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## **Evidence from the Formal and Informal Sectors**

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**Inter-American Development Bank**  
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## Abstract<sup>1</sup>

This paper describes the determinants of housing demand in Brazil, with the intention of informing policy aimed at reducing the housing deficit and increasing home ownership. As price elasticity for renters is slightly higher, public policies that aim to influence the price of dwellings and/or the income of households are expected to affect renters more than owners. Given that rent is a pro-cyclical variable and that housing-price supply elasticity tends to be low, a social housing policy focused on the rental market might be an effective option, at least in the short run, to satisfy the increasing housing demand observed in Brazil.

**JEL classification:** O54, R21, R23, R28, R31, R58

**Keywords:** Housing market, Housing policy, Brazil, Latin America, Homeownership, *Favelas*, Informality

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## 1. Introduction

Homeownership is in vogue. In developed and developing countries, policymakers increasingly speak of the benefits that come attached to owning a home. From improving public health by lowering the likelihood of outbreak and transmission of disease, to stimulating economic growth by providing workplaces for home-based entrepreneurs, to lowering crime and improving citizenship, homeownership appears to be at the center of housing policy.

Brazil is no exception. As is the case with many of its Latin American neighbors, the Brazilian government has actively pursued homeownership policies (and to a much lesser extent, rental arrangements) in the *formal* sector as housing policy objectives. However, there is evidence that Brazil, like other Latin America countries (see Fontenla and González, 2009, on Mexico), has a substantial housing deficit. With 86 percent of its total population living in urban areas and a rate of urbanization that hovers around 1.8 percent,<sup>2</sup> Brazil faces significant urban housing challenges, with an estimated deficit of between 6.4 and 7.2 million housing units<sup>3</sup> (Government of Brazil, 2010; UN Habitat, 2010; Joao Pinheiro Foundation, 2007) and increasing formation and growth of *favelas*.<sup>4</sup> Every year, according to indicators from the Brazilian Institute of Geography and Statistics (IBGE), demographic changes alone (i.e., population growth) create demand for 580,000 additional housing units among low-income households.<sup>5</sup>

Since 2003, the Federal Government has implemented various housing policies with the purpose of reducing the housing deficit among lower-income households and increasing the amount of credit available through the *Caixa Economica Federal* (CEF).<sup>6</sup> The stock of permanent dwellings has increased dramatically since then, almost doubling

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<sup>2</sup> Average rate of change in the size of the urban population between 2005 and 2010 (estimate), according to the *Instituto Brasileiro de Geografia e Estatística* (IBGE).

<sup>3</sup> UN Habitat (2010) estimates the housing deficit to be made up of 1.5 million poor households, 2.5 million families in cohabitation, 2 million houses with excessive rent, and 0.4 million houses in excessive density.

<sup>4</sup> In Brazil, the term *slums* is usually used to describe what are known as *favelas*. However, as pointed out by Lall et al. (2006, p.3), slums include *favelas*, *cortices*—“high-density collective housing in city centers”—and irregular *loteamentos*—“usually developed in peripheral areas irregularly, if not illegally”. In spite of the differences, in this paper the terms *slums* and *favelas* are used interchangeably. By one estimate, one-sixth of the population of Sao Paulo—around 1.5 million people—currently lives within the city’s over 1,700 *favelas* (UN Habitat, 2010).

<sup>5</sup> Brazilians earning up to 3 minimum wages per month. In 2008, the minimum wage was 415 *reais* or about U\$177.58 per month.

<sup>6</sup> One of the most celebrated programs is named “Minha Casa Minha Vida.”

in the North, and rising by around 10-15 percent elsewhere.<sup>7</sup> However, the housing deficit remains high and concentrated among households with monthly income less than three minimum wages, and much of this is concentrated in slums.<sup>8</sup>

There is some evidence that the large increase in ownership of permanent dwellings in Brazil over the first decade of this century has been associated with a strong decline in poverty<sup>9</sup> and reduction in income inequality,<sup>10</sup> and with increasing formalization of labor.<sup>11</sup> There are two important transmission mechanisms at work here. First, rising real incomes among lower-income groups reduce what Angel (2000) calls “lack of affordability.” In other words, the observed reduction in poverty and inequality as well as the increasing formalization in the labor market may have boosted housing demand by relaxing the “affordability constraint.” Secondly, as the extent of poverty, inequality, and informal employment is reduced, low-income households face lower constraints in terms of acquiring formal dwellings. It can be argued that efforts geared at increasing access to credit by the poor (e.g., *Caixa Econômica Federal*) constitute an important piece of the picture. This, in turn, means access to collateral, which increases participation in the formal credit markets (Besley, 2008; de Soto, 2000), as well as consumption-smoothing capabilities through asset holding. Thus the well-rehearsed arguments for homeownership appear to have some support in the Brazilian case.

Parallel to the problem of the high housing deficit is the issue of tenure security. Approximately 5.5 percent of the national population (or around 7.6 million individuals) live in dwellings without formal property rights. Again, tenure insecurity is highest in *favelas*: around 26 percent of households in *favelas* have no tenure security compared to around 5 percent of households living in formal housing.

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<sup>7</sup> Data from [www.ipeadata.gov.br](http://www.ipeadata.gov.br)

<sup>8</sup> Out of a 10.8 percent housing deficit in urban Brazil, about half is concentrated within *favelas*. This situation is worse in the North, where over 60 percent of housing deficit is concentrated in *favelas* (João Pinheiro Foundation, 2007, Tables 3.1 and 3.4).

<sup>9</sup> Brazil does not have an official poverty line. Some authors, such as Barros et al. (2010) and Neri et al. (2007), use regionalized poverty lines. In this paper we define the poor as people living on less than half the minimum wage, in line with Lavinhas et al. (2001).

<sup>10</sup> See Piza et al. (2011) for details.

<sup>11</sup> Abramo (2003) also establishes a connection between labor market and housing market. He argues that informality in labor markets helps to explain the demand for informal dwellings and, to some extent, the increase in slum areas.

It is this dualistic feature of the Brazilian urban housing market that we wish to incorporate into our analysis.<sup>12</sup> This paper aims to provide evidence on the determinants of housing demand in Brazil, with the intention of informing policy aimed at reducing the housing deficit and increasing home ownership. Given recent rapid increases in housing prices in metropolitan areas of Brazil, this analysis acquires some urgency. Our contribution to the somewhat extensive literature on housing demand is that we estimate the income and price parameters of housing demand for 10 metropolitan areas of Brazil separately for owners and renters. As far as we can ascertain, ours is the first study to compare housing demand in the rented sector with that of the ownership sector. We use a Box-Cox transformation, as is now standard in the empirical literature (see, e.g., Fontenla and González, 2009), to allow for non-linearities in the model. In addition, we control for selection bias by first modeling tenure choice and incorporating in to the demand models selection terms for the formal vs. informal<sup>13</sup> sector. Although earlier studies have done this (see, for example Goodman, 1988) more recent studies have ignored the possibility of selection effects (Ermisch et al., 1996, is an exception). Our estimates are broadly in line with other estimates obtained in the empirical literature for developing countries, with some caveats that we discuss below.

Because there are two key steps in our analysis, i.e., understanding tenure choice and estimating housing demand, two related literatures are reviewed here. The literature on tenure choice spans some four decades of research. In 1972, Kain and Quigley analyzed the effects of spatial segregation and racial discrimination on homeownership differences in Missouri, USA. They found that blacks pay more than whites for dwellings of similar quality, and that blacks, single females, larger households, and women-headed households are less likely to own their homes. Li (1977) shows that income, household size, age, and race are the primary determinants of homeownership. Rosen (1979) and Goodman (1988) explain that the user costs associated with owning vis-à-vis renting significantly affect the tenure decision. Iwarere and Williams (1991) find that permanent income, housing prices, wealth, and demographic variables significantly affect housing

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<sup>12</sup> See Piza et al. (2011) for an earlier version, which contains broadly similar estimates and a more detailed discussion of some of the trends in ownership and policy interventions.

<sup>13</sup> The term informal lacks a precise definition, being used to describe housing with no tenure security, temporary housing, or housing lacking certain physical attributes or access to services. We discuss this in more detail in Section 2.



tenure. Ioannides (1987) earlier concluded that wealth and homeownership are positively correlated. Painter et al. (2001) show that endowment differences in income, education, and immigrant status explain the homeownership gap between Latinos and whites in Los Angeles.

While these studies pertain to developed countries and focus on housing arrangements that take place within the context of the formal sector, the need is pressing for similar studies of developing countries to include considerations for the informal sector. In developing countries, the variety and incidence of informal tenure arrangements—squatting, purchase of illegal sub-divisions, renting a bed or a room, shared arrangements—demands the analysis to be more inclusive. To do otherwise would be to ignore an important sub-group of the population: the *house poor* (Gilbert, 1993).

