners Versus Landlords?

For total occupied units, US\$105.4 billion of this residential wealth (75.1% of the total) belongs to owner occupied units, and the rest is property of the landlords of rented and rent free units. In the case of lower income households, the landlords could be another lower income family.

6.3 What Is the Distribution of residential Wealth by Household Income Groups?

Table 5 shows that the percentage of homeowners is quite similar for all household income groups. For example nearly three quarters of the households in the lowest household income group (less than three minimum salaries with average annual income of only US\$4,407) are homeowners. A key reason for these high homeownership levels is that those living in squatter settlements (i.e., *favelas*) or other informal housing can declare themselves homeowners, even if they do not legally own the land on which their home is located. In fact, land ownership in squatter settlements is a complex legal question on which even lawyers may not agree, as the chances of removal (at least removal without compensation) are quite low, and those living on land without a legal title may be eligible for squatter's rights after five years

under Brazilian law. The 2010 Census showed over 520,000 households living in squatter settlements (more than 15% of the total private permanent urban households) in Metro Rio. Note that *favelas* constitute only one type of informal housing. Low income settlements in less than fully serviced and legalized subdivisions in peripheral areas (i.e., *loteamentos populares*) are another very prevalent form of informal housing.

Table 5. Metro Rio: Key Indicators by Household Income Group in Minimum Salaries, 2010 (*)

Income group (Minimum salaries)	Average annual household income US\$	% homeowners	% of total households	% of total residential wealth for homeowners (*)
Total	23,766	76.2	100.0	100.0
Less than 2	4,407	74.9	25.3	15.3
2 to 4	9,986	76.1	32.1	22.8
4 to 6	17,239	76.6	14.7	13.2
6 to 8	24,462	76.6	7.5	8.1
8 to 10	31,547	77.0	4.7	6.1
10 +	86,743	77.8	15.6	34.5

Source: Authors' calculations with 2010 Census microdata.

Note: (*) Excludes households that declare no income (5.9% of total households) and with missing value for the independent variables of the model.

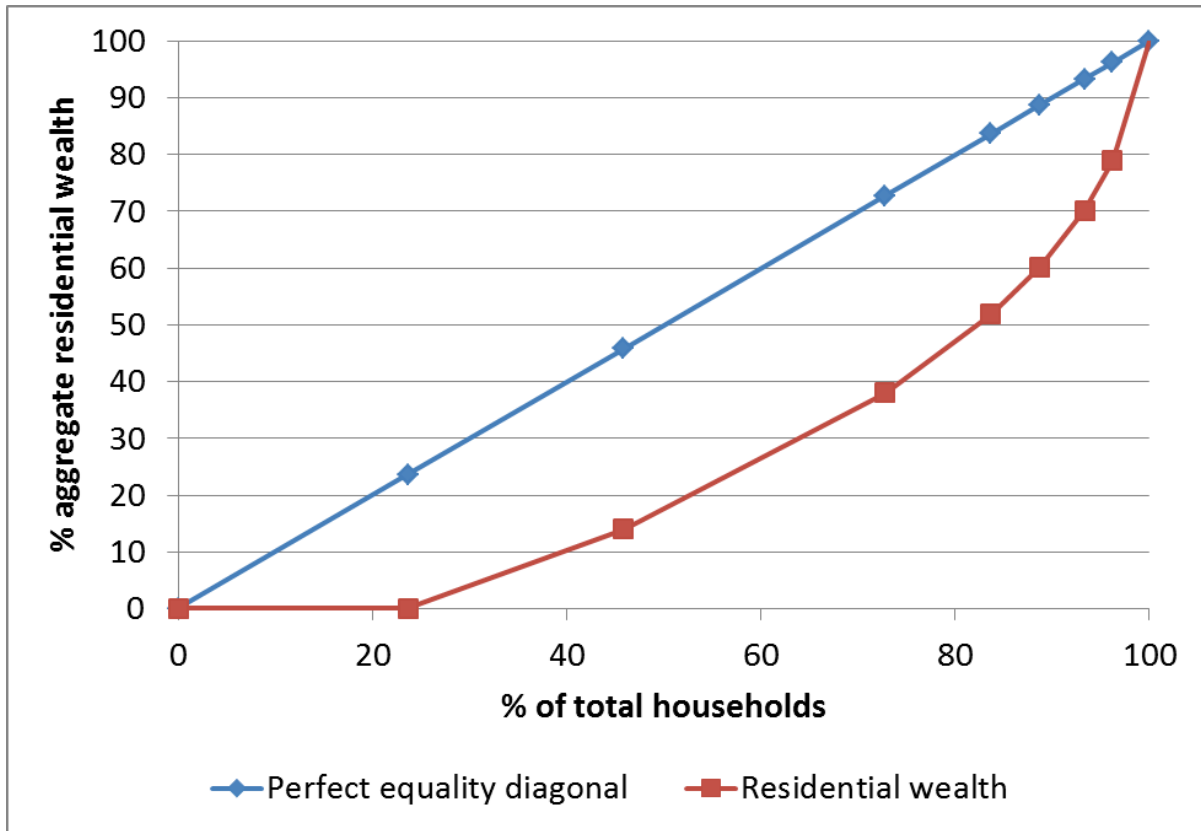
Table 5 shows the distribution of total households and aggregate residential wealth of homeowners by household income group. In Metro Rio, although 25.3% of total households earned less than two minimum salaries (US\$ 6,960 per year), the homeowners in this income group held only 15.3% of aggregate residential wealth of homeowners. Whereas only 15.6% of households earned 10 or more minimum salaries (US\$34,800 per year), homeowners in this income group held 34.5% of aggregate residential wealth of homeowners. Nonetheless, lower income households have more residential wealth than one might expect, in part because they are often homeowners in informal settlements of various kinds. Another reason for this is that the rental demand for housing is income inelastic.²³

