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WORKING PAPER

The Impact of the Sense of Security from Crime on Residential Property Values in Brazilian Metropolitan Areas

David M. Vetter

Kaizô I. Beltrão

Rosa M. R. Massena

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David Vetter Consultoria Econômica Ltda.

Rio de Janeiro

Abstract

Using a hedonic residential rent model for Brazil's metropolitan areas calibrated with micro data from Brazil's annual household survey, we estimate that increasing the sense of security in the home by one standard deviation would increase average home values by R$1,513 (US$757) or about US$13.6 billion if applied to all 18.0 million households in the study area. Our principal components analysis of sense of security and crime victimization variables indicates that higher income households tend to feel more secure from crime in the home, even though theft and robbery victimization tend to rise with household income and rent. Higher levels of home protection measures by higher income households partially explain this.

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Introduction

In terms of support for the idea that "crime is a major threat to the wellbeing of the nation" among countries in Latin America, Brazil ranked only after El Salvador, the country with the highest homicide in the hemisphere (Pérez 2010). Fear of crime has long been recognized as a significant social problem and an important intangible cost of crime. Corbacho et al. (2012) note that "Crime has high direct tangible costs (. . .). But the welfare implications of crime are potentially far deeper. Crime does not only victimize individuals; it can also weaken the fabric of social life by increasing fear, suspicion, and distrust."

The fear a crime (or its complement, the sense of security from crime) refers to one's perception about becoming a crime victim, rather than the actual probability or risk of becoming a victim as measured by some indicator (e.g., robbery per 100,000 inhabitants).

This research addresses the questions: Are households willing to pay more for residential properties where their sense of security from crime is higher? What variables influence this sense of security from crime? To address these questions, we use the extraordinarily rich data on security from crime and crime victimization from IBGE's[1] 2009 national household survey (IBGE 2010)[2] to:

- Develop a hedonic residential rent model to measure the willingness of households to pay for greater security from crime.
- Use principal components analysis to study the variables that could impact the sense of security from crime, including victimization from three different types of crime (robbery, theft, and physical aggression)and home protection measures (e.g., intercoms, bars on windows, high walls, surveillance cameras, and security personnel)..
- Utilize the component scores generated as independent variables in a hedonic residential rent model.

In this way, our study differs from many others that have been done on the impact of crime on residential property values, because we analyze the impact of the sense of security from crime on residential property values, whereas most such studies focus only on crime

[1] Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística), Brazil`s main statistical agency.
[2] Pesquisa Nacional por Amostra de Domicílios

victimization as reported to the police (i.e., the risk of crime victimization). We find that the sense of security from crime does significantly impact on residential rents. Higher income groups tend to pay higher rents for housing that has more home protection measures and in which, partially because of these measures, they feel more secure. However, higher income groups tend to have a significantly higher risk of being victims of theft and robbery. In effect, although the higher income families tend to feel more secure in their homes in part due to greater home protection measures, they are at greater risk of being crime victims.

In the following sections, we review the literature on hedonic housing models and fear of crime, and then we discuss our methodology and its results. Our methodology will proceed in three steps. First, we will develop a basic hedonic residential rent model to assess the willingness to pay for increased sense of security from crime. Then, we use principal components analysis to study variables influencing this sense of security, including home protection measures, crime victimization, and gender of the reference person. Finally, we use the component scores from this analysis in a more elaborate hedonic residential rent model.

Literature Review

This paper links several different strands of literature. Following a long tradition, we use the hedonic model of residential prices to measure the impact of crime on housing prices. However, we link this model with the fear of crime literature by using the sense of security from crime as the measure of crime impact, rather than crime victimization per se, as so many other studies have done. In this way, we link the hedonic price model approach to the growing literature on fear of crime and crime victimization that has developed with the increase of surveys at the micro level. Corbacho et al. (2012) note that "These surveys have allowed researchers to study the socioeconomic determinants of victimization, where the burden of crime on society is the main empirical concern. They have also been used to correct the significant underreporting that is suspected in aggregated official crime data."

Using Hedonic Housing Price Models to Measure the Impact of Crime

According to Soares (2009), "The level of crime and violence in the surrounding area may be an additional attribute of a house, and individuals may be willing to pay more to live in an area with lower crime. An estimate of how much the attribute 'low-crime' is worth in

the pricing of a house immediately provides an estimate of the cost of crime. If, everything else constant, individuals are willing to pay more to live in an area with lower crime, it means that their willingness to pay for the corresponding reduction in violence is at least equal to that amount." In our approach, we analyze the willingness to pay to live in an area where one feels a greater sense of security from crime, rather than in an area where the crime rate is lower. See Appendix B for a discussion of hedonic housing price methodology and its use in Brazil.

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 employment and other opportunities (A), and neighborhood characteristics (N) that can include indicators of crime, pollution and other factors influencing quality of life in it. 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 = Structural characteristics, including size and building materials, number of bathrooms

A = Access to employment and other opportunities

N = Neighborhood characteristics, including 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.

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

What follows is a concise summary of the vast literature on hedonic models that we discuss in more detail in Appendix B. The hedonic housing price methodology is widely used and generally accepted. For instance, in the US, hedonic price indices are used to adjust the prices of residential and non-residential structures in calculation of real GDP (Wasshausen and Moluton 2006). The whole of France is now covered by quarterly hedonic housing price indexes (Laferrère 2005). Brazil's Instituto de Pesquisa Econômica Aplicada (IPEA) uses the hedonic method to estimate the stock of residential capital using PNAD micro data.

There is a substantial literature on the theory and methodological issues of hedonic housing models and many reviews of their use in general and for specific ends such as measuring environmental amenities (e.g., parks and green space) and problems (e.g., crime. pollution, hazard waste sites, etc.). In the international and Brazilian literature using hedonic pricing related to crime, the units of analysis are most often spatial units (e.g., neighborhoods or census tracts) rather than micro data on individual households, and the crime data are from police reports.

Ihlanfeldt and Mayock (2009) argue that crime levels should be treated as endogenous variables in hedonic housing models for a number of reasons, including that "neighborhoods with more expensive homes attract criminals by offering higher expected payoffs in terms of the market value of stolen goods," and that higher levels of "self protection is expected to be greater in wealthier neighborhoods because property owners are more able to afford it and they have more at risk." In targeting higher income households, the thieves and robbers follow the strategy of the bank robber Willie Sutton who responded when asked why he robbed banks: "because that's where the money is." In other words, thieves and robbers seek higher income victims who have more to steal. In response, those with more to steal seek to protect themselves with security personnel, high fences, etc. If this is true, one would expect higher victimization rates for higher income households living in higher rent neighborhoods with greater home protection measures. As a result, higher income households might feel secure from crime in their homes due to the home protection measures. The seemingly paradoxical result would be that the hedonic residential rent model would show positive signs on the coefficients for both sense of security from crime in the home and also so for victimization from theft and robbery.

Studies of the Sense of Security from Crime and Crime Victimization

The literature shows that the actual risk or probability of being a victim of crime may *not* be the most important variable influencing the sense of security from crime (or its complement, fear of crime). Variables other than the risk of victimization influencing the fear of crime include social class, gender and age, neighborhood characteristics, home protection measures and confidence in the police protection.

Dealing with perceptions of the risk of crime victimization rather than risk per se can be challenging, as illustrated by an interesting study in Bogotá (Gaviria et al. 2008): "households who report feeling safe in their neighborhoods pay less rent for their houses.

(. .) This result should be interpreted cautiously, however, because it might be driven by differences in perceptions between the richest and the poorest households: if the richest live in safer neighborhoods and yet they feel more unsafe than the poorest do, the coefficient would be capturing these differences in perceptions rather than the effect of greater security on capitalized house values." In other words, the author notes the possible difference between the perception of an individual household and that of the other potential home buyers or renters. In their analysis of crime patterns, Gaviria and Pagés (2002) and Gaviria and Velez (2001) find that property crime victimization tends to be higher among middle- and higher-income households.