Van Lindert and Van Westen (1991), analyzing housing shelter strategies of low-income groups in Bamako and La Paz, argue that both “choice” and “constraint” arguments can apply to different social categories in the same income bracket. In Bamako, households without financial constraints to secure homeownership chose to continue renting. In La Paz, many *conventillo* inhabitants prefer to remain in their centrally located rental dwellings rather than become owners in the periphery. Grootaert and Dubois (1988) find that stage in the life cycle and mobility are the two prime determinants of tenancy status in Ivory Coast. Along similar lines, Arimah (1997) concludes that income, investment motivation, number of children, the gender of the head of household, life-cycle variables, duration of stay in the city, and access to land are the main determinants of housing tenure in Ibadan, Nigeria. Jacobs and Savedoff (1999) show that life-cycle variables influence the decision between owning and renting, whereas choosing between buying a complete housing unit and progressively building it depends on income and asset levels.

Furthermore, based on research in three informal *barrios* in Resistencia, Argentina, Coccato (1996) finds that rental and sharing arrangements increase the number of choices for those who cannot buy and for those who are in search of job opportunities. Meanwhile, renting also provides a means of income generation or financing for poor owners. Gilbert (1993) criticizes the approach taken by Latin American governments to encourage owner-occupation at the expense of other forms of housing tenure that could

increase living standards. He adds that rental arrangements must be considered as part of the policy mix. In this spirit, the World Bank (1993) states that an effective housing policy must consider a multiplicity of solutions to meet housing demand.

With respect to housing demand, Malpezzi (1999) provides an extensive review of housing demand studies in developing countries (see also Malpezzi and Mayo, 1987). Using cross-sectional data, most suggest that income elasticity is an important determinant of housing demand both in terms of owners and renters. For owners, the income elasticity appears to range between 0.6 and 1.2. For renters, the income elasticity is estimated at between 0.4 and 0.8. In both cases, permanent income elasticities tend to be higher than temporary income elasticities. Generally, price elasticities, when reported, are lower (in absolute terms) than income elasticities, and housing demand is price-inelastic. One of the most up-to-date studies on a developing country is that by Fontenla and González (2009) on Mexico. Their empirical findings show that housing price plays a significant but relatively small role in explaining housing demand (they derive an estimate of the price elasticity of housing demand of -0.3). Like Brazil, Mexico has a sizeable housing deficit, which would tend to dampen price elasticity. The authors also find that permanent income plays a much larger role in explaining housing demand than temporary income (the respective elasticities are 0.8 and 0.04).

These studies provide us with a benchmark for our own estimates of the income and price elasticities and other parameters. In the next section we describe our data set and the construction of some key variables. In Section 3 we outline the methodology for estimating housing demand and present our results. Our analysis is conducted for owners and renters separately, and the final estimation follows four steps as discussed in detail below. Section 4 concludes.

## **2. Data**

The data come from the Brazilian National Household Survey, the PNAD (*Pesquisa Nacional por Amostra de Domicílios*) of 2008, an annual household survey conducted by the Brazilian Bureau of Statistics (IBGE) that covers around 150,000 dwellings and about 500,000 individuals in Brazil. Although this survey constitutes one of the main sources of household microdata in Brazil, there are some disadvantages in this database as far as

analyzing the housing sector is concerned. For example, the PNADs do not report on the size of the dwelling in square meters or the value of dwellings, and there is no information on access to credit. Nevertheless, the PNAD is the only annually nationally representative survey that permits an analysis of housing demand in Brazil, and it does contain a number of highly pertinent variables. The data allow us to distinguish between households that own or rent their homes, and for owners, whether the owner has tenure security. We have detailed information on each household's socioeconomic characteristics, demographic data,<sup>14</sup> household income, and labor force status. Principal component analysis was used to compute what is usually referred to in the literature as a "wealth index," and here summarizes a vector of durable goods, including radio, stove, washing machine, computer, refrigerator, and freezer as well as access to the Internet, mobile phone, landline, and number of bathrooms in the dwelling. In terms of housing demand, we have data on monthly rent paid for housing (not including housing services such as water and electricity), and we estimate imputed rent for owned households (in the absence of any data on house values, mortgages, etc.).

Two important decisions need to be made for our analysis. First we need to be able to distinguish between formal and informal status, because we believe this to be a source of selection bias in our housing demand estimates. Secondly, we wish to be able to identify credit-constrained households in our tenure choice model. Neither of these is straightforward.

Dowall (2006) suggests a framework combining the lack of access to infrastructure services, physical characteristics of dwellings, and tenure security as an alternative way of defining a dwelling as *informal*. Although this is a useful framework, in practice, this identification is not easily determined. For instance, regarding the PNAD, information about tenure security is not available for rented dwellings. As a result, focusing exclusively on tenure security would render very imprecise measures of

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<sup>14</sup> The PNAD does not ask the head of household if he/she is married or not. However, we are able to identify if the household is a single head or a couple with or without children. In our tenure choice model we include four dummies for different types of households. *Couple1* is a dummy for a couple without children, *Couple2* for couples with children under 14 years old, *Couple3* for couples with children older than 14 years old, and *Couple4* for couples with children in both age groups. The base group is "Single."

informal housing in Brazil.<sup>15</sup> Similarly, if we define informality according to physical characteristics of dwellings, the hedonic price (and rent) models estimated below will produce misleading estimates since many variables will be dropped due to perfect collinearity.

Hence, we focus on access to services as possible indicators of informality. The João Pinheiro Foundation (JPF, 2007) classifies as *inappropriate dwellings* those with no access to *at least* one of the following basic services: electricity mains, water mains, garbage collection, and sewerage system (either via the mains system or a septic tank). Table 1 illustrates access to these basic public services, in *favelas* and in other areas, and by tenure security.

**Table 1. Access to Public Services in Urban Areas and *Favelas***

|  | <i>Other Areas</i> |                 | <i>Favelas</i>    |                 |
|--|--------------------|-----------------|-------------------|-----------------|
|  | Tenure Insecurity  | Tenure Security | Tenure Insecurity | Tenure Security |
| Sewerage = general network or septic tank    | 0.62               | 0.62            | 0.58              | 0.57            |
| Water Network = general network distribution | 0.93               | 0.93            | 0.97              | 0.88            |
| Garbage Collection = daily collected garbage | 0.78               | 0.89            | 0.63              | 0.78            |
| Electricity                                  | 1.00               | 1.00            | 1.00              | 1.00            |

Source: IBGE-PNAD, 2008.

Even dwellings with tenure security have relatively limited access to a sewage disposal system and garbage collection services. Access to a sewage disposal system is the indicator with the lowest level of penetration and according to Biderman (2008), sewerage connection is likely to be a reasonable proxy for informal housing for the Brazilian case.

Consequently, we decided to define informal dwellings as those without access to sewerage connection. This decision is not, of course, exempt from criticism since it may under or overestimate the true extent of informal housing in Brazil. Furthermore, dwellings in *favelas* will not be regarded as informal *per se*. However, Table 1 shows that

<sup>15</sup> This might be why the estimates of tenure insecurity mentioned in Section 1 are so low—they neglect the rented sector.

in fact there are many dwellings in *favelas* that can be considered formal by various criteria. Hence, since the definition proposed in this paper is in line with what is suggested by JPF and many other authors (Dowall, 2006, and Biderman, 2008, among others) and provides a way of identifying rented dwellings as formal or informal, we believe that there is sufficient support for its use.

Using this classification of formal and informal dwellings, we obtain the following distribution of households across tenure type. Using this classification, we estimate that 30 percent of households are informal.<sup>16</sup>

**Table 2. Households by Formality of Occupation**

|                  | Number of households | Percent of sample |
|------------------|----------------------|-------------------|
| Formal Owners    | 36,960               | 54.25             |
| Formal Renters   | 10,759               | 15.79             |
| Informal Owners  | 16,306               | 23.93             |
| Informal Renters | 4,102                | 6.02              |
| Total            | 68,127               | 100               |

*Source:* IBGE-PNAD, 2008.

Regarding credit constraints, unfortunately the PNAD does not report any variables that might allow us to test explicitly the effect of access to credit on housing demand. However, as shown by Linneman and Wachter (1989), the omission of credit constraints in a tenure choice model of homeownership will likely imply an omitted variable bias. In this case, the coefficient of permanent income tends to be higher than it would have been had credit constraints been taken into consideration in the model.