6.4 What Is the Distribution of Residential Wealth by Housing Value Group?

Chart 1 shows the **Lorenz Curve for the distribution of aggregate residential** wealth of homeowners by housing value groups. This distribution is quite unequal, because the nearly 23.7% who are not homeowners have no such wealth (as shown where the Lorenz curve runs along the bottom of the axis) and, of course, also because those living in higher priced housing have greater residential wealth.

²³ Using our microdata, we estimated the income elasticity of rental demand to be 0.40, so that an increase of 10% in household income would result in only a 4% rise in rental expenditure. The R2 for the log-log regression was 0.39 and the coefficient was statistically significant at the 0.001 level.

Chart 1. Metro Rio: Lorenz Curve of the Distribution of Residential Wealth by Housing Value Groups, 2010

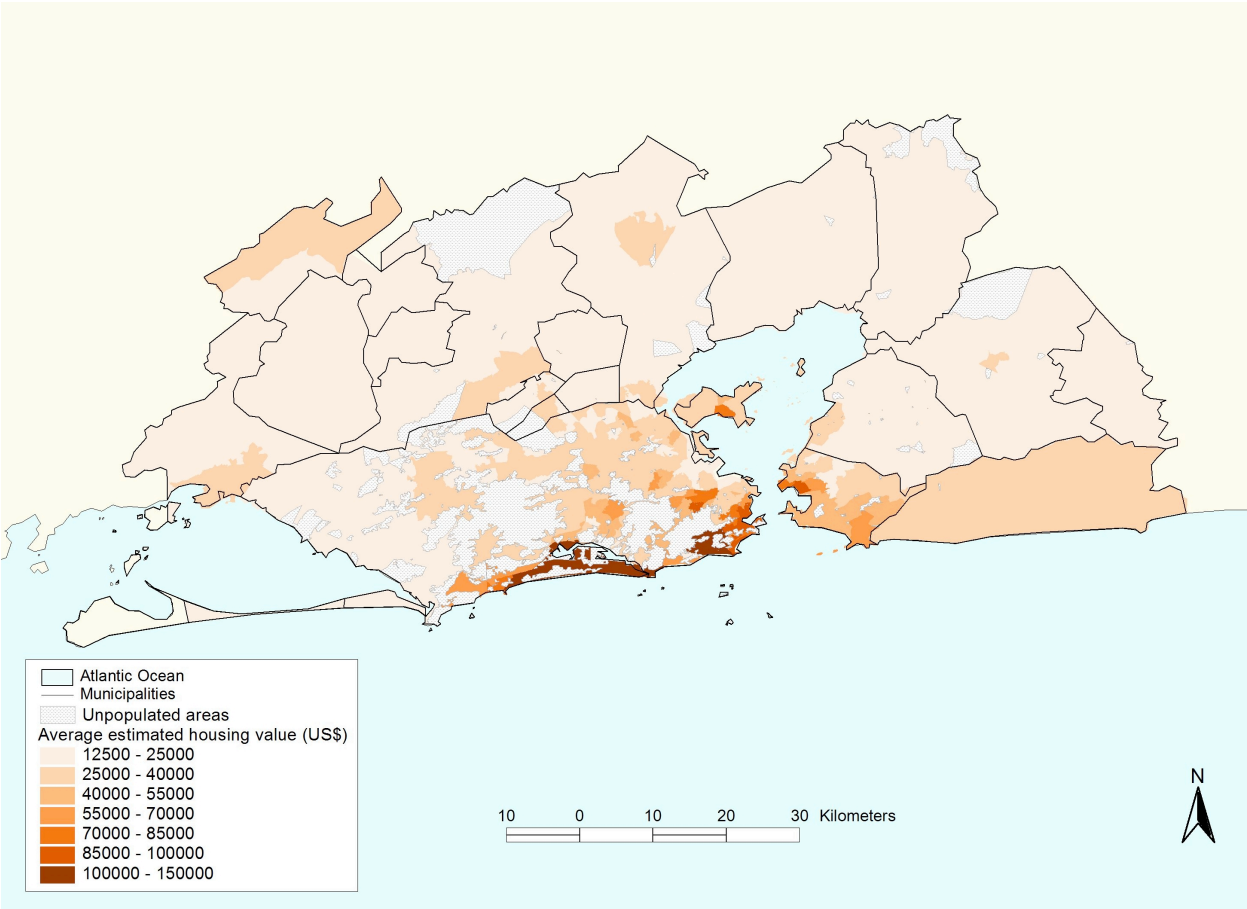


Source: Authors' calculations with 2010 Census block conditions and sample data.

7. What Is the Spatial Distribution of Residential Wealth in Metro Rio?

Map 4 shows the distribution of average housing values in US\$ estimated using our methodology. These values, of course, tend to be highest in areas of relatively low commute times (See Map 2) and good access to urban infrastructure and services.

Map 4. Metro Rio: Average Estimated Housing Values for Census Areas in US\$, 2010



Source: Authors' calculations with 2010 Census block conditions and sample data.