Socio-Demographic and Neighborhood Characteristics

Based on their testing of alternative models of fear of crime, Taylor and Hale (1986) provide the following general conclusions. "First, fear of crime at the individual level appears to be largely a function of the individual's position in the larger society. Social class and demographic characteristics have emerged as the strongest predictors of fear responses." Some of the socio-demographics variables, such as being female and age, and other variables such as lower income and rental status relate to the concept of social vulnerability. "Nonetheless, the performance of socio-demographic predictors should not obscure the consistent role played by residents' perceptions of local conditions and by involvement in locale." Finally, they note that "the results underscore the loose linkage between crime and fear. (. . .) Crime was weaker as a predictor of fear of crime than perceptions of locale and sociodemographics." Thelon (2007) develops multivariate models of the fear of crime, perceived disorders and property crime rates with area characteristics and regions as the independent variables. He concludes that "area characteristics predict fear of crime and disorders better than property crime rates."

Home Protection Measures: Establishing Defensible Space

Since Oscar Newman's book on *Defensible Space* (1972), there has been a discussion of the potential for crime prevention through environmental design. As Newman notes in his 1996 analysis of five case studies, "All Defensible Space programs have a common purpose: They restructure the physical layout of communities to allow residents to control the areas around their homes." Defensible space involves more than just changing the structure of buildings and their surrounding space, in that it. "It depends on resident involvement to reduce crime and remove the presence of criminals. It has the ability to bring people of different incomes and race together in a mutually beneficial union. For low-income people,

Defensible Space can provide an introduction to the benefits of mainstream life and an opportunity to see how their own actions can better the world around them and lead to upward mobility." Newman and Franck's (1980) path analysis showed that the physical environment can have a significant impact on crime.[3] An important advantage of Defensible Space strategies is that they rely on "self-help rather than on government intervention, and so it is not vulnerable to government's withdrawal of support." Households may be willing to pay more for home protection measures.

Crime Victimization and Police Protection

There is evidence that confidence in police protection can reduce fear of crime, even for those who have been crime victims. For example, using probit models with micro-level data from the Survey of Living Conditions (2005) in Trinidad and Tobago, Mohammed et al. (2009) find that fear of crime does reflect whether the persons has been a victim of crime. However, their results show that the "probability of individuals who were victims of crime being fearful of crime was not affected, if they reported the incident to the police and action was taken by the police. On the other hand, when individuals have not reported the incident or reported the incident, but action was not taken, they have a higher probability of being fearful of crime than those who have not being victims of crime."

Methodology

Our methodology builds on the above by first calibrating a basic hedonic residential rent model using PNAD micro data with our indicator of security from crime in the home as one of the independent variables. Next, we use principal components analysis to identify the underlying relationships among the host of variables available that can impact this sense of security, including crime victimization, home protection measures, and sex and age of the reference person. Finally, we introduce the components generated into our hedonic rent model. In parallel with this model development, we also explored the relationships among the key variables by generating and analyzing the tables and graphs shown below.

[3] In *Crime Prevention Through Environmental Design*, Crowe (2000) discusses the evolution of these ideas and the continuing debate on the effectiveness of such measures.

Hedonic Residential Rent Model

Our basic hedonic residential rent model will be an extension of those developed by a number of Brazilian authors[4] with PNAD micro data and also used by IPEA to estimate the stock of residential capital. The dependent variable is monthly rent. The independent variables housing characteristics, median commute time to work and neighborhood characteristics that are available in the PNAD (variables for matrices S, A and N in equation 1, respectively). As with the IPEA models, we initially use median household income of the sector as an indicator of overall neighborhood quality (N). However, we also add the indicator: Sense of security from crime in the home.

One advantage of using monthly rent from the PNAD as the measure of housing value in Brazil is that a national tenant law[5] 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, eviction, and civil and criminal penalties. Under this law, residential rental 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. We know of no incidence of rent control in Brazil. Thus, we do not need an independent variable for contract conditions (C in equation 1).

Our basic unit of analysis is the household. For each household, we generate indicators using characteristics for the following levels:

- Housing unit: The characteristics of the housing unit (e.g., number of rooms and home protection measures)
- Household: The characteristics of those living in the housing unit (e.g., household income, age and sex of reference person), including the sense of security from crime and victimization.
- Census sector: Indicators of the characteristics of the households living in the census sector (*setores censitários*) in which the household is located (e.g., median household income of the sector, as well as indicators of the sense of security from crime and crime victimization).

[4] Cruz and Morais (2000), Reiff and Barbosa (2005) and Tafner and Carvalho (2007). See Appendix B for a detailed discussion of these studies.

[6] 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."

In other words, for each household, we will have indicators for the housing unit per se (e.g., number of bathrooms and home protection measures), the persons living in the unit (e.g., sense of security from crime and crime victimization) and on the census sector in which it is located (e.g., % of those living in the sector who feel secure from crime).

We initially test essentially the same log-linear functional form and weighted ordinary least squares method used in the previous hedonic models with PNAD micro data. 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, we can also drop T from equation 1. So then, the final model to be tested is:

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

In our basic hedonic model, we will introduce only two indicators of neighborhood quality: Median household income of the sector (as in the IPEA model) and sense of security from crime at the household and sector levels. Because the sense of security from crime at the household level will depend on the many variables discussed in the literature (e.g., gender and age of the different household members), we do not expect the coefficient for this binary variable to be significant. However, we do expect that the sense of security at the sector level to be significant, as this is an indicator of the general view of the security level by those living in the neighborhood.

A Principal Components Analysis

A common problem with the analysis of the matrix of neighborhood indicators (N) in the hedonic models is that many of the "independent" variables are in fact correlated (Malpezzi 2002).[6] 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 Archer and Wilkinson (1973) and more recently have Day et al. (2003) and Bhattacharjee et al. (2011). Factor analysis has also been used in the analysis of the security from (fear of) crime. For example, Thelon (2007) uses factor analysis as part of his multivariate analysis of fear of crime, perceived disorders and property crime victimization at the area-level. Jackson (2006) uses confirmatory factor

[6] 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."

analysis with multiple indicators to assess the scaling properties of some new measures of the fear of crime.

As Day et al. (2003) note, 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."

Our approach is, then, 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. We first analyze the unrotated components because these provide a compact summary of the indicators and the relationships among them. The component loadings allow us to interpret them as collections of correlated housing and neighborhood characteristics, such as presence of security devices, sense of security from crime and crime victimization. We then use varimax rotation to generate component scores.

Using the Component Scores in the Hedonic Residential Rent Model

In this final step, we introduce the component scores for the most pertinent components from our principal components model into our hedonic price model with the log of monthly rent as the dependent variable.

The Data

Our data is from the PNAD 2009 micro data on the IBGE website.[7] We selected households living in private permanent households, located in urban areas in the nine metropolitan areas and Brasilia/ the Distrito Federal (Hereafter, Metro Areas). The basic questions on sense of security from crime and crime victimization are asked of all those 10 years of age or more. Our total sample of persons 10 or more years of age is 118,286 who are distributed among a total of 2,784 sectors in the 10 Metro Areas defined above. After pair wise deletion of missing values, there were a total of 40,095 households in our sample.

[7] For a detailed discussion of the PNAD sample, see Appendix C.

Variables for the Basic Hedonic Residential Rent Model

The dependent variable is the natural log of monthly rent. The independent variables are indicators of the general characteristics of the housing unit and its access to employment (S and A in equation 1). See Table A.1 in Appendix A. In our initial model, we use only two indicators of neighborhood quality (N): median income of the census sector and sense of security from crime in the home. PNAD 2009 asked all persons of 10 or more years of age: Do you feel secure from crime in your home? In your neighborhood? In your city? At this initial stage, we will use only the security for the home. For each household, we generate the binary variable for security from crime as:

= 1, if all of persons 10 years of age or more feel secure from crime

= 0, if not

For each sector, we also calculate the percentage of households in which all persons 10 years or more feel secure from crime.

Variables for the Principal Components Analysis

We use the following types of variables in the principal components analysis: sense of security from crime, crime victimization, home protection measures, age/ sex of reference person and Metro Area. Table A.2 provides descriptions of all of these variables.