In order to circumvent this problem, we used status in labor market as a proxy for “credit constraint.” We considered informal sector workers as more credit constrained than formal sector workers given that in most cases access to housing finance is linked to the status of the worker in the labor market. We define “lack of affordability” as a dummy for households with a gross monthly income not more than three minimum wages. This aims to capture lack of affordability and has been included because there seems to be a direct connection between poverty and the quality of housing demanded by

<sup>16</sup> Dowall (2006) uses the access to infrastructure as proxy for informal housing in Brazil and find that the proportion of informal dwellings varies sharply between metropolitan regions. While in Sao Paulo the proportion is around 10 percent, in Recife it is over 50 percent.

households (see Angel, 2000) and also because of the high concentration of housing deficit among households whose gross monthly income is not more than three minimum wages.<sup>17</sup> We also considered using an interaction between gender and labor market status to pick up possible credit constraints. However, given the low participation of women in formal labor markets (and an even smaller proportion of non-white women), we concluded that this was unlikely to yield useful results. Thus, we used status in labor market as a proxy for credit constraints rather than any interaction term with race and/or gender.<sup>18</sup> Using these two dummies (informal sector worker and low income), we hope to capture some effects of credit constraints and affordability in the tenure choice model.

In Table 3, we present summary statistics of the main variables used in our analysis of housing demand according to each of these tenure types.

**Table 3. Descriptive Statistics**

| Variable                                     | Formal Owners |           | Formal Renters |           | Informal Owners |           | Informal Renter |           |
|--|---------------|-----------|----------------|-----------|-----------------|-----------|-----------------|-----------|
|  | Mean          | Std. Dev. | Mean           | Std. Dev. | Mean            | Std. Dev. | Mean            | Std. Dev. |
| Age of the head                              | 43            | 12        | 37             | 11        | 41              | 11        | 35              | 10.50     |
| Years of schooling of the head               | 7.96          | 3.34      | 8.60           | 3.11      | 7.39            | 3.34      | 7.83            | 3.22      |
| Male head                                    | 0.69          | 0.46      | 0.66           | 0.47      | 0.70            | 0.46      | 0.71            | 0.45      |
| Non-white head                               | 0.49          | 0.50      | 0.52           | 0.50      | 0.62            | 0.49      | 0.60            | 0.49      |
| Couple 1                                     | 0.16          | 0.37      | 0.18           | 0.38      | 0.14            | 0.35      | 0.18            | 0.38      |
| Couple 2                                     | 0.25          | 0.44      | 0.33           | 0.47      | 0.32            | 0.47      | 0.38            | 0.49      |
| Couple 3                                     | 0.23          | 0.42      | 0.09           | 0.28      | 0.19            | 0.39      | 0.08            | 0.27      |
| Couple 4                                     | 0.11          | 0.31      | 0.07           | 0.26      | 0.12            | 0.33      | 0.08            | 0.26      |
| Informal worker ( <i>Credit Constraint</i> ) | 0.64          | 0.48      | 0.57           | 0.50      | 0.69            | 0.46      | 0.61            | 0.49      |
| Public servant                               | 0.06          | 0.23      | 0.05           | 0.21      | 0.07            | 0.25      | 0.04            | 0.21      |
| Formal worker                                | 0.36          | 0.48      | 0.43           | 0.50      | 0.31            | 0.46      | 0.39            | 0.49      |
| Formal domestic worker                       | 0.02          | 0.12      | 0.02           | 0.15      | 0.01            | 0.11      | 0.03            | 0.17      |
| Employer                                     | 0.04          | 0.20      | 0.04           | 0.19      | 0.04            | 0.21      | 0.04            | 0.19      |
| Gross Monthly household income               | 1,675         | 1,113     | 1,506          | 1,043     | 1,323           | 926       | 1,235           | 898       |
| Wealth index                                 | 0.21          | 1.5       | -0.44          | 1.48      | -0.63           | 1.38      | -1.05           | 1.32      |
| Number of household members                  | 4             | 1         | 3.23           | 1.45      | 3.81            | 1.48      | 3.35            | 1.47      |

Source: IBGE-PNAD, 2008.

<sup>17</sup> See Piza et al. (2011) for details.

<sup>18</sup> We would like to thank Bouillon and Dowall for this suggestion.

Table 3 shows that renters are younger and better educated than homeowners in both the formal and informal housing sectors. They are also less likely to be more credit constrained than homeowners. Female-headed households are more likely to own a dwelling than male-headed households. Around 53 percent of owners of formal dwellings are female, and this proportion holds for others kinds of ownership: formal rent, informal homeowners, etc.

### **3. Estimating Housing Demand**

This section presents the four steps suggested by Goodman (1988) for a consistent estimation of housing demand price and income elasticities. As discussed in Goodman and Kawai (1984), Goodman and Kawai (1986), and Ermisch et al. (1996), consistent estimates for price and income elasticities of housing are key information to support the design of effective housing public policy. For instance, low price elasticity of demand among owners would suggest that any intervention that results in lower prices would have little effect. An income elasticity close to unity might suggest that a small change in income may be a better approach to increasing home-ownership.

The first step consists of estimating a human capital model to disentangle permanent from temporary income. Many studies have shown that housing demand is more responsive to permanent than temporary income and, hence, the income elasticity would be more precisely estimated by permanent income rather than current income. The second step consists of estimating the hedonic price model. The hedonic price model is an important step because it allows us to compute a price index when more than one market has been considered. In this paper, we are working with ten markets that are represented by metropolitan areas.

The third and fourth steps focus on housing demand. Goodman (1988) included a tenure choice model before estimating housing demand.<sup>19</sup> He argued that the housing demand model should include a correction term because tenure choice is not random and there is selection into particular markets. Since we are dealing with rental as well as ownership markets, we model the choice between each market separately using a probit

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<sup>19</sup> Ermisch et al. (1996) do the same for Britain.

model.<sup>20</sup> Goodman and Kawai (1984), Zabel (2004), and Fontenla and González (2009) estimated the housing demand in three steps, missing the estimation of a selection term. The fourth and final step is the estimation of housing demand.

### 3.1 Permanent Income Model

The aim of the permanent income model is to disentangle the permanent from transitory income as permanent income seems to play the main role in terms of explaining the elasticity of housing demand. Permanent income is given by the predicted value of the following model:

$$\frac{y^\theta - 1}{\theta} = \alpha + \beta_1 \frac{age^\lambda - 1}{\lambda} + \beta_2 \frac{educ^\lambda - 1}{\lambda} + \delta' X + \varepsilon,$$

where  $\varepsilon \sim N(0, \sigma^2)$  and  $\theta, \lambda \in (-\infty, \infty)$ . The dependent variable is transformed by the parameter  $\theta$  while the strictly positive continuous independent variables are transformed by the parameter  $\lambda$ . The variable *age* refers to the age of the head, *educ* stands for years of schooling of the head, and the *X* vector includes a set of dummies, such as gender of the head, race of the head, if the head is a public servant, a formal worker, the occupation variables, the proxy for credit constraint, and if the household lives in the metropolitan area. The vector also includes dummies for regions. The base group is white, female, self-employed, and Sao Paulo metropolitan area.

The Box-Cox transformation is a very flexible way of estimating empirical models since it embeds many widely used functional forms, such as semi-log, linear and multiplicative inverse. The linear case occurs when  $\theta = \lambda = 1$  whereas the semi-log (or log-linear) emerges for the case in which  $\theta = \lambda \rightarrow 0$ . Finally, for  $\theta = \lambda = -1$  the functional form becomes the inverse multiplicative.

Table A.1 in the appendix presents the Box-Cox estimates for determinants of permanent income for heads living in formal and informal housing, respectively.

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<sup>20</sup> In Piza et al. (2011), we also estimate a multinomial logit model for tenure choice. Our results are in line with the literature covered by Malpezzi (1999) and suggest, for instance, that life cycle, income, household size, affordability, credit constraints, wealth, and neighborhood characteristics matter in the decision of the head of whether to own or rent a dwelling.



### 3.2 The Hedonic Price Model

Once the permanent income model is estimated, we can include the new variable “permanent income” on the right-hand side of the hedonic “price” (rent) model. The estimation of hedonic price is essential in the present case because the estimation of housing demand depends on the availability of price index at metropolitan regions level, given that the regions are quite heterogeneous in terms of infrastructure and socioeconomic characteristics of the households.

The estimation of the hedonic price model is based on the following reduced-form model:<sup>21</sup>

$$\frac{\pi^\theta - 1}{\theta} = \alpha + \beta_1 \frac{age^\lambda - 1}{\lambda} + \beta_2 \frac{educ^\lambda - 1}{\lambda} + \beta_3 \frac{(y^p)^\lambda - 1}{\lambda} + \beta_4 \frac{\#Rooms^\lambda - 1}{\lambda} + \beta_5 \frac{\#Bedrooms^\lambda - 1}{\lambda} + \beta_6 \frac{\#Bath^\lambda - 1}{\lambda} + \beta_7 \frac{density^\lambda - 1}{\lambda} + \gamma'Z + \varphi$$

where  $\varphi \sim N(0, \sigma^2)$  and  $\theta, \lambda \in (-\infty, \infty)$ . The dependent variable is the rent value transformed by the parameter  $\theta$  while the continuous independent variables strictly positive are transformed by the parameter  $\lambda$ .  $Z$  is a column vector that includes a dummy for male head, a dummy for non-white head, temporary income, dummies for access to public services, neighborhood characteristics (imperfectly proxied by the share of households in the metropolitan area with monthly income per capita lower than half of a minimum wage in 2008), and a set of dummies for the metropolitan regions.