The bulk of aggregate residential wealth is held by those living in the suburbs and periphery, although the average value of their housing units is lower. Table 6 shows that subregions 4 and 5 (the Suburbs and Periphery) hold 79.0% of Metro Rio's total households (3.1 million) and 58.1% of aggregate residential wealth (US\$80.9 billion). Subregion 2 (the older higher income neighborhoods along the bay and coast) holds 6.3% of Metro Rio's households (about 242,000 households) and 19.0% of its residential wealth.

Table 6. Metro Rio: Homeowners of Urban Private Households—Aggregate and Average Residential Wealth and Annual Household Income, 2010

The six subregions		% Home-owners	% of total households	% of aggregate residential wealth	% of aggregate annual household income
Total		76.2	100.0	100.0	100.0
1	Center and other central areas	71.4	10.2	13.8	17.0
2	Older higher income along the bay and coast	65.7	6.3	19.0	19.0
3	Higher income expansion area along the coast	70.8	2.1	7.6	8.1
4	Suburbs	73.8	27.9	25.4	25.7
5	Large Squatter Settlements in Rio	68.7	2.5	1.4	1.0
6	Periphery	80.4	51.1	32.7	29.2

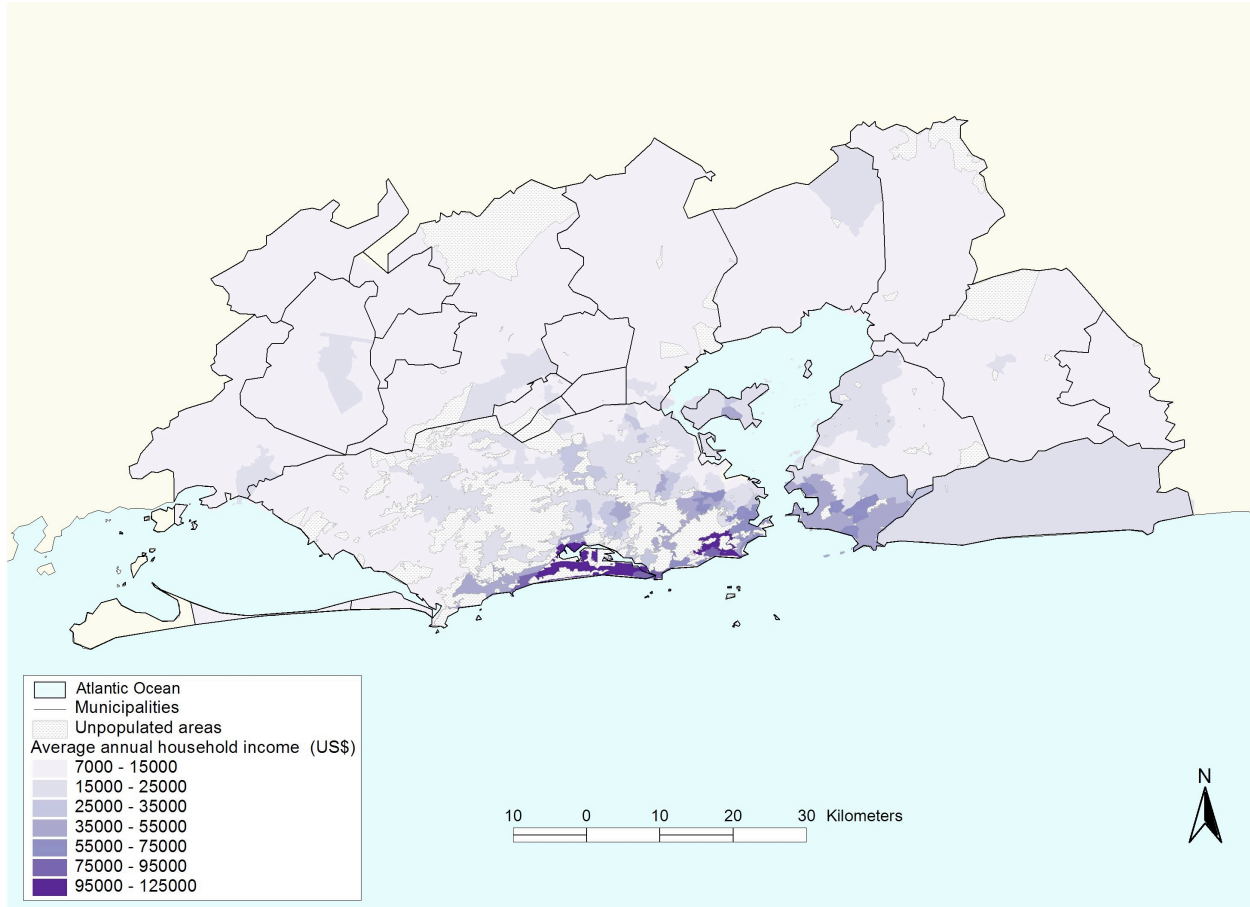
Source: Authors' calculations with 2010 Census block conditions and sample data.

Table 6 also shows the **distribution of households by tenure and the subregions**. The percentage of renters is high in the large squatter settlements (Subregion 5) at 28.6% with an additional 2.7% of rent free units. Homeownership rates are highest (80.4%) in the Periphery (Subregion 6), where many live on land for which they do not have a fully legal title, but generally not in squatter settlements as defined by IBGE.