Sense of Security from Crime

Our indicators of sense of security in the home, neighborhood and city are for all persons in the household and the reference person (formerly called household head) at both the household and census sector levels.

Crime Victimization and Police Protection

Table A.2 shows the crime victimization indicators for robbery, theft, and physical aggression for both the household and census sector levels. The crime victimizations questions cover:

- Theft (*furto*) of property without threat or violence (Hereafter, Theft)
- Robbery (*roubo*) using threat, force or violence (Hereafter, Robbery).

- Physical Aggression (*agressão física*) defined as bodily injury caused by firearms, the perpetrator's body or weapons of any type or where the victim has the integrity of his body affected by the offender in some way, including rape, sexual violence, hitting or pushing (Hereafter, Aggression). Under US law, this could include battery[8], rape or assault with a deadly weapon.

With regard to both Theft and Robbery, the questions asked for all persons of 10 or more years of age include:

- Have you been a victim Robbery involving violence or threats of violence?
  - If so, where? Your home? Home of another? Commercial establishment? School? Gym or sports event? Public transport? Public street?
  - If so, what was stolen? Money? Car?
  - If so, did you report the crime to the police? If not, why not?
  - If so, did you register the crime with the police? If not, why not?
  - What was stolen?

Basically, the same questions were asked with regard to Theft. In the case of Aggression, victims were also asked about the aggressor. Was the aggressor an unknown person, the spouse or ex-spouse, a policeman, etc.? Because the PNAD's informant could possibly be the aggressor in the case of children, the questions were asked only of those 18 years of age or older.

Based on these questions, we developed the indicators on the following aspects of the crimes shown in Table A.2 for Theft and Robbery:

- Frequency: Was more than one person victim of the crime or one person a victim more than once?
- Place of the last occurrence: Was the last occurrence in the home?
- Was a car stolen?
- Last occurrence reported to the police
  - If not, why not? Fear of the police? Did not want to involve the police? Fear of reprisal?
- Did the police record the last occurrence?

[8] Battery is the use of force against another, resulting in harmful or offensive contact.

- If not, why not? Police did not want to register the crime? Fear of the police? Did not want to involve the police? Fear of reprisal? Police did not want to record the occurrence?

In addition, for Aggression, the results identify the aggressor (e.g., unknown person, policeman, or spouse or ex-spouse). One potential problem is, of course, that the survey`s informant could potentially be the aggressor.

Home Protection Measures

The PNAD 2009 also asks about the types of devices and methods that households use to increase the security of its home:

- Door chains, door viewer or intercom
- Extra locks or bar locks on doors or windows to prevent break ins
- Bars on the windows or doors
- Electric fence, wall or fence more than two meters high or wall topped with glass chards or barbed wire or electronic alarm
- Surveillance camera
- Private security guard or doorman
- Dog for security

Given these indicators of home protection measures shown in Table A.2, we can test the hypothesis that they are positively correlated with the sense of security in the home, even in areas where the occurrences of theft or robbery are high. In other words, in a principal components analysis, the loadings on both sense of security in the home and theft could be high and positive. Living in an apartment could also be correlated with these home protection measures, and some may choose to live in an apartment as part of a personal protection from crime strategy.

Age/ Gender of Reference Person and Metro Area

Given the importance attributed to age and gender in the fear of crime studies, we include the age and gender of the reference person as variables in the factor analysis. We also include binary variables for the Metro Areas, as these arguably constitute separate housing markets (Malpezzi 2002).

2009 PNAD = Security from Crime/ Victimization + Basic Household Surveys

Given that the 2009 PNAD provides data on security from crime/ victimization and also the basic household and neighborhood characteristics, we can do a far more comprehensive analysis of the impact of the sense of security from crime and crime victimization on residential property values than most other studies of this type, as summarized in Table 1. PNAD provides data on sense of security from crime and home protection measures, as well both reported and unreported crime of three types (Theft, Robbery and Aggression). Reporting to police is important because the PNAD data indicate that less than half (48.5%) of those who were victims of robbery with violence and only 44.1% of those who suffered physical aggression reported the crimes to the police. The 2009 PNAD covers households and those living in them, as well as spatial units (census sectors). While most hedonic studies cover only one urban area, the PNAD sample covers all households in Brazil.

Table 1. Some of the Differences between Most Hedonic Housing Models of the Impact of Crime on Residential Prices and Our Study

Characteristics	Most hedonic housing models of the impact of crime	Our study
Covers sense of security from crime	No	Yes, sense of security in the home, neighborhood and city
Covers home protection measures	No	Yes, covers a number of measures, including intercoms, bars on windows, surveillance cameras and security personnel
Covers both reported and unreported crime	Reported crime only	Both reported and unreported crime, and also the reasons for not reporting. Also covers whether the crime was registered by the police or on the internet
Crime coverage	One or two types	Theft, robbery and physical aggression, as well as the frequency and location.
Unit of analysis	Spatial units such as neighborhoods and districts	Households, persons living in them and also census sectors
Area coverage	One city or urban areas	All of Brazil
Sources of data	Normally data from a number of sources (e.g., real estate sales, crime reports, census).	Very large sample that covers sense of security from crime, crime victimization, as well as other housing and household characteristics.

Results

In this section, we first calibrate the initial hedonic residential rent model. Then, we do the principal components analysis of the variables impacting neighborhood quality, including security from crime. Finally, we introduce the resulting component scores into the residential rent model as independent variables.

The Initial Hedonic Residential Rent Model

In this section, we first review the indicators on sense of security from crime and then the results of the initial hedonic residential rent model.

Sense of Security from Crime

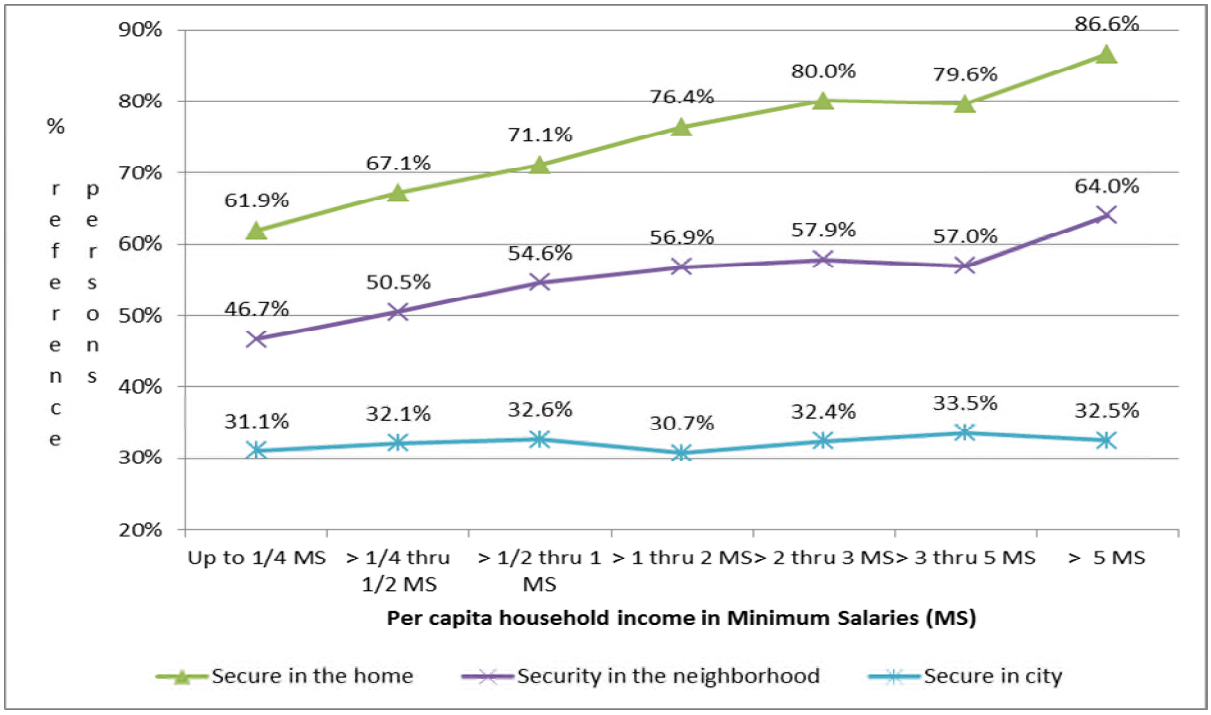
Figure 1 shows that the sense of security from crime in the home rises significantly from 61.9% for the lowest per capita household income group (US$58 or US$233 for a family of

four)[9] to 86.6% for the highest group of five minimum salaries (about US$1,160 per month or US$4,640 for a family of four), The sense of security from crime in the neighborhood is generally lower than for the home for all household income groups, but rises from 46.7% for the lowest per capita income group to 64.0% for the highest group. Finally, the sense of security from crime in the city is much lower than that in the home or neighborhood for all income groups in the Metro Areas, ranging from 31.1% for the lowest income group to 33.5% in the second to the highest income group.