The house’s structure is captured by the strictly positive continuous independent variables. The Brazilian Statistics Bureau, IBGE, states that an adequate dwelling is one with walls constructed with cement or processed wood and roofs with tile or cement. The size of dwelling corresponds to the number of bedrooms and number of other rooms, number of bathrooms and number of members of family per bedroom (density per bedroom).<sup>22</sup>

<sup>21</sup> For precarious dwellings in the metropolitan regions of Bahia and Minas Gerais, we had to replace the Box-Cox specification by models specified as semilogs because the estimations did not converge when we used the Box-Cox method.

<sup>22</sup> Although the fact that the permanent income is an estimated regressor in the hedonic price model and therefore its standard errors should be computed with the bootstrap technique (see Wooldridge, 2002), it is not possible to run a bootstrap using a weighted sample. Thus, we decided to keep the sample weighted and

Given that there are 10 metropolitan regions and each of them is taken as a distinct market, we estimate 10 hedonic price regressions for formal renters and another 10 for informal renters.<sup>23</sup> Table 4 summarizes the elasticities across markets. We have taken a weighted average of the coefficients in the 10 regressions and computed the elasticities at median values of the continuous variables.<sup>24</sup>

**Table 4. Elasticities at Median**

| TRANSFORMED VARIABLES       | <i>Formal</i> |              | <i>Informal</i> |              |
|-----------------------------|---------------|--------------|-----------------|--------------|
|                             | <i>Renter</i> | <i>Owner</i> | <i>Renter</i>   | <i>Owner</i> |
| Number of bathrooms*        | 0.188         | 0.177        | 0.059           | 0.057        |
| #Bedroom                    | 0.245         | 0.23         | 14.7            | 0.14         |
| #Rooms (excluding bedrooms) | 0.714         | 0.88         | 1.34            | 2            |

\* The number of baths is not strictly a continuous variable given that its maximum value is 2. Even so its elasticity has been computed.

The first column reports the elasticities for formal rented dwellings. Doubling the median number of bathrooms (1 to 2) increases the dwelling price by 19 percent. Increasing of number of bedrooms from 2 to 4 raises the price of a dwelling by 25 percent. Finally, a 20 percent increase in the median number of other rooms (excluding bedrooms), from 5 to 6, raises the price of a dwelling by 14 percent. Therefore, the price of a dwelling is very inelastic with respect to these three characteristics. It is a bit more responsive, though, to the number of rooms.

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use a standard algorithm to compute the standard errors given that the main results did not change. The estimates with bootstrapped standard errors are available upon request.

<sup>23</sup> The 20 hedonic regressions are not shown here but are available upon request.

<sup>24</sup> Since we have used Box-Cox method to run the hedonic “price” (rent) regressions, the elasticities for transformed variables,  $x$ , are computed as follows:

$$\eta_x \equiv \frac{\partial \pi}{\partial x_k} \frac{x_k}{\pi} = \beta_k \frac{x_k^\lambda}{\pi^\theta}$$

For non-transformed independent variables, the elasticities are given by:

$$\eta_z \equiv \frac{\partial \pi}{\partial z_j} \frac{z_j}{\pi} = \psi_j \frac{z_j}{\pi^\theta}$$

For dummy variables, we have followed Fontenla and González (2009) and computed the percentage change in the dependent variable given a change in the dummy variable. That is,  $\frac{\partial y / \partial z_k}{\pi} = \frac{\psi_k}{\pi^\theta}$

Except for the magnitude of elasticity of other rooms, the estimates reported to formal rental dwellings are higher (similar pattern emerges for owned dwellings). In other words, the price is less elastic to those dwelling characteristics in the informal part of the housing market than in the formal part. Maybe this is because the informal (or precarious) housing market has been defined according to sewerage connection. In this case, an additional bath in a dwelling without sewerage connection does not seem to affect the rent of dwelling as it does when sewerage connection is present.

Abramo (2003) argues that the housing price in slum areas is higher relative to formal dwellings due to the low supply elasticity of housing in slum areas. In this case, it is likely that the rental of dwellings in slum areas should be high enough to be substantially affected by an additional room or bath. This argument could be partially applied to our case since a higher number of precarious numbers tend to be concentrated in slum areas when compared to other areas.

Figure A.1 illustrates the rent values in formal and informal dwellings for each of the 10 metropolitan regions. As expected, Figure A.1 shows that rent values in informal dwellings are lower than rents in formal dwellings.

Figure A.2 illustrates the rent index by metropolitan region. The rent index is computed dividing the rent predicted by the hedonic “price” (rent) model by the rent of informal dwellings in metropolitan region of Sao Paulo, the base group. Put another way,

$$p_j = \frac{v(H_n; \beta_j)}{v(H_n^*; \beta_i)} \times 100,$$

where the rent of the house,  $v(\cdot)$ , expresses the flow of services provide by the house and it depends on  $H_n$ , a vector of housing and neighborhood characteristics. The  $\beta_j$  vector is the vector of unknown parameters. The variable  $v(H_n^*; \beta_i)$  is the average rent of a standard precarious dwelling in the Sao Paulo metropolitan region.<sup>25</sup> Notice that in the Sao Paulo metropolitan area  $p_j = p_i = 100$ .

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<sup>25</sup> The price of informal dwellings in the metropolitan region of Rio Grande do Sul has been dropped because it is an outlier.

According to Figure A.2, for the most cases, the renters of non-precarious dwellings are paying less than 100 to rent a housing of constant quality because the ratio is lower than a unit. In this case, the division of the rental of a typical dwelling by a number smaller than one will render a value higher than the true rent. This means that the renters of formal dwellings are paying less for dwellings they occupy than these dwellings are really worth (Angel, 2000). For the same reason, the renters of a typical informal dwelling are living in houses worth less than what they are paying for them.<sup>26</sup>

### 3.3 Housing Demand for Renters

This section describes the third and fourth steps of the estimation of housing demand model. Now we have an estimate for permanent and temporary income and the price of house, we are able to use this set of variables as the main covariates in the housing demand model. However, according to Goodman (1988) and Ermisch et al. (1996), tenure choice and housing demand are simultaneous decisions taken by households. Therefore, a housing demand model should include a correction term in the right-hand side of the demand model. In his paper, Goodman (1988) uses a probit model to estimate the first step and then includes the inverse Mill's ratio as an additional regressor in the Box-Cox specification of housing demand. Thus, the model would be specified as follows:<sup>27</sup>

$$\frac{q_j^\theta - 1}{\theta} = \alpha + \beta_1 \frac{p^\lambda - 1}{\lambda} + \beta_2 \frac{(y^P)^\lambda - 1}{\lambda} + \beta_3 \frac{age^\lambda - 1}{\lambda} + \beta_4 \frac{hhsizel^\lambda - 1}{\lambda} + \psi'X + \rho \frac{\overline{\phi(Z)}}{\Phi(Z)} + \varepsilon$$

where  $\varepsilon \sim N(0, \sigma^2)$  and  $\theta, \lambda \in (-\infty, \infty)$ .

The dependent variable is given by the division between the value of the housing unit  $n$  in the  $j$ -th market by the  $i$ -th household and the price index in the  $j$ -th market,  $p_j$ , i.e.  $q_{ij} = v_{nj}^i / p_j$ . The quantity of housing is then transformed by the parameter  $\theta$  while the continuous independent variables strictly positive are transformed by the parameter  $\lambda$ . The variable  $p$  is the price index, the  $y^P$  variable is the permanent income, and age is the

<sup>26</sup> Figures A.3 and A.4 replicate the analysis for owners.

<sup>27</sup> Given that we have four computed regressors on the right hand side – permanent income, transitory income, wealth index, and the inverse Mill's ratio – the standard errors are computed by bootstrapping with 100 replications. See Piza et al. (2011) for more details.

age of the head of the household. Household size refers to the number of members in the household.

The vector  $X$  includes the non-transformed variables as well as additional controls, such as: dummies for gender and skin color, temporary income, and dummies for metropolitan areas. We opted to exclude the metropolitan region of Distrito Federal as the price index suggests that it is an outlier. This is likely true given that Brasilia, the capital of Brazil, display the country's highest per capita income, and many politicians live in the city only temporarily. These two factors pressure the rents up.