8. What Is the Spatial Distribution of Household Income?

One result of the interplay of market forces that shape residential rent and housing prices is that the distribution of aggregate household income mirrors to a great extent the distribution of aggregate residential wealth. In other words, there is a relatively high residential segregation by income groups with the lower income families concentrated in the large squatter settlements and in the Suburbs and Periphery (Subregions 4, 5 and 6). High spatial concentration of higher income households generates higher aggregate income and demand in these areas that supports higher level services that, in turn, make these areas more attractive to higher income homebuyers and renters. Map 5 shows that the average annual household incomes for the Census Areas in 2010 reflect to a large extent the distribution of average housing values (Map 4), commute to work times (Map 2) and neighborhood attractiveness (Map 3).

Map 5. Metro Rio: Average Annual Household Incomes for Census Areas in US\$, 2010



Source: Authors' calculations with 2010 Census block conditions and sample data.

9. What Are the Implications of This Process for the Two Subregions with the Highest and Lowest Average Household Incomes?

Table 7 shows that in 2010, the high income Subregion 3 (Barra da Tijuca) held only 2.1% of total households in Metro Rio, but 8.1% of aggregate household income and 6.6% of aggregate residential wealth. Whereas, the four large squatter settlements of Subregion 5 held 2.5% of total households, but only 1.0% of aggregate household income and 1.5% of residential wealth. Nonetheless, the aggregate residential value in these four large squatter settlements was nearly US\$2 billion and the average housing value was about US\$21,000. In summary, the results show a relatively high spatial concentration of both aggregate household income and residential wealth that is tempered slightly by the homeownership in informal settlements.

Table 7. Metro Rio: Subregions 3 and 5—Summary of the Indicators of Size and Distribution of Aggregate Residential Wealth and Household Income, 2010

Indicators	Subregion 3: Higher income expansion area/ Barra da Tijuca	Subregion 5: Four Large Squatter Settlements
Number of households	80,659	97,013
% Homeowners	70.8	68.7
% of total households in Metro Rio	2.1	2.5
% of aggregate residential wealth in Metro Rio	7.6	1.4
% of aggregate annual household income in Metro Rio	8.1	1.0
Aggregate residential wealth US\$ billions	10.65	2.02
Average housing value US\$	132,262	20,954
Average annual household income (US\$)	87,194	9,349
Aggregate annual household income US\$ billions	7.0	0.9
Average commute to work time (minutes)	56.8	42.0
Average Score on Component 1	1.4	(1.0)

Source: Authors' calculations with 2010 Census block conditions and sample data.

10. Conclusions

10.1 How Useful Is This Methodology?

This methodology provides interesting insights into residential wealth's macroeconomic and social importance, as well as on the variables that generate it and its distribution among household tenure, income and housing value groups, as well as among subregions including informal settlements. The strong assumptions required in using the methodology must be taken into account when interpreting the results. The indicators generated on commute to work time and neighborhood attractiveness provide interesting insights into Metro Rio's internal structure in and of themselves

In fact, residential wealth can be interpreted as a measure (or *numeraire*) for quality of urban life generated by access to opportunities, urban infrastructure and services, and other amenities. One potential problem with using residential wealth as a social indicator is that the elimination of infrastructure and service deficits could reduce residential wealth. If there are no differences in access to infrastructure, there would be no differential rent. However, it will be many years before Metro Rio will face this issue.

10.2 What Are the Policy Implications?

Government services, investments and regulatory actions can result in benefits (e.g., access to employment, urban services and amenities) and costs (e.g., taxes, fees and negative environmental impacts) that are capitalized into the value of housing in the affected neighborhoods. For homeowners, positive net benefits from government actions increase their

residential wealth, as they are capitalized in the value of their housing. However, for renters and homebuyers, these same government actions can cause rents and housing prices to rise along with these net benefits. This can cause some households, especially the lower income renters and homebuyers, to leave the benefited area or prevent potential new ones from locating in the area. In summary, housing tenure is important in determining whether a household receives the net benefits of government investments and regulatory actions or not.

Capitalization of the net benefits of government actions would clearly be an issue for the over 30% of the households in the four large squatter settlements that are not homeowners, as well as those entering the market to buy housing. Although there are no good data on housing turnover, we know that the total number of urban households in Metro Rio increased by almost 657,000 (over 20%) during the 2000/10. This increment was 14% higher than the total number of households in the Municipality of Curitiba²⁴ in 2010 (and over twice the 2010 number of Washington DC). All of these new households plus all of the renters (about one fifth of total households) and also homeowners wishing to move would be subject to increases in rents and housing prices generated by the net benefits government actions.

So then, there is a need for policies to assure that rising rent and housing prices do not exclude renters and homebuyers from areas where public services and infrastructure are being improved. For example, financial assistance for home purchases could be part of the improvement program. One way of financing the needed lower income housing and investment programs would be to capture part of the value being generated by infrastructure investments from higher income households. In other words, capturing part of the value generated by urban infrastructure investments could help finance additional housing subsidies for lower income families, as well as added investment, thereby providing a kind of investment multiplier.

So then, a strategy based on increasing residential wealth and the equity of its distribution would be quite different from most low income housing programs that focus on increasing the number of affordable housing units. To provide such affordable units, such programs often construct units on land that is low cost because it lacks access to employment and basic urban services. The inverse would be true if the objective was to increase the residential wealth, as about two thirds of residential wealth is generated by such access to employment and basic services provided mostly by urban infrastructure. Such infrastructure could be financed in large part by capture of the value generated by it. For example, one approach would be to develop whole “smart” neighborhoods that are socially integrated and ecologically sustainable financed by value capture and providing some cross subsidies to lower income families. In summary, a residential wealth strategy could shift the focus from building housing units to developing whole neighborhoods.