However, With regard to sense of security in the city, Figures 2a and 2b show that there is a lot of variation among the Metro Areas for individual males and females of 10 or more years of age. This sense of security in the city declines significantly from the lower to the higher income groups for both males and females for the four Metro Areas shown (Belem, Rio de Janeiro, Salvador, São Paulo). Belem showed the lowest senses of security in the city levels by far, especially for the highest household income group where only 8.5% of the males and 6.4% of females felt secure in the city versus 31.4% and 26.3% in São Paulo for males and females, respectively. For the lowest per capita income group (up to ¼ minimum salary of about US$58 per month), only 15.1% of the males and 13.4% of the females felt security in the city in Belem versus 48.0% of the males and 40.3% of the females in São Paulo.

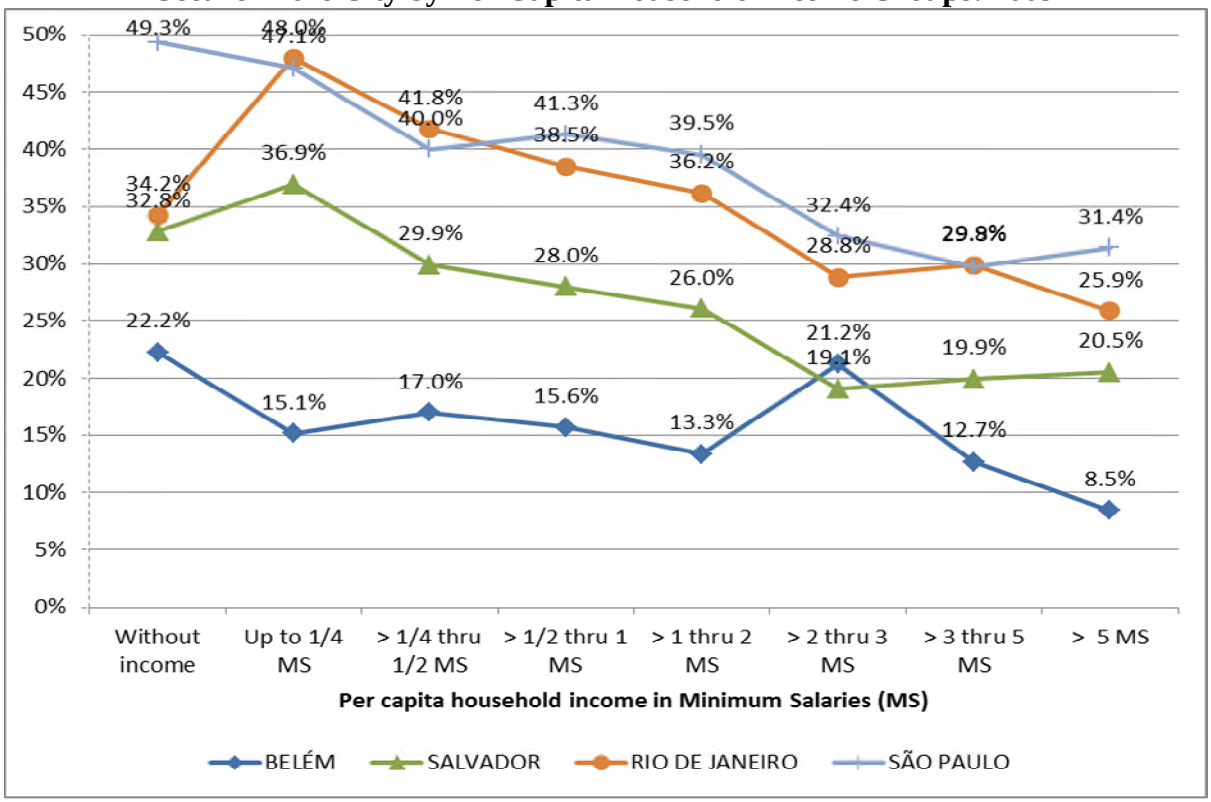
[9] See Table A.5 in Appendix A for the limits of the income groups in local currency and US dollar equivalents.

Figure 1. Brazil: Metro Areas: % of Reference Persons in Rented Households Who Feel Secure in Their Home, Neighborhood and City by Per Capita Household Income Groups: 2009



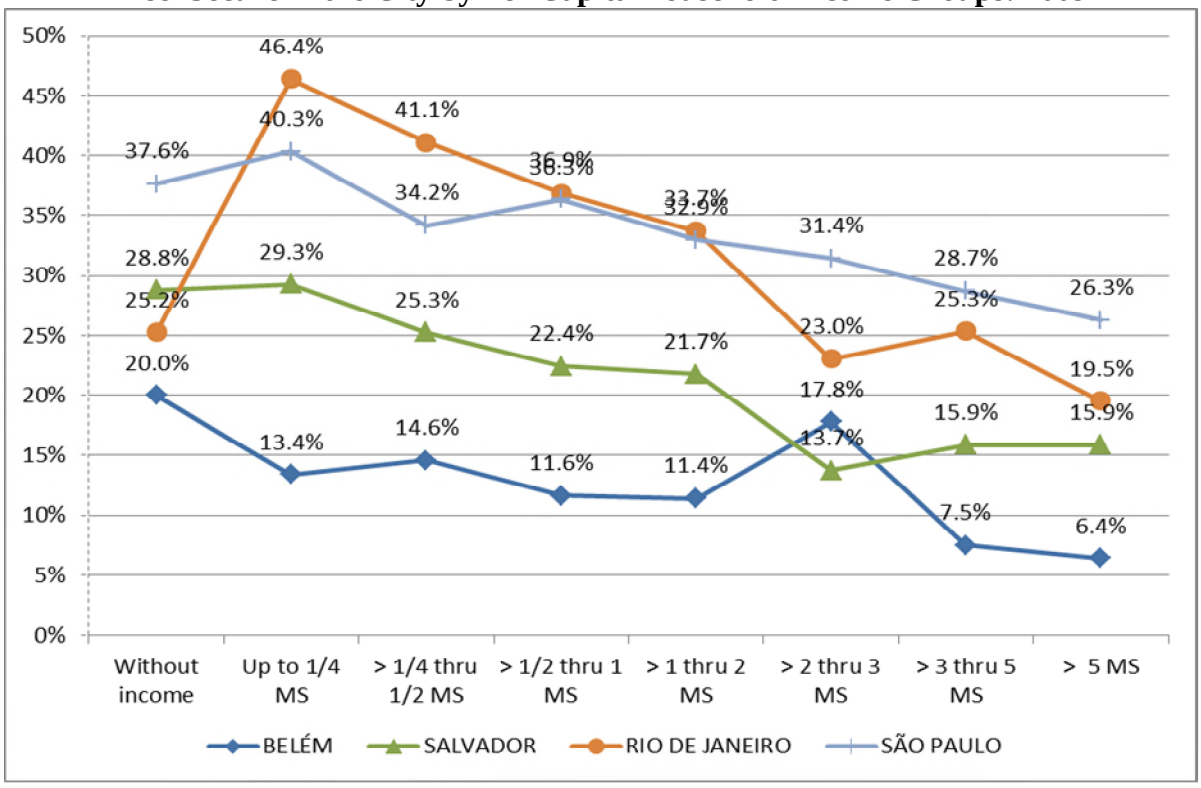
Source: Authors' calculations with 2009 PNAD micro data.