The term  $\frac{\phi(Z)}{\Phi(Z)}$  is the inverse Mill's ratio computed with the pseudo-residuals of the probit model used to estimate the first step, i.e., the endogenous decision of the head to participate in the formal rental market. Like Goodman (1988), we use a probit model to estimate the selection component in the *Heckman two-step procedure* model. In our case, though, we estimate a probit for renters and a probit for owners. In the first case, the dependent variable is equal to 1 for formal renter and 0 for informal renter. In the second, the dependent variable is equal to 1 for formal homeowner or 0 for informal owner.<sup>28</sup> The vector  $Z$  corresponds to the identifying instruments used in the first step and are given by the set of dummies that identify the occupation of the head, the wealth index, life-cycle variables, household size, the dummy for lack of affordability, dummy for credit constraint, and one for years of schooling of the head.

The variable “poor neighborhood” controls for neighborhood characteristics and is defined as the proportion of households with monthly income per capita lower than half of a minimum wage in 2008. The positive coefficient for formal owners might be suggesting that the higher the proportion of poor households the less developed is the rental market. Table A.2 illustrates the first-step estimates for renters and owners.

Instead of estimating the housing demand model pooling owners and renters, we follow Goodman and Kawai (1984), who estimated two separate models, one for renters and the other for owners. They argue that the motivations behind the decision to rent or own a dwelling are quite diverse and hence pooling renters and owners together would

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<sup>28</sup> We also estimated the probit models with the dependent variable being equal to 1 for formal renters (owners) and 0 for anyone else. The results are similar to those shown in Piza et al. (2011).

render misleading estimates for income and price elasticities. The authors argue, for instance, that i) tax benefits are usually available for owners but not for renters; ii) transaction costs are higher for owners than renters; and iii) the decision of own a house is presents both a consumption and an investment motivation whereas the renting decision might be explained by the life-cycle component, with younger couples more likely to rent than own a dwelling.<sup>29</sup> The main implications of these assumptions are: (1) price elasticity should be lower for owners than for renters due to the higher transaction costs faced by owners, and (2) permanent income elasticity should be lower for renters because of the life-cycle component.<sup>30</sup>

While Goodman (1988) argues that many studies have found that renter demand is more price elastic than owner demand, and our results confirm that evidence, Fontenla and González (2009) suggest that price elasticities for renters have a higher range and that the point estimates vary depending on the econometric approach used. Although Tiwari and Parikh (1999) estimate a price elasticity for renters of about -1, Goodman and Kawai (1986) show that the usual alternative functional forms, such as linear, log-log, and log-linear, are strongly rejected in a set of simulations. Table 5 presents the estimate for renters.

The estimate for price elasticity for renters is in line with the benchmark of the literature, whereas the result for permanent income elasticity is slightly higher than what has been documented by the empirical literature.<sup>31</sup> The relatively high value of income elasticity and the positive sign of the schooling elasticity of renters may be reflecting i) that better-educated heads might prefer renting an expensive dwelling to owning a simple house, or ii) that better-educated renters might be postponing homeownership because they are relatively younger and have no children or younger children (see Table 3). Another possibility is that the “informal worker” dummy is not capturing credit

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<sup>29</sup> Since, as argued by Arnott (1987), rents move pro-cyclically, the business cycle matters and should be taken into account when working with more than one period.

<sup>30</sup> Arnott (1987) argues that housing demand should be price-inelastic not only because of transaction costs but also because tenure choice is affected by variables not directly related to the price itself, such as neighborhood and location.

<sup>31</sup> In their literature review on housing demand in developing economies, Malpezzi and Mayo (1987) report income elasticities for 16 cities in 8 countries. For some very few cases, they found the point estimate to be around a unit. Thus, our estimate for permanent income elasticity seems to be similar to the upper bound of the benchmark.

constraints properly. This could partially explain the high value of permanent income elasticity (see Linneman and Wachter, 1989).

The temporary income elasticity is low but positive and highly statistically significant. This is an expected result and is totally in line with what is reported in the literature (e.g., Goodman and Kawai, 1984; Fontenla and González, 2009).

The coefficient for the “informal” dummy is -0.17 but is not statistically significant. However, for the sake of illustration, it allows us to estimate the elasticities for informal renters. The estimate of the price elasticity for renters of informal dwellings is slightly higher in absolute terms, -0.94, while the elasticity of permanent income is 1.32.

The coefficient of the inverse Mill’s ratio is negative and highly significant, suggesting that there is a self-selection mechanism that should be accounted for. The negative sign suggests that unobservable characteristics of households are associated with a lower probability of being a formal renter compared to an informal renter.

### ***3.4 Housing Demand for Owners***

The estimates for owners were computed with imputed rents for owners, since the PNADs do not report the price or value of the house. In this case, we generated a new variable—imputed rent—making use of the coefficients of a linear regression of the “rent” against the same variables used to estimate the hedonic rent regressions. This variable is important to generate the quantity demand of housing of owners.

The variable “imputed rent” was computed with the coefficients of the following model:

$$\begin{aligned} rent_i = & \alpha + \beta_1 Bedroom_i + \beta_2 Room_i + \beta_3 density_i + \beta_4 wallquality_i + \beta_5 roofquality_i + \\ & \beta_6 pipedwater_i + \beta_7 sewerage_i + \beta_8 garbagecollection_i + \beta_9 bath_i + \beta_{10} Poorhh_i + \beta_{11} favela_i + \varepsilon_i \end{aligned}$$

The variable “bath” represents the number of baths in the  $i$ -th dwelling, and “oorhh” is a variable that captures neighborhood characteristics, as defined earlier.

The variable “imputed rent” is the output of vector of coefficients estimated by the multiple regression outlined above and  $X$  variables of houses occupied by the owners, i.e.:

$$\text{Imputed\_Rent}_i = \hat{\beta}' X_i$$

The price index was computed following the same rationale used for the renters, i.e., dividing the price of the  $i$ -th house in the  $j$ -th market by the price of a precarious house in the Sao Paulo metropolitan region. These sets of prices correspond to the prices predicted by the hedonic price regressions. Table 4 above shows the elasticities for number of baths, number of bedrooms, and number of other rooms for owners across metropolitan regions. In general, the estimates for owners are quite similar to those found for renters. The exceptions are the elasticities of “rooms,” which are slightly higher for formal owners than for formal renters but significantly higher for informal owners when compared to informal renters. The main reason is that the median number of rooms of owned dwellings is 6, while it is 5 in rented dwellings.

Table 5 illustrates the price and income elasticities for homeowners.

**Table 5. Determinants of Housing Demand for Renters and Owners:  
Box-Cox Method with Selection Correction Term**

| VARIABLES                        | <i>Renters</i>      |                      | <i>Owners</i>       |                      |
|----------------------------------|---------------------|----------------------|---------------------|----------------------|
|                                  | Coefficients        | %Change/Elasticities | Coefficients        | %Change/Elasticities |
| <i>Non-Transformed Variables</i> |                     |                      |                     |                      |
| Male                             | 0.0386<br>(0.000)   | 0,039                | 0.0446<br>(0.000)   | 0.03                 |
| Non-white                        | 0.00370<br>(0.000)  | 0,004                | 0.0395<br>(0.000)   | 0.029                |
| Temporary Income                 | 0.000142<br>(0.000) | 0,02 <sup>a</sup>    | 1.04e-05<br>(0.000) | 0,003 <sup>a</sup>   |
| <i>Inverse Mill's ratio</i>      | -0.981<br>(0.000)   | -                    | -0.695<br>(0.000)   | -                    |
| <i>Pará</i>                      | 0.0151<br>(1.000)   | 0,015                | -0.102<br>(1.000)   | -0.075               |
| <i>Ceará</i>                     | -0.398<br>(1.000)   | -0,4                 | -0.0621<br>(1.000)  | -0.045               |
| <i>Rio Grande do Norte</i>       | -0.318<br>(1.000)   | -0,32                | -0.134<br>(1.000)   | -0.098               |
| <i>Bahia</i>                     | -0.295<br>(0.000)   | -0,297               | -0.354<br>(0.000)   | -0.259               |
| <i>Minas Gerais</i>              | -0.365<br>(0.000)   | -0,368               | 0.0113<br>(0.000)   | 0.008                |
| <i>Rio de Janeiro</i>            | -0.205<br>(0.000)   | -0,21                | 0.0948<br>(1.000)   | 0.069                |
| <i>Paraná</i>                    | -0.231<br>(0.000)   | -0,23                | 0.265<br>(1.000)    | 0.194                |