²⁴ Parana’s state capital in the south of Brazil.

10.3 Future Studies

Future residential wealth studies could:

- Use data from the real property registries or other sources to complement those from the census. For example, the dependent variable could be the property value data from the property register.
- Estimate residential wealth in Metro Rio for 2000 to analyze its evolution over time.
- Calibrate separate models for the large favelas (Subregion 5) or the other subregions and compare this with the general model.
- Analyze the ownership of rental properties squatter settlements, as this would indicate that the rent payments stay within the settlement.
- Analyze all the favelas in addition to the four larger ones by generating a 2010 Census database with a binary variable indicating whether the household is located in such a settlement or not. This information exists in the census, but it was not included on the sample census file available to the public. Given restrictions to assure privacy of census results, IBGE would probably have to generate this database with only the needed data in order to prevent identification of the informants.
- Study the evolution of residential wealth over the family life cycle. For example, does residential wealth rise with age of the family head and family composition?
- Estimate residential wealth with alternative methodologies and compare the results such as done in other countries (Rosiers 2002).
- Putting the Census Area results for the dependent and independent variables on a Google Earth type map that would allow users to zoom in on specific areas.

Annex A.
Definition of Variables in the Hedonic Rent Model

Annex Table A.1. Definition of Variables in the Hedonic Rent Model

Variables	Description
Dependent variable	
Monthly rent	Natural log of monthly rent payment
Independent Variables: General characteristics of the housing unit	
Type of housing unit	
Apartment	1, if apartment; 0, if otherwise
House in a condominium or closed street ²⁵	1, if condo or closed street; 0, if otherwise
Type of materials used in walls	1, if finished masonry ²⁶ ; 0, otherwise
Rooms	
Number of bathrooms	Number of bathrooms for exclusive household use ²⁷
Water supply	
Public water system	1, if public water system piped to inside of home; 0, otherwise
Sewage system	
Public sewer system	1, if public sanitary or storm sewer system; 0, otherwise
Septic tank	1, septic tank; 0, otherwise
Adequate garbage collection	1, if there is direct garbage collection; 0, otherwise
PC with access internet	1, yes; 0, otherwise
Car ownership	1, yes; 0, otherwise
Census Area level	
Average commute to work time for employed commuters	Average commute to work in minutes of all employed commuters all households
Components: Neighborhood Characteristics	See Variables in Table 7 in the main text

²⁵ Casa de vila é o domicílio localizado em casa que faça parte de um grupo de casas com acesso único a um logradouro. Na vila, as casas estão agrupadas umas junto às outras, constituindo-se, às vezes, de casas geminadas. Cada uma delas possui uma identificação de porta ou designação própria. Casa em condomínio é a casa que faz parte de um conjunto residencial (condomínio) constituído de dependências de uso comum (tais como áreas de lazer, praças interiores, quadras de esporte, etc.). As casas de condomínio geralmente são separadas umas das outras, cada uma delas tendo uma identificação de porta ou designação própria.

²⁶ Alvenaria com revestimento—quando as paredes externas fossem de tijolo com revestimento (emboço, reboco, chapisco), de pedra, concreto pré-moldado ou aparente, como, também, as recobertas de mármore, metal, vidro ou lambris.

²⁷ Bathroom for the exclusive use of the household with a toilet and shower (or bathtub).

The Operational Definition of Squatter Settlement

IBGE defines a *favela* as an “Agglomerado Subnormal”²⁸ as a census sector composed of: A group of a minimum of 51 housing units built on land owned by others (public or private) that is, in general, characterized by high density, disorderly land use, and lacking basic public services. The debate on how to operationally define *favelas* (and other Squatter Settlements) has continued for decades. More recently, Cavallieri (2010) notes that the public sector needs data on *favelas*, while discussing some of the limitations of IBGE’s definition.

As the legality of land ownership is a key criterion for operationally defining *favelas* or other Squatter Settlements included in its definition of a “subnormal” settlement, IBGE included a question in the 2000 population census on the ownership of land on which a housing unit is located. *Favela* residents tend to declare themselves "owners" of the land, as they do not distinguish between the condition of ownership of the building and the land that it occupies.

How Effectively Do the Brazilian Microdata Models Measure Residential Wealth?

Table A.2 summarizes some of the main differences of Brazilian hedonic rent models calibrated with census or household survey microdata and models using other types of data (e.g., asking prices or from property registers). In general, the Brazilian models with microdata can provide estimates for all of the questions covered by the household survey or census which enables them to generate the estimates of residential wealth for the national wealth accounts (their original purpose). Most of the studies using other data sources cover only one city or metropolitan areas. The Brazilian microdata can also be used to analyze the distribution of residential wealth over the family life cycle and for other household characteristics in the census or PNAD, as well as among different neighborhoods within a metropolitan area (where sample size permits).