Figure 2a. Brazil: Four Metro Areas: % of Males 10 years of Age or Older Who Feel Secure in the City by Per Capita Household Income Groups: 2009



Source: Authors' calculations with 2009 PNAD micro data.

Figure 2b. Brazil: Four Metro Areas: % of Females 10 years of Age or Older Who Feel Secure in the City by Per Capita Household Income Groups: 2009



Source: Authors' calculations with 2009 PNAD micro data.

Results of the Basic Hedonic Model

Table 2 shows the descriptive statistics of the variables to be used in the basic hedonic residential rent model defined above with the total sample size of 7,718 rented households after excluding some variables with missing values and other adjustments.[10] The average monthly rent was R$324.

Table 2. Households in Rental Units: Variables In the Initial Hedonic Residential Rent Model: Means And Standard Deviations

Variables	*Mean*	*Std. Deviation*
Natural log of monthly rent	5.780	.616
Household: Apartment	.252	.434
Household: Masonry walls	.976	.152
Household: Water from the general system	.971	.167
Household: Sewer system	.878	.328
Household: Septic tank	.044	.204
Household: Direct collection of garbage	.938	.240
Household: Conventional telephone	.464	.499
Household: Access to internet	.338	.473
Household: Number of bathrooms	1.221	.563
Sector: Median commute time to work (minutes)	30	14
Sector: % of households where all persons feel secure from crime	.409	.184
Sector: Median household monthly income	2113	1712

Source: Authors' calculations with 2009 PNAD micro data.

Table 3 shows the results for the initial hedonic residential model with the sense of security in the home variables that was calibrated using weighted ordinary least squares (as in the hedonic studies discussed above) using SPSS (version 16).[11] The first column shows the results with the sense of security in the home at the household level (binary) and the second with the percentage of households with all persons feeling secure in the census sector. With the exception of the sense of security in the home at the household level, the coefficients of all the variables are significant at the 0.01 level or beyond and have the expected signs. As we have discussed, the level of insecurity of those living in an individual household is a function of many factors other than the actual risk of crime victimization, whereas the percentage of those living in the census sector provides an average of the views with regard to its security levels. The R2 for both models is 0.57. Using the usual adjustment for binary

[10] See Appendix C for a full discussion of the PNAD sample.

[11] Although we had originally planned to use the SPSS complex samples module, we found that the variables were very highly significant, so that the marginal gain in statistical accuracy of using the system would not be worth the effort and its cost.

variables with log-linear models,[12] having masonry walls would add 14.3% to the monthly rent of the housing unit and having connection to the general water system would add 10.2% to monthly rent.

Table 3. Regression Results: Basic Residential Rent Model with Sense of Security from Crime in the Home Variable: Natural Log of Monthly Rent as the Dependent Variable

Variables	*Household: Feel secure in home (binary variable)*		*Sector: % of households in which all persons feel secure from crime in the home*	
Constant	4.4388	****	4.3800	****
	[0.0474]		[0.0479]	
Household: Apartment	0.1440	****	0.1333	****
	[0.0121]		[0.0121]	
Household: Masonry walls	0.1325	****	0.1335	****
	[0.0308]		[0.0307]	
Household: Water from the general system	0.0930	****	0.0969	****
	[0.0279]		[0.0279]	
Household: Sewer system	0.3202	****	0.3109	****
	[0.0177]		[0.0177]	
Household: Septic tank	0.1276	****	0.1316	****
	[0.0277]		[0.0276]	
Household: Direct collection of garbage	0.1352	****	0.1336	****
	[0.0194]		[0.0193]	
Household: Conventional telephone	0.1734	****	0.1671	****
	[0.0105]		[0.0105]	
Household: Access to internet	0.2363	****	0.2327	****
	[0.0117]		[0.0116]	
Household: Number of bathrooms	0.2513	****	0.2554	****
	[0.0097]		[0.0097]	
Sector: Median commute time to work (minutes)	-0.0011	***	-0.0011	***
	[0.0003]		[0.0003]	
Sector: Median household monthly income	0.0001	****	0.0001	****
	[0.0000]		[0.0000]	
Household: Feel secure in home	-0.0006		0.0000	
	[0.0094]		0.0000	
Sector: % of households in which all persons feel secure from crime			0.1868	****
			[0.0274]	
Observations	7718		7718	
Adjusted R Square	0.566		0.566	

Standard errors in brackets.
Significance levels: **** 0.001, *** 0.01, **0.05, * 0.1

Source: Authors' calculations with 2009 PNAD micro data.

[12] Halvorsen and Palmquist (1980) show that a much better approximation of the percentage change in rent due to a change of an independent binary variable is the natural log of the coefficient minus one.

Given the coefficient for the percentage of households in the sector in which all persons feel secure from crime is 0.187, a 10 percentage point increase in this percentage in the sector would result in a 1.87% increase in the rent paid by the household. The standard deviation of this percentage of households feeling secure at the sector level is 18.4%. Increasing this percentage feeling secure by 18.4 percentage points would raise rents by 3.4%.

What would be the impact on the market value of house of the sense of security in the home at the sector level by one standard deviation (18.4%)? We first use the model to estimate monthly rent at the means of all of the independent variables. The resulting estimated monthly rent for the Metro Areas is R$325. At the monthly discount rate of 0.75% (9.38% annual rate) used by IPEA in its residential wealth calculations, the estimated price at the original security level would be R$43,350. Increasing sense of security at the sector level by one standard deviation (18.4%) would increase average home values by R$1,513 (about US$757) or about US$13.6 billion if applied to all 18.0 million households in the Metro Areas studied.

	Estimate: At the means of the variables	Estimate: +1 standard deviation for security	Increment in value due to great sense of security in the home
	A	B	C = B - A
Estimate of house price: R/i	43,350	44,863	1,513
Estimate of monthly rent	325.12	336.47	11.35

Results of the Principal Components Analysis

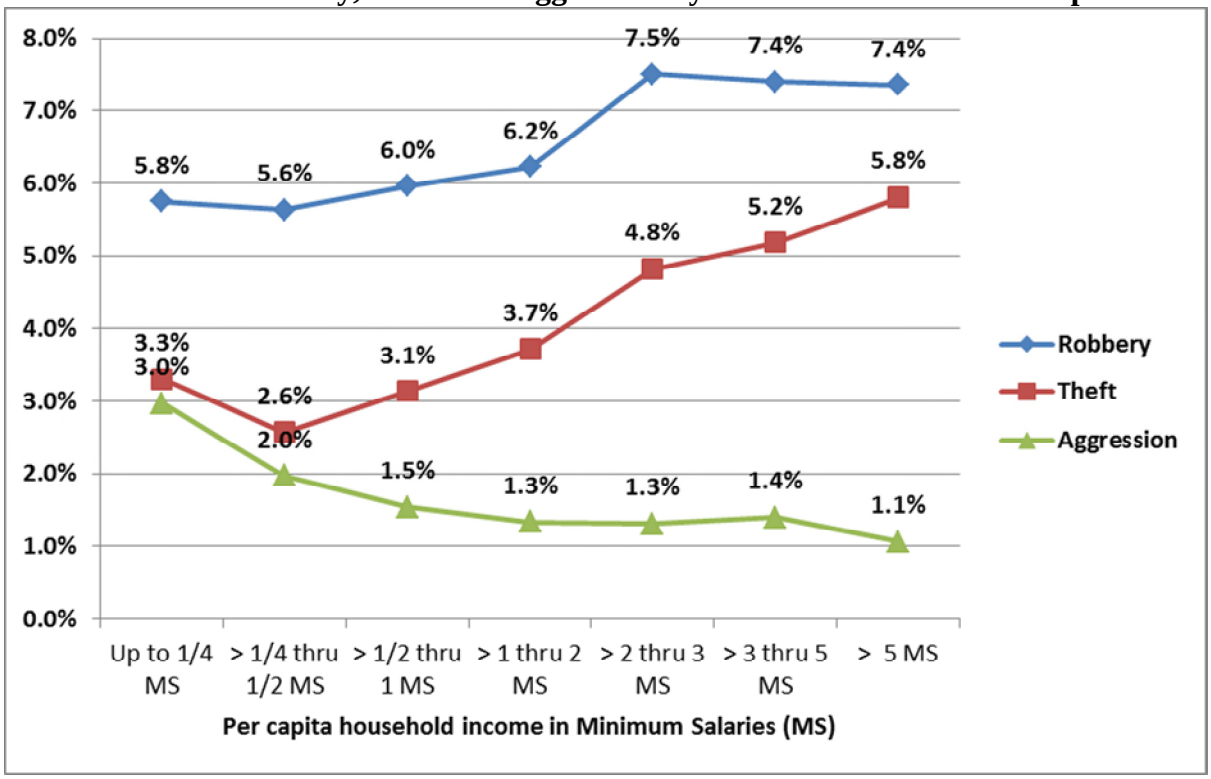
As discussed above, principal components analysis allows us to introduce the variables related to neighborhood characteristics (N) into the model without the usual multicollinearity problems. These variables include: Sense of security from crime in the home, neighborhood and city; victimization from three different types of crime (robbery, theft, and physical aggression); and home protection measures (e.g., intercoms, bars on windows, high walls, surveillance cameras, and security personnel).