**Table 5., continued**

| VARIABLES                               | <i>Renters</i>      |                      | <i>Owners</i>      |                      |
|---|---------------------|----------------------|--------------------|----------------------|
|   | Coefficients        | %Change/Elasticities | Coefficients       | %Change/Elasticities |
| <b><i>Non-Transformed Variables</i></b> |                     |                      |                    |                      |
| <i>Rio Grande do Sul</i>                | -0.339<br>(0.000)   | -0,34                | -0.306<br>(0.000)  | -0.22                |
| <i>Distrito Federal</i>                 | -0.00219<br>(1.000) | -0,002               | -<br>-             | -                    |
| <i>Informal housing</i>                 | -0.170<br>(1.000)   | -0,171               | -0.322<br>(1.000)  | -0.24                |
| <b><i>Transformed Variables</i></b>     |                     |                      |                    |                      |
| Price                                   | -3.264<br>(0.000)   | -0.89 <sup>a</sup>   | -1.152<br>(0.000)  | -0.56 <sup>a</sup>   |
| Age of the head                         | 0.246<br>(0.000)    | 0.089 <sup>a</sup>   | 0.0822<br>(0.000)  | 0.055 <sup>a</sup>   |
| Permanent Income                        | 2.660<br>(0.000)    | 1.4 <sup>a</sup>     | 0.472<br>(0.000)   | 0.39 <sup>a</sup>    |
| Members                                 | 0.114<br>(0.000)    | 1.86 <sup>a</sup>    | 0.146<br>(0.000)   | 0.1 <sup>a</sup>     |
| Years of schooling of the head          | 0.0441<br>(0.000)   | 0.026 <sup>a</sup>   | -0.0346<br>(0.000) | -0.035 <sup>a</sup>  |
| Constant                                | 4.503<br>(0.000)    |                      | 3.275<br>(0.000)   |                      |
| Lambda                                  | -0.278<br>(0.000)   |                      | -0.204<br>(0.000)  |                      |
| Theta                                   | -0.00513<br>(0.000) |                      | -0.267<br>(0.000)  |                      |
| Sigma                                   | 0.337               |                      | 0.152              |                      |
| H0:                                     | Chi2                |                      | Chi2               |                      |
| Theta = Lambda = -1                     | 1.9e+06***          |                      | 2.1e+06***         |                      |
| Theta = Lambda = 0                      | 4969.06***          |                      | 2.8e+05***         |                      |
| Theta = Lambda = 1                      | 9.1e+05***          |                      | 5.5e+06***         |                      |
| Log-likelihood                          | -1421659            |                      | -5855816.3         |                      |
| LR chi2(20)                             | 1379573.70          |                      | 9883154.31         |                      |
| Observations                            | 731,105             |                      | 4,901,620          |                      |

Note:  $p > \chi^2$  in parentheses. <sup>a</sup> Elasticity. \*\*\*Significant at 1%.

The estimate of price elasticity is relatively low but still in line with the benchmark in the literature, since it suggests that housing is a necessary good and that transaction costs may be a key component of the household tenure decision. The result for permanent income elasticity is substantially lower than renter income elasticity, but it is quite similar to that found by Goodman and Kawai (1984) but slightly lower than what has been documented in the most recent empirical literature. Even so, it still supports the thesis that housing is a normal good. The temporary income is low but, again, positive and statistically significant.

The coefficient for the “precarious” dummy is -0.32, and it would allow one to estimate the elasticities for informal homeowners. However, the coefficient is statistically insignificant.

The coefficient of the IMR is negative and highly significant, suggesting, again, that unobservable characteristics of the head make him less likely to be a formal owner compared to an informal owner.

#### **4. Final Remarks and Policy Recommendation**

This paper describes the characteristics of the housing sector in Brazil. We first examined the determinants of tenure decisions. The main conclusion is that relatively poorer households tend to own their homes, whereas households with higher incomes and with better educated heads tend to rent. We found some evidence that credit constraints, proxied in our analysis by labor force status, are associated with a higher probability of renting in the informal housing sector.

Second, we examined housing demand, estimating price and permanent income elasticities for owners and renters separately, taking into account selection effects, i.e., that owners (renters) can choose (rent) between a formal and an informal dwelling. Our main findings are in line with the benchmark in the literature.

Housing demand of owners is price inelastic and about 0.5 in absolute terms. This suggests that potential owners face transaction costs high enough to make them relatively unresponsive to price changes. The permanent income elasticity of about 0.4 also suggests that homeowners do not tend to respond much to income variation. This seems to be greatly influenced by the life-cycle component and investment decisions of the household.

Price elasticity for renters is slightly higher, in line with the literature. Hence, price changes are expected to influence renters more than owners. The literature also establishes that owners are more sensitive to income variation than renters. However, our estimate of the permanent income elasticity of renters is slightly higher than the benchmark (about a unit of elasticity). Thus, according to our results, public policies that aim to influence the price of dwellings and/or the income of the households are expected to affect renters more than owners. This might reflect recent very rapid increases in housing prices in some metropolitan areas in Brazil.

Moreover, given that rent is a pro-cyclical variable and that housing-price supply elasticity tends to be low, a social housing policy focused on the rental market might be

an effective option, at least in the short run, to satisfy the increasing housing demand observed in Brazil.

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## Appendix Tables

**Table A.1. Determinants of Income, Box-Cox (Formal Housing)**

| VARIABLES                       | Formal Housing     |                      | Informal Housing   |                      |
|---------------------------------|--------------------|----------------------|--------------------|----------------------|
|                                 | Coefficients       | %Change/Elasticities | Coefficients       | %Change/Elasticities |
| <i>No transformed variables</i> |                    |                      |                    |                      |
| Male                            | 0.163<br>(0.000)   | 0,254                | 0.0406<br>(0.000)  | 0,029                |
| Non-white                       | -0.144<br>(0.000)  | -0,224               | -0.0575<br>(0.000) | -0,041               |
| Public worker                   | 0.568<br>(0.000)   | 0,884                | 0.242<br>(0.000)   | 0,173                |
| Formal worker                   | 0.170<br>(0.000)   | 0,265                | 0.0996<br>(0.000)  | 0,071                |
| Formal domestic worker          | 0.0159<br>(0.000)  | 0,025                | 0.0673<br>(0.000)  | 0,048                |
| Employer                        | 0.808<br>(0.000)   | 1,257                | 0.375<br>(0.000)   | 0,268                |
| <i>Pará</i>                     | -0.387<br>(0.000)  | -0,602               | -0.217<br>(0.000)  | -0,155               |
| <i>Ceará</i>                    | -0.651<br>(0.000)  | -1,013               | -0.377<br>(0.000)  | -0,269               |
| <i>Rio Grande do Norte</i>      | -0.690<br>(0.000)  | -1,074               | -0.410<br>(0.000)  | -0,293               |
| <i>Bahia</i>                    | -0.494<br>(0.000)  | -0,769               | -0.402<br>(0.000)  | -0,287               |
| <i>Minas Gerais</i>             | -0.127<br>(0.000)  | -0,198               | -0.221<br>(0.000)  | -0,158               |
| <i>Rio de Janeiro</i>           | -0.318<br>(0.000)  | -0,495               | -0.257<br>(0.000)  | -0,184               |
| <i>Sao Paulo</i>                | -0.0410<br>(0.000) | -0,064               | -0.207<br>(0.000)  | -0,148               |
| <i>Paraná</i>                   | -<br>(0.000)       |                      | -0.0601<br>(0.000) | -0,043               |
| <i>Rio Grande do Sul</i>        | -0.145<br>(0.000)  | -0,226               | -<br>(0.000)       |                      |
| <i>Distrito Federal</i>         | -0.0984<br>(0.000) | -0,153               | -0.197<br>(0.000)  | -0,141               |
| <i>Transformed variables</i>    |                    |                      |                    |                      |
| Age of the head                 | 0.00714<br>(0.000) | 0.96                 | 0.0101<br>(0.000)  | 0.98                 |
| Years of schooling of the head  | 0.0426<br>(0.000)  | 0.61                 | 0.0283<br>(0.000)  | 0.4                  |
| Constant                        | 7.534<br>(0.000)   |                      | 5.337<br>(0.000)   |                      |
| Lambda                          | 1.39<br>(0.000)    |                      | 1.122<br>(0.000)   |                      |
| Theta                           | 0.059<br>(0.000)   |                      | -0.0468<br>(0.02)  |                      |
| Sigma                           | 0.887              |                      | 0.408              |                      |
| H0:                             | Chi2               |                      | Chi2               |                      |
| Theta = Lambda = -1             | 15197.41***        |                      | 2258.38***         |                      |
| Theta = Lambda = 0              | 479.34***          |                      | 61.208***          |                      |
| Theta = Lambda = 1              | 10390.35***        |                      | 2692.33***         |                      |
| Log likelihood                  | -160714.85         |                      | -31106.494         |                      |
| LR chi2(18)                     | 7133.62            |                      | 1316.36            |                      |
| Observations                    | 20,077             |                      | 4,039              |                      |

Note:  $p > \chi^2$  in parentheses. \*\*\*Significant at 1%.