Table A.2. Comparison of the Methodologies of Hedonic Housing Models: Brazilian Studies Using Microdata Versus Other Models

Characteristics	Many hedonic housing models	Brazilian models using census and household survey microdata
Unit of analysis	Individual home sales or rents or spatial units such as neighborhoods and districts	Households and persons living in them that can be used to generate indicators for spatial units (e.g., Census Sectors or Areas)
Sources of data	Normally data from a number of sources (e.g., real estate sales, cadasters, census, crime reports).	Very large sample of renters that covers all of the needed variables
Geographic coverage	Usually, one city	Can do estimates for all urban areas covered by the census or household survey (PNAD)
Measures of s or rent	Offer prices of housing, registered sales prices, etc. Covers only the units offered for sale or that have been sold	Rents paid by all renters in the sample with a national law setting the guidelines for rental contracts
Housing characteristics covered	Cadaster or property register data may have detailed data on lot and housing unit size, building materials, etc.	Data on many characteristics including building materials, type of unit (single family or apartment), connection to public water and sewer system, garbage collection and number and type of rooms (bathrooms and bedrooms), but without data on their size or the lot size
Data on household characteristics of household members	Normally do not have data on characteristics for each household or its members and use data on the spatial unit	Can use all of the variables in the census or household survey (e.g., family income, age of head and commute times of occupied workers)

One limitation is that the census and PNADs data provide only on the number of rooms by type (i.e., bathrooms and bedrooms), but not detailed measurements of the size of the housing unit or its lot that data from property registers and cadasters used in other studies often have. In addition, the census and PNAD data show only data on the durability of the materials used in the walls (e.g., unfinished or finished masonry, wattle and daub, etc.) but not of its quality and cost (marble versus plain cement). Data from property registries or other sources with these more detailed data on unit size could eventually be used to complement these microdata (Eurostat 2013). For example, the data from the registry and census could be used to generate a database with the census tract as the unit of analysis, as is the case in other countries (Rosiers 2002).

**Annex B.
Data on Metro Rio**

Annex Table B.1. Metro Rio: Urban Households—Average Commute to Work Time of Household Members Who Commute to Work Daily and Were Employed on the Week of the Interview

Commute time groups	Employed commuters
Total	100.00%
5 minutes or less	5.90%
6–30 minutes	32.10%
31–60 minutes	33.40%
61 minutes–2 hours	23.20%
More than 2 hours	5.50%

Source: Authors' calculations with 2010 Census microdata.

Annex Table B.2. Metro Rio: Private Permanent Households in Urban Areas in Areas with Regular Street Layout by Block Conditions, 2010

Block Conditions	Total	Private permanent households in urban areas	
		With regular street layout by existence of the block condition	Without block condition, or with irregular street layout or missing value
Street lighting	100.0%	85.9%	14.1%
Street paving	100.0%	75.0%	25.0%
Sidewalks	100.0%	69.0%	31.0%
Street curbs	100.0%	71.9%	28.1%
Storm water inlets or drains	100.0%	63.3%	36.7%
Street signs	100.0%	64.1%	35.9%
Wheelchair ramp	100.0%	6.2%	93.8%
Street trees	100.0%	55.0%	45.0%
Open sewer	100.0%	7.3%	92.7%
Accumulated garbage on street	100.0%	6.0%	94.0%

Source: Authors' calculations with 2010 Census block conditions data: IBGE, Censo 2010, Características Urbanísticas do Entorno dos Domicílios

Annex Table B.3. Metro Rio: Descriptive Statistics of the Variables Used in the Principal Components Analysis of the Census Area Indicators

Variables	Average	Standard Deviation
% with street signs	63.7%	20.9%
% with street lighting	85.3%	16.5%
% with street paving	74.5%	23.1%
% with sidewalks	68.6%	25.2%
% with street curbs	71.4%	23.4%
% with storm water inlets or drains	62.9%	24.9%
% with ramps for wheelchairs	6.2%	13.3%
% with street trees	54.7%	24.8%
% with open sewer	7.2%	7.6%
% with accumulated garbage on street	5.9%	5.6%
% single family homes	68.4%	29.9%
% homes in condominiums	6.4%	5.5%
% apartments	24.5%	29.6%
% renters	19.0%	7.6%
% with finished masonry walls	88.7%	7.0%
% with public sewer system	83.3%	17.9%
% with septic tank	6.9%	8.4%
% with water from public system	87.8%	20.7%
% with water from well or spring	9.4%	17.9%
% with direct garbage collection	87.4%	12.9%
% with indirect garbage collection	10.1%	12.5%
% with PC with internet connection	43.5%	17.9%
% with car	34.9%	14.3%
Average household income (R\$)	3,288	2,913

Source: Authors' calculations with 2010 Census block conditions and sample data.

Annex Table B.4. Expanded Descriptive Statistics for the Variables in the Hedonic Residential Rent Model

Variables	Type	Matrix	Average	Standard Deviation
Natural log of monthly rent	Log		.647	0.666
Geometric mean of monthly rent (R\$)	Mean		397	
Household: House in a condominium or closed street	Binary	S	9.7%	29.5%
Household: Apartment	Binary	S	35.7%	47.9%
Household: Finished masonry walls	Binary	S	94.9%	22.1%
Household: Log of number of private bathrooms	Log	S	.154	0.33
Household: Geometric mean of number of private bathrooms	Average	S	1.17	
Census Area: Log of mean commute to work time	Log	A	3.872	0.217
Census Area: Geometric mean of commute to work time	Average	A	48	
Household: Public sewer system	Binary	N	88.6%	31.8%
Household: Septic Tank	Binary	N	5.2%	22.3%
Household: Public water system	Binary	N	92.8%	25.9%
Household: Direct garbage connection	Binary	N	88.3%	32.1%
Household: PC with access to internet	Binary	N	42.4%	49.4%
Household: Car ownership	Binary	N	27.5%	44.6%
Component 1. Overall neighborhood attractiveness	Score	N	0.168	0.962
Component 2. Lower income single family homes	Score	N	-0.159	1.137
Component 3. Higher income poor infrastructure	Score	N	0.017	0.925
Segmentation: Higher income (Subregions 2 and 3)	Binary	N	10.9%	31.1%
Segmentation: Higher income binary * log bathrooms		N	0.052	0.216
Segmentation: Higher income binary * Component 1		N	-	-
N			40,099	

Source: Authors' calculations with 2010 Census block conditions and sample data.