Crime Victimization and Household Income

To understand the results from introducing the crime victimization variables into our model, we first analyze the relationship between crime rates and per capita family income

groups. Figures 3 and 4[13] show that the risks of being the victim of Robbery or Theft rise considerably with per capita household income.[14] For Robbery, the percentage of persons of 10 or more years of age rises from the lowest to highest per capita household income group (although not monotonically): from 5.8% to 7.4% (5,751 to 7,354 per 100,000 persons of 10 or more years of age), respectively. Theft rates are lower than those of Robbery, but rise more rapidly with household income. Aggression rates are much lower and decline significantly with income from 2,969 per 100,000 for the lowest income group (1/4 minimum salary per capita) to 1,064 for the highest income group (five minimum salaries per capita). As we discussed above, thieves and robbers are obviously selecting victims who have more to steal. Comparing Figures 3 and 4 with Figures 2 and 3 shows that those living in higher income households tend to feel more secure in their homes, even though they are more likely to be victims of Theft and Robbery, although many times in their neighborhood or the city at large, rather than in their homes. One reason for this that we will analyze below may be that the higher income households tend to have more home protection measures.

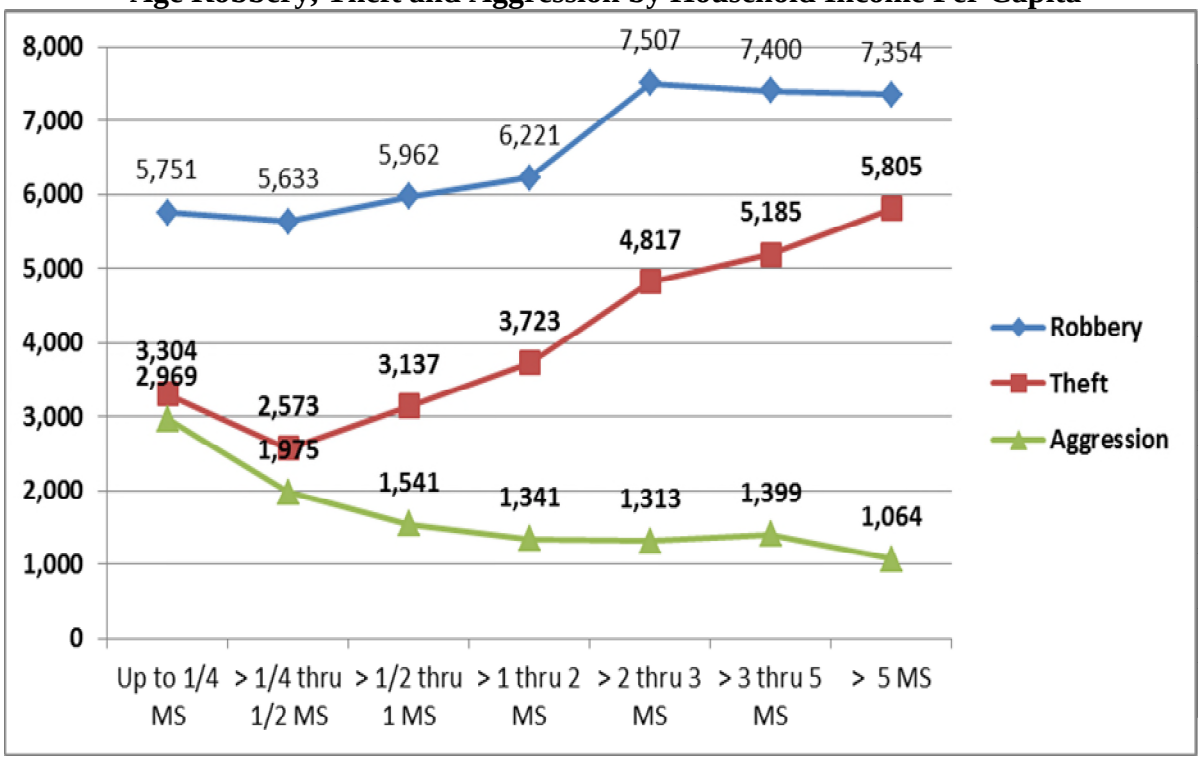
Figure 3. Brazil: Metro Areas: % of Persons of 10 or More Years of Age Who Were Victims of Robbery, Theft and Aggression by Household Income Per Capita: 2009



Source: Authors' calculations with 2009 PNAD micro data.

[13] Because studies use both the percentages and the rates per 100,000, we provide both.
[14] As also found by Gaviria and Pagés (2002) and Gaviria and Velez (2001) in Colombia.

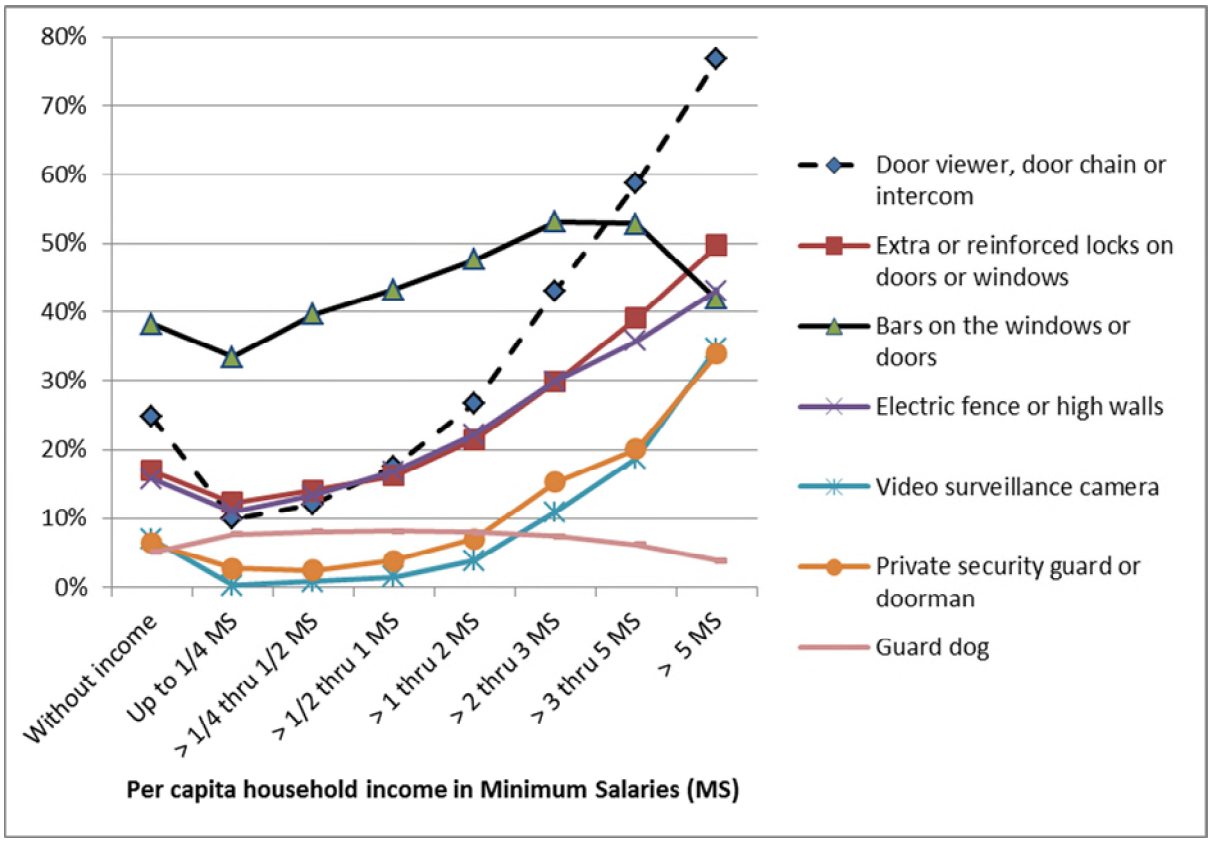
Figure 4. Brazil: Metro Areas: Crime Rate Per 100000 Persons of 10 or More Years of Age Robbery, Theft and Aggression by Household Income Per Capita