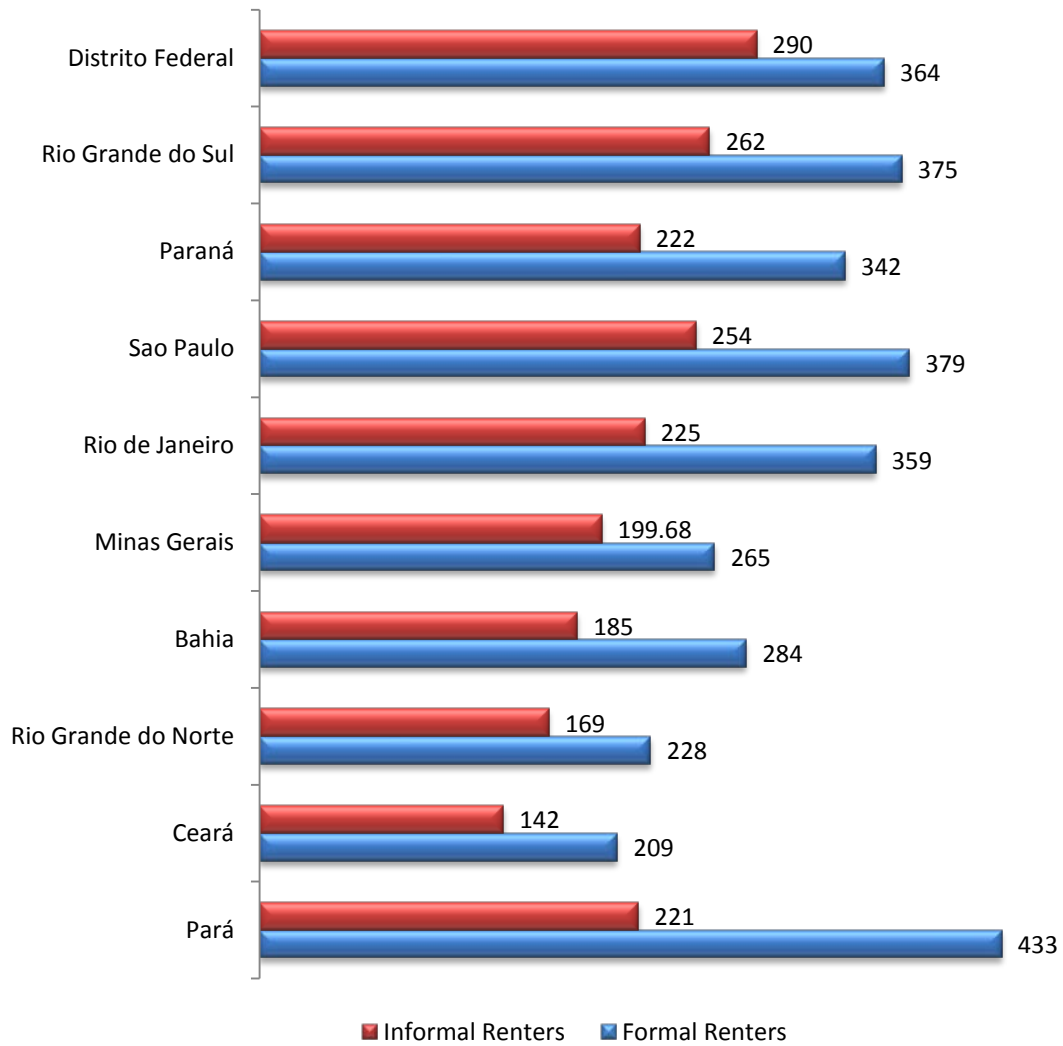


**Table A.2. First-Step Estimates for Formal Rents and Formal Ownership, Probit Model Coefficients**

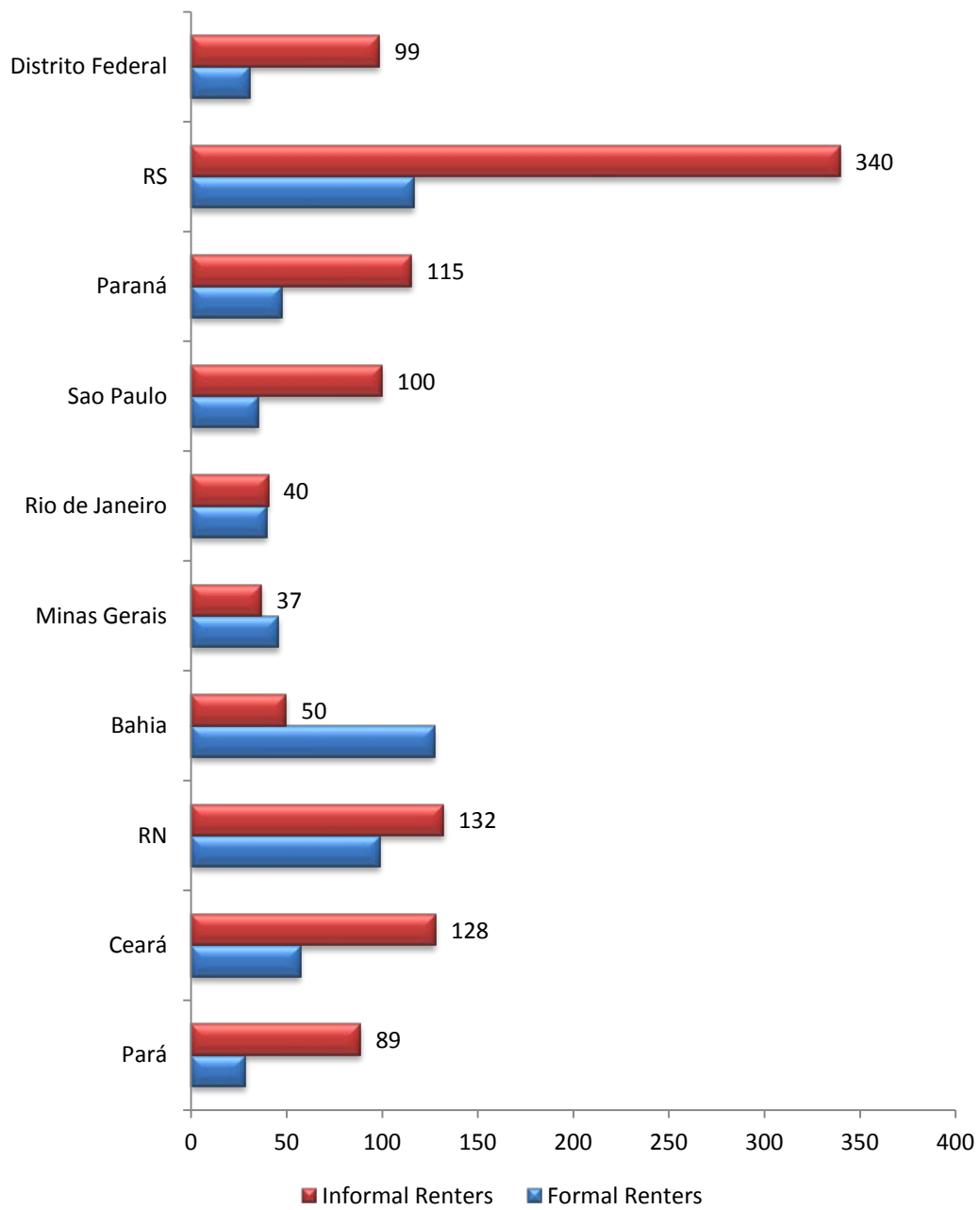
| VARIABLES                                      | <i>Renters</i>            | <i>Owners</i>            |
|--|---------------------------|--------------------------|
|  | Formal/Informal           | Formal/Informal          |
| Age of the head                                | -0.00718<br>(0.00511)     | 0.00129<br>(0.00276)     |
| Age of the head square                         | 0.000154***<br>(5.83e-05) | 6.30e-05**<br>(2.82e-05) |
| Affordability (=1 if income <= 3minimum wages) | -0.0213<br>(0.0425)       | -0.0314<br>(0.0253)      |
| Number of members                              | -0.0419***<br>(0.00896)   | -0.0437***<br>(0.00425)  |
| Years of schooling of the head                 | 0.0109***<br>(0.00374)    | 0.00466**<br>(0.00193)   |
| Household monthly income ( <i>in ln</i> )      | 0.0873***<br>(0.0215)     | 0.0385***<br>(0.0116)    |
| Male   | -0.147***<br>(0.0278)     | -0.0817***<br>(0.0154)   |
| Non-white                                      | -0.121***<br>(0.0225)     | -0.171***<br>(0.0123)    |
| Couple 1                                       | -0.0729**<br>(0.0351)     | -0.0603***<br>(0.0204)   |
| Couple 2                                       | -0.0936***<br>(0.0344)    | -0.105***<br>(0.0204)    |
| Couple 3                                       | -0.152***<br>(0.0483)     | -0.119***<br>(0.0215)    |
| Couple 4                                       | -0.0835<br>(0.0552)       | -0.0942***<br>(0.0261)   |
| Public servant                                 | -0.141***<br>(0.0478)     | -0.164***<br>(0.0149)    |
| Formal worker                                  | 0.139***<br>(0.0250)      | -0.256***<br>(0.0247)    |
| Formal domestic worker                         | 0.0273<br>(0.0751)        | 0.162***<br>(0.0538)     |
| Employer                                       | -0.167***<br>(0.0548)     | -0.182***<br>(0.0306)    |
| Wealth index                                   | 0.132***<br>(0.00921)     | 0.184***<br>(0.00478)    |
| Constant                                       | 0.306<br>(0.192)          | 0.536***<br>(0.107)      |
| Pseudo-R2                                      | 0.05                      | 0.07                     |
| Log likelihood                                 | -8923.3681                | -30324.775               |
| Observations                                   | 16,136                    | 52,847                   |

*Note:* Standard errors in parenthesis. \*\*\*, \*\*, \* Statistically significant at 1%, 5% and 10% respectively.