Annex Table B.5. Metro Rio: Resident Population and Households by Municipality and Location in Urban or Rural Areas, 2010

No.	Municipalities of Metro Rio	Resident Population			Households		
		Total	Urban	Rural	Total	Urban	Rural
	Total Metro Rio	11,835,708	11,777,497	58,211	3,905,905	3,887,894	18,011
1	Belford Roxo	469,332	469,332	-	145,677	145,677	-
2	Duque de Caxias	855,048	852,138	2,910	269,353	268,433	920
3	Guapimirim	51,483	49,746	1,737	15,741	15,223	518
4	Itaboraí	218,008	215,412	2,596	69,422	68,619	803
5	Itaguaí	109,091	104,209	4,882	33,910	32,387	1,523
6	Japeri	95,492	95,492	-	28,409	28,409	-
7	Magé	227,322	215,236	12,086	70,394	66,729	3,665
8	Maricá	127,461	125,491	1,970	42,810	42,188	622
9	Mesquita	168,376	168,376	-	53,103	53,103	-
10	Nilópolis	157,425	157,425	-	50,514	50,514	-
11	Niteroi	487,562	487,562	-	169,237	169,237	-
12	Nova Iguaçu	796,257	787,563	8,694	248,186	245,558	2,628
13	Paracambi	47,124	41,722	5,402	15,249	13,368	1,881
14	Queimados	137,962	137,962	-	42,209	42,209	-
15	Rio de Janeiro	6,320,446	6,320,446	-	2,144,445	2,144,445	-
16	São Gonçalo	999,728	998,999	729	325,882	325,624	258
17	São João de Meriti	458,673	458,673	-	147,450	147,450	-
18	Seropédica	78,186	64,285	13,901	24,256	20,120	4,136
19	Tanguá	30,732	27,428	3,304	9,658	8,601	1,057

Source: IBGE-Censo Demográfico, SIDRA, 2010.

Annex Table B.6. Municipality of Rio de Janeiro: Population and Households by Administrative Region, 2010

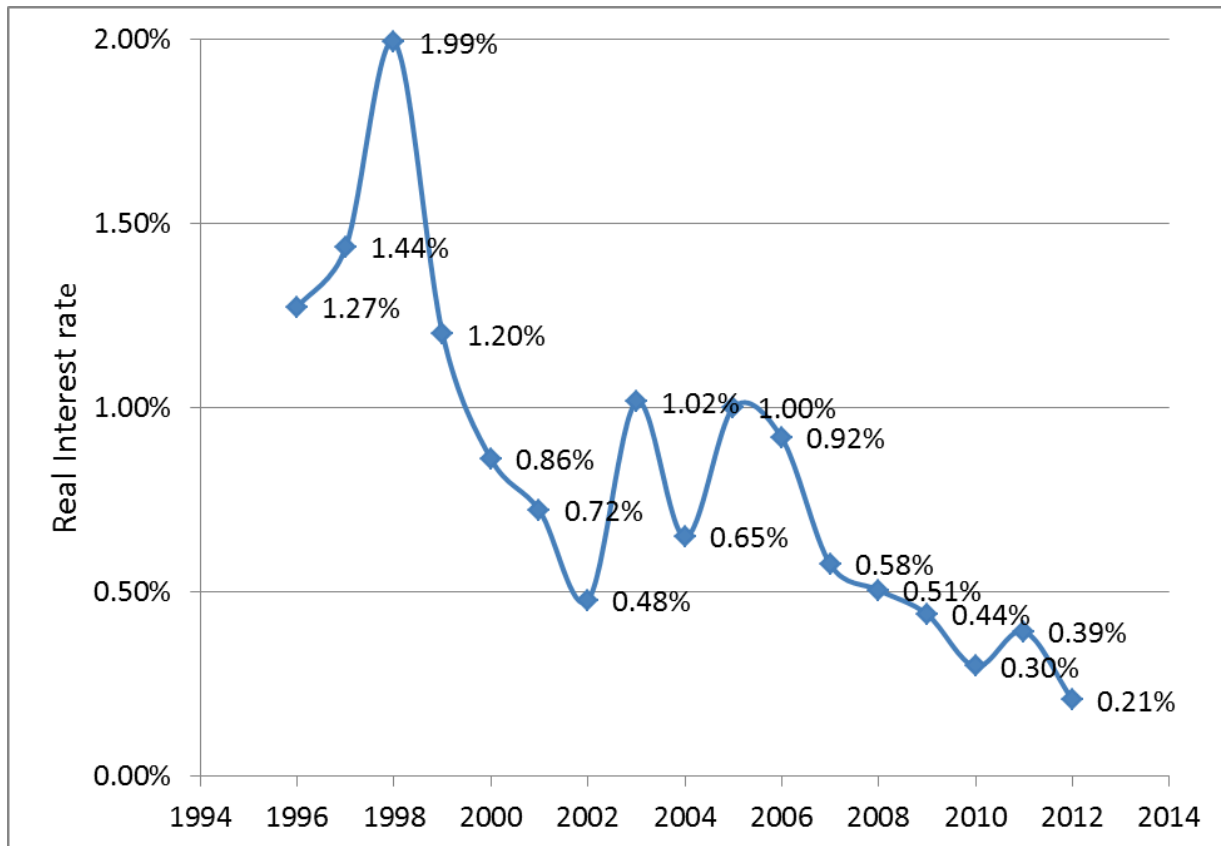
Administrative regions	Population	Households
Total	6,320,446	2,408,891
Portuária	48,664	17,368
Centro	41,142	22,646
Rio Comprido	78,975	28,553
Botafogo	239,729	113,975
Copacabana	161,191	88,587
Lagoa	167,774	78,366
São Cristovão	84,908	30,020
Tijuca	181,810	74,469
Vila Isabel	189,310	76,125
Ramos	153,177	54,581
Penha	185,716	64,566
Méier	397,782	153,174
Irajá	202,952	75,239
Madureira	371,968	137,343
Jacarepaguá	572,617	215,784
Bangu	428,035	144,764
Campo Grande	542,084	197,171
Santa Cruz	368,534	132,456
Ilha do Governador	212,574	75,786
Ilha de Paquetá	3,361	2,223
Anchieta	158,318	56,021
Santa Teresa	40,926	16,671
Barra da Tijuca	300,823	136,743
Pavuna	208,813	71,537
Guaratiba	123,114	48,605
Inhaúma	134,349	49,134
Rocinha	69,356	24,543
Jacarezinho	37,839	11,881
Complexo do Alemão	69,143	21,272
Maré	129,770	43,038
Realengo	243,006	87,406
Cidade de Deus	36,515	12,285
Vigário Geral	136,171	46,559