Source: Authors' calculations with 2009 PNAD micro data.

Note victimization rates shown in the figures are for persons, but do not specify whether the crime took place in the home or outside of it, as we do in some of our other indicators in Table A.2. If victimization rates for Theft and Robbery rates are higher in higher income areas where rents are usually higher, one would expect a positive sign on the coefficients rather than a negative one as in most previous hedonic studies. Figure 5 shows that the percentages of urban households with most home protection measures rise quite rapidly with per capita household income.

Figure 5. Brazil: Metro Areas: % of Households with Home Protection Measures by Per Capita Household Income Groups



Source: Authors' calculations with 2009 PNAD micro data.

The Principal Components Analysis

We used the correlation coefficients matrix and the communalities[15] of variables to eliminate some of the variables listed in Table A.2 that proved to be less relevant.[16] The following results of our principal components analysis are for the 74 variables selected. To provide us with a broader overview of the relationships involved, we used all 40,095 households in the sample for this analysis, rather than just the rental units that we use for calibrating the hedonic model.

As noted by Kain and Quigley (1970), there is no generally accepted way of unambiguously determining the appropriate number of components. As a first step, we decided to analyze in detail the first two components before rotation, because they provide intuitively meaningful bundles of variables for the home protection measures, and also the

[15] The communality is the sum of the squared factor loadings for a given variable for all the factors generated. In this way, the communality is the percent of the variance of a given variable that is explained by these factors.
[16] For example, because the results showed that the number of observations for the questions on why an occurrence was not reported to the police or registered by them was not large enough to be statistically significant, we dropped these variables from the analysis.

sense of security from crime, crime victimization and the other indicators. These two components explained 16.8% of the total variance. In the second stage of the analysis, we do the rotation to generate the component scores to be used in the hedonic regression model.

Table 4 shows the variables in the first component with positive or negative loadings of 0.200 or more that are ranked from highest to lowest loading. A loading of 0.200 is, of course, rather low, but we use it because it does indicate some correlation of the variable with the component. Based on these loadings, we label Component 1: High crime, low sense of security from crime. This component explains 9.9% of the total variance. The loadings shown in Table 4 for all three types of crime show are positive, and those for sense of security from crime in the home, neighborhood and city at both the household and sector levels are negative. The Metro Area of Belem showed a positive loading, as expected, and, surprisingly given the amount of crime covered in the press, Rio de Janeiro showed a negative loading, albeit a relatively low one.

Component 2 of the unrotated matrix in Table 5 is quite interesting, as the loadings on sense of security from crime in the home are relatively high, despite high positive theft loadings, that may be explained in part by the high loadings on presence of home protection measures, and also willingness to report the Theft to the police and for the police to register it (indicating confidence in them and efficacy on their part). The high positive loadings for household income and the negative loading for informal sector (i.e., *favela*) indicate that social strata also impacted on this. Thus, the picture is much more complex than presented by most hedonic models in which only crime rates are used. Basically these component loadings define are higher income areas with good home protection measures, significant confidence in the police but also higher theft levels. In this way, this component is in line with the arguments of Ihlanfeldt and Mayock (2009) who argue that crime rates and home protection measures are higher in higher income (and rent) neighborhoods. Component 2 explains 6.9% of total variance.

Table 4. Component 1 of the Unrotated Matrix: Variables with Highest and Lowest Loadings Ranked: High Crime Victimization, Low Sense of Security from Crime in the Home, Neighborhood and Sector

Variables	*Component Loadings*	*No.*
Sector: Households with one Aggression	.711	1
Sector: Households with one robbery	.711	2
Sector: Robbery reported to police	.648	3
Sector: Robbery registered by police	.623	4
Sector: Households with more than one robbery	.601	5
Household: Households with one robbery	.445	6
Sector: Households with one Theft	.435	7
Household: Robbery reported to police	.400	8
Sector: Aggression by unknown person	.399	9
Household: Robbery registered by police	.386	10
Sector: Aggression reported to police	.381	11
Sector: Aggression registered by Police	.370	12
Sector: Theft reported to police	.356	13
Household: Households with more than one robbery	.347	14
Sector: Households with more than one Theft	.344	15
Sector: Theft registered by police	.342	16
Sector: Car robbed	.336	17
Sector: Theft in home	.309	18
Sector: Robbery in home	.309	19
Sector: Households with more than one Aggression	.303	20
Household: Households with one Theft	.270	21
Household: Households with one Aggression	.267	22
Metro area: BELÉM	.257	23
Sector: Aggression in home	.232	24
Household: Theft reported to police	.229	25
Household: Aggression by unknown person	.229	26
Household: Aggression reported to police	.225	27
Household: Theft registered by police	.222	28
Household: Car robbed	.218	29
Metro area: RIO DE JANEIRO	-.222	30
Household: Feel secure in home	-.285	31
Reference Person: Feel secure in home	-.315	32
Sector: % all persons in households: Feel secure in	-.361	33
Household: Feel secure in city	-.374	34
Household: Feel secure in neighborhood	-.387	35
Reference Person: Feel secure in city	-.401	36
Reference Person: Feel secure in neighborhood	-.419	37
Sector: % reference persons: Feel secure in home	-.435	38
Sector: % all persons in households: Feel secure in city	-.497	39
Sector: % reference persons: Feel secure in city	-.504	40
Sector: % all persons in households: Feel secure in	-.547	41
Sector: % reference persons: Feel secure in	-.565	42
Observations	40,095	
Variance explained	9.88	

Source: Authors' calculations with 2009 PNAD micro data.

Table 5. Component 2 of the Unrotated Matrix: Variables with High Loadings Ranked: High Loadings: Household Income, Apartment, Home Protection, Security in Home and Neighborhood, Theft and Robbery

Variables	***Component Loadings***	***No.***
Sector: median per capita income	.732	1
Sector: median household income	.732	2
Sector: % all persons in households: Feel secure in home	.565	3
Household: Monthly income	.558	4
Home protection: Door viewer or intercom	.504	5
Household: Apartment	.495	7
Home protection: Surveillance camera	.472	8
Sector: Theft reported to police	.446	9
Sector: Theft registered by police	.442	10
Sector: % all persons in households: Feel secure in neighborhood	.425	11
Home protection: Security gate or person	.403	12
Sector: % reference persons: Feel secure in home	.365	13
Sector: Households with one Theft	.365	14
Household: Feel secure in home	.350	15
Home protection: Extra locks	.311	16
Household: Feel secure in neighborhood	.299	17
Sector: Theft of car	.298	18
Home protection: High walls or other barriers	.293	19
Household: Theft reported to police	.282	20
Household: Theft registered by police	.281	21
Reference Person: Feel secure in home	.266	22
Sector: % reference persons: Feel secure in neighborhood	.265	23
Sector: Households with more than one Theft	.258	24
Sector: Car robbed	.252	25
Household: Households with one Theft	.237	26
Reference Person: Feel secure in neighborhood	.230	27
Sector: % all persons in households: Feel secure in city	.216	28
Sector: Informal (*favela*)	-.250	29
Observations	40,095	
Variance explained	6.94	

Source: Authors' calculations with 2009 PNAD micro data.

Table 6 shows the results of the rotated matrix for the first 10 components, including the labels that we developed based on their variable loadings. The Rotation Sums of Squared Loadings show that these 10 components explain 40.5% of the variance. The rotation split up the different Robbery, Theft and Aggression indicators among a number of different components, as it also did with those related to security from crime in the home, neighborhood and city.

Table 6. Results of the Rotated Matrix: First 10 Components with Labels and the Rotation Sums of Squared Loadings

Component labels	*No.*	*Rotation Sums of Squared Loadings*	
		% of Variance	Cumulative %
High sector robbery	1	5.81	5.81
High sector theft	2	4.63	10.44
High household robbery	3	4.25	14.69
High household all persons and reference person feel secure in home	4	4.11	18.80
High household aggression	5	4.00	22.80
High sector security in home, neighborhood and city	6	3.98	26.78
High household income, surveillance camera, sector income	7	3.59	30.37
High income, apartment, security measures, and Sector: high security in the home	8	3.54	33.92
Household and sector secure in the neighborhood and city	9	3.30	37.21
High sector aggression	10	3.27	40.49

Source: Authors' calculations with 2009 PNAD micro data.

Using the Component Scores in the Hedonic Residential Rent Model

In Table 7, we introduce the 10 component scores for most pertinent components from our principal components model as independent variables into our hedonic residential rent model. As with the initial hedonic model, the first variables cover household characteristics and access to employment (S and A in equation 1). To these we add the 10 component scores related to neighborhood characteristics (N). The R2 of the model is 0.58.

Table 7. Regression Results with Log-Linear Specification: Natural Log of Monthly Rent as the Dependent Variable

Variables	***Coefficients***	
Constant	5.0644	****
	[0.04916]	
Household: Masonry walls	0.0995	***
	[0.03024]	
Household: Water from the general system	0.0810	***
	[0.02746]	
Household: Sewer system	0.2501	****
	[0.01768]	
Household: Septic tank	0.0554	**
	[0.02741]	
Household: Direct collection of garbage	0.1375	****
	[0.01906]	
Household: Conventional telephone	0.1463	****
	[0.01047]	
Household: Access to internet	0.2099	****
	[0.01173]	
Household: Number of bathrooms	0.0935	****
	[0.01163]	
Sector: Median commute time to work (minutes)	-0.0017	****
	[0.00033]	
Components		
1 High sector robbery	0.0205	****
	[0.00451]	
2 High sector theft	0.0383	****
	[0.00433]	
3 High household robbery	0.0165	****
	[0.00458]	
4 High household: all persons and reference person feel secure in home	0.0029	
	[0.0046]	
5 High household aggression	-0.0040	
	[0.00404]	
6 High sector security in home,	0.0448	****
	[0.00472]	
7 High household income surveillance camera, sector income	0.2868	****
	[0.00756]	
8 High income, apartment, security measures, and Sector: high security in the home	0.1625	****
	[0.00511]	
9 Household and sector secure in the neighborhood and city	-0.0429	****
	[0.00472]	
10 High sector aggression	-0.0031	
	[0.00436]	
Observations	7414	
Adjusted R2	0.584	

Standard errors in brackets.
Significance levels: **** 0.001, *** 0.01, **0.05, * 0.1

Source: Authors' calculations with 2009 PNAD micro data.

The results on Components 6 and 8 (Sector: high security in the home and High income, apartment, security measures,) confirm those of Table 3 with the sense of security in the home at the sector level along with income level being significantly and positively related to monthly rent. Also as in Table 3, the sense of security in the home at the household level was not significant. Why the negative sign on Component 9 (Household and sector secure in the neighborhood and city)? This may be because the sense of security in the neighborhood and city are sometimes higher in lower income areas than higher income ones (as shown in Figure 2). As expected, the component of high income and surveillance camera showed a significant and positive sign.

Also confirming the results of Tables 3 and 4, the components 1, 2 and 3 showing higher levels of Robbery and Theft showed highly significant positive signs, as expected based on the incidence of these crimes for higher income groups (See Figures 3 and 4). The household and sector level Aggression components (5 and 10) are not significant, probably because the incidence of Aggression is relatively low and the aggressor may be a member of the family or relative.

Conclusions

Using a hedonic residential rent model calibrated with micro data from Brazil's annual survey for metropolitan areas, we find that there is a strong and significant relationship between monthly rent and the sense of security in the home. Using these results, we estimate that increasing the sense of security in the home by one standard deviation would increase average home values by US$1,513 (US$757 at the average exchange rate of 2009) or about US$13.6 billion if applied to all 18.0 million households in the study area. Our principal components analysis of sense of security and crime victimization variables indicates that higher income households tend to feel more secure from crime in the home, even though theft and robbery victimization tend to rise with household income and rent. Higher levels of home protection measures and greater confidence in the police (as evidenced by willingness to report crime to them, and of the police to register the crime) to by higher income households partially explain this seeming paradox. The introduction of the component scores into our hedonic rent model support these findings.

If such home protection measures are effective in increasing the sense of security from crime, they could point to another set of policy options involving changes policies on buildings and their surrounding areas to make them safer, as well as greater community

involvement. This would involve studies to identify the changes in community involvement, and also in buildings and their surrounding areas that make them safer from criminals, as well as incentives to use them, such as through public information programs, regulatory changes or fiscal changes.

Mohammed et al. (2009) conclude that increasing police effectiveness would have an impact on reducing the fear of crime by increasing confidence in them. Efforts to improve this confidence could involve increasing technical expertise in solving crimes (e.g., improved information systems and training), prosecution of police crime and improvements in the way the public is treated when reporting crime. Corbacho et al. (2012) would agree in general with these policy measures, but also stress the importance of reducing crime victimization per se to increase the confidence in the police.

Future Studies

We think that our work to date shows that the 2009 PNAD crime and victimization supplement provides the data necessary for a systematic, robust, and comprehensive analysis of the economic impact of crime and violence in Brazil. Obviously, we were able only to initiate this analysis of this rich database within the rigorous time constraint of this study. There are, of course, numerous further steps that could be taken using the 2009 PNAD data in future studies. IBGE may also do another PNAD crime and victimization supplement in 2013 or 2014. The following are some suggestions for future studies with the PNAD micro data.

Further analysis of key aspects of the sense of security and crime victimization

There are a number of topics that could best be studied with individuals, rather than for households as the unit of analysis. In other words, the dataset would be generated for the all of the more than 110,000 persons of 10 years of age or more in the sample, rather than grouping them into households. Indicators of household characteristics (e.g., income and size) and those of the census sector in such the individual lives could, of course, be calculated for each individual. This would allow a more detailed analysis of the impact of gender and age on the sense of security from crime and crime victimization. For example, it would be interesting to use such a database to analyze the relationships between sense of security and reporting crime to the police along the lines of Mohammed et al. (2009) and Crobacho et al.

(2012), including the attitudes about the police as shown by willingness to report crime and the of police to register the crime. Aggression, especially violence against women, certainly deserves further analysis of the aggressors as well as the impact of such violence on labor force participation and infant mortality.

Use the Hedonic Model to Estimate the Impact of Improved Sense of Security on Residential Wealth

We could use the hedonic residential rent model to simulate the impacts of improvements in the sense of security from crime on housing on housing prices and therefore the