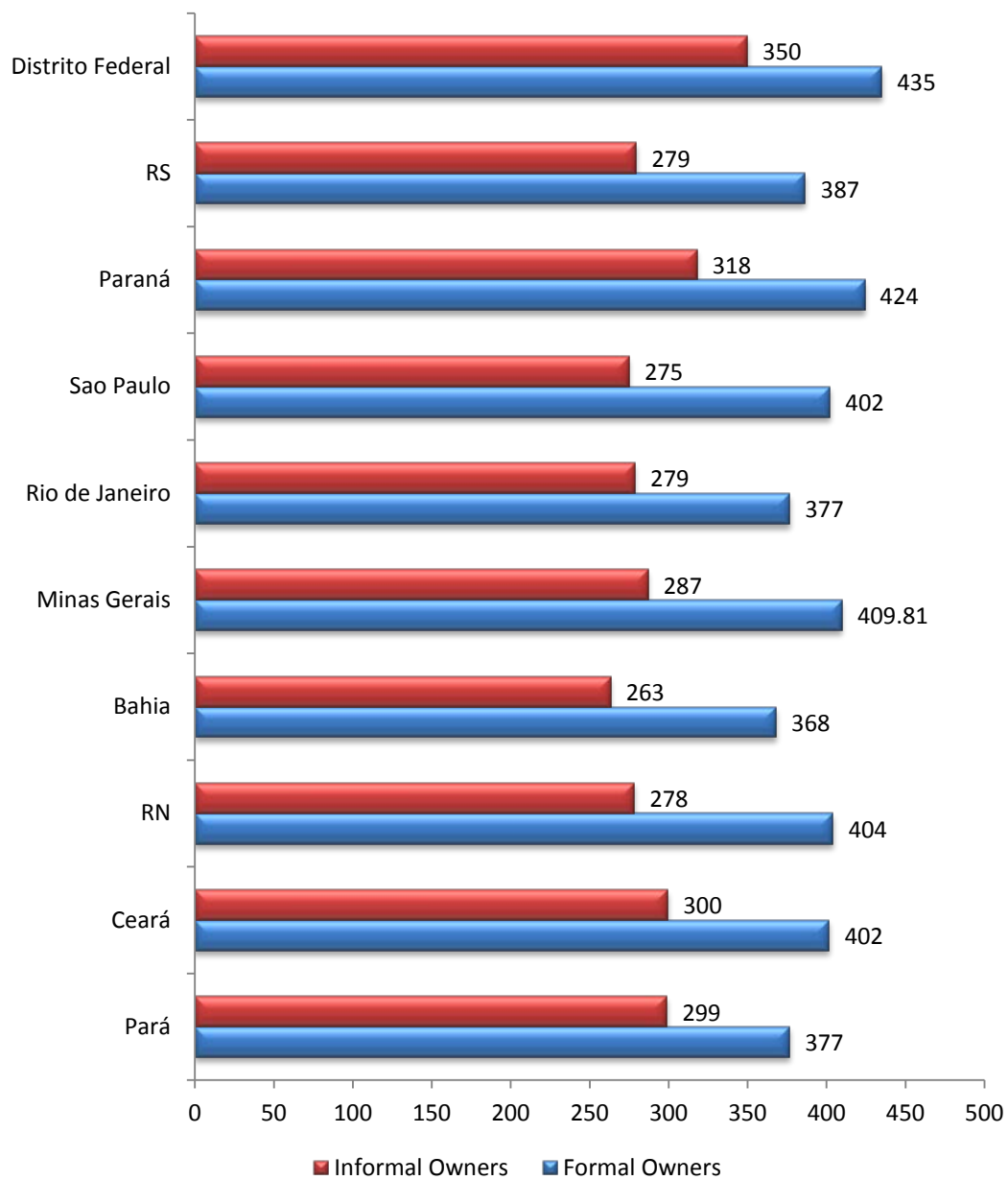
**Figure A.1. Rent by Metropolitan Region**



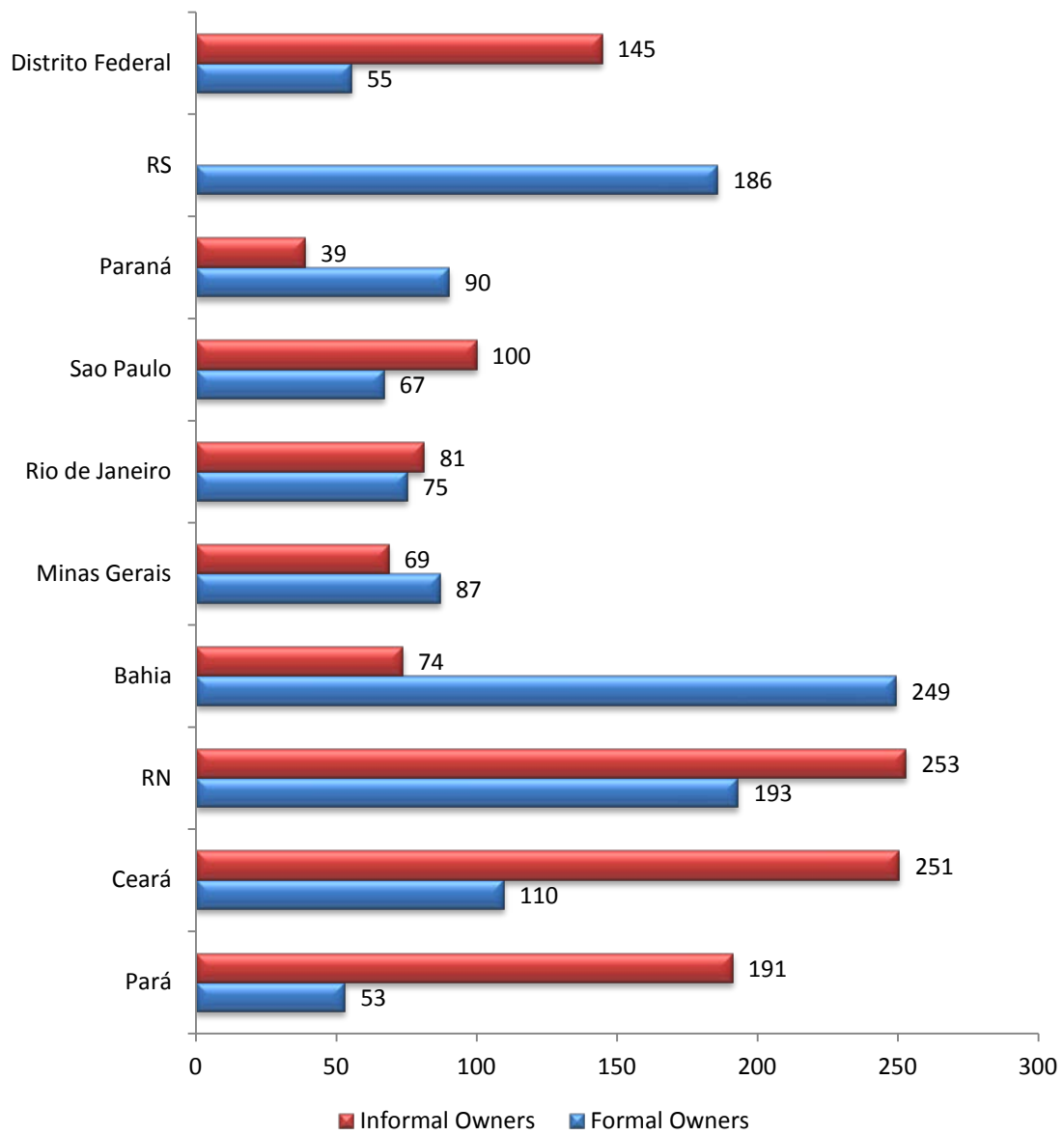
**Figure A.2. Rent Index by Metropolitan Region**



**Figure A.3. Price by Metropolitan Region**



**Figure A.4. Price Index by Metropolitan Region**



*Note:* Price of precarious dwellings in Rio Grande do Sul was excluded because it is an outlier.