Source: IBGE-Censo Demográfico, SIDRA, 2010.

Annex C. The Evolution of Real Interest Rates

We calculated the real interest rate by subtracting the monthly rate of inflation as measured by the Índice Nacional de Preços ao Consumidor Amplo (IPCA) from the Selic overnight rate (Selic is the basic rate that the government pays to banks that lend them money) with data from Ipeadata. Chart C.1 shows the evolution of the average monthly real interest rates for each year in Brazil for the 1996/2012 period.

Annex Chart C.1. Brazil: Evolution of the Average Monthly Real Interest Rates for Each Year, 1996/2012



Source: Authors' calculations with data from Ipeadata.

Annex D.
The Definition of the Subregions

Annex Table D.1. Metro Rio: The Municipalities and Administrative Regions in the Subregions

Subregions	Muni Rio: Administrative Regions	Other municipalities of Metro Rio
<i>Center and other central areas in Muni Rio and the Municipality of Niteroi</i>		
	1 VIII Tijuca	Niteroi
	2 IX Vila Isabel	
	3 XXI Paqueta	
	4 XXIII Santa Teresa	
	5 VII São Cristóvão	
	6 III Rio Comprido	
	7 I Portuária	
	8 II Centro	
<i>Older higher income along the bay and coast in Muni Rio</i>		
	9 IV Botafogo	
	10 V Copacabana	
	11 VI Lagoa	
<i>Higher income expansion area along the coast in Muni Rio</i>		
	12 XXIV Barra da Tijuca	
<i>Suburbs of Muni Rio</i>		
	13 XIII Méier	
	14 XII Inhaúma	
	15 X Ramos	
	16 XI Penha	
	17 XX Ilha do Governador	
	18 XIV Irajá	
	19 XV Madureira	
	20 XXII Anchieta	
	21 XXV Pavuna	
	22 XVI Jacarepaguá	
	23 XXXIV Cidade de Deus	
<i>Large Squatter Settlements in Muni Rio</i>		
	23 XXVII Rocinha	
	24 XXIX Complexo do Alemão	
	25 XXVIII Jacarezinho	
	26 XXX Maré	
<i>Periphery</i>		
	27 XVII Bangu	Belford Roxo
	28 XXXIII Realengo	Duque de Caxias
	29 XVIII Campo Grande	Guapimirim
	30 XIX Santa Cruz	Itaguaí
	31 XXVI Guaratiba	Japeri
		Magé

		Mesquita
		Nilópolis
		Nova Iguaçu
		Paracambi
		Queimados
		São João de Meriti
		Seropédica
		Itaboraí
		Maricá
		São Gonçalo
		Tanguá

Annex Table D.2. Metro Rio: Regression with Monthly Rent (R\$) as the Dependent Variable and Binary Variables Denoting the Subregions as the Independent Variables, 2010

Variables	Coefficient	t statistic	significance
Constant	649.2	25.92	0.0001
Higher income along the bay and coast	592.4	14.41	0.0001
Higher income expansion area along the coast	798.6	13.16	0.0001
Suburbs	-212.6	-7.18	0.0001
Large Squatter Settlements in Muni Rio	-383.4	-6.63	0.0001
Periphery	-346.9	-12.42	0.0001
R2	0.77		
Degrees of freedom	330		

Source: Authors' calculations with 2010 Census block conditions and sample data.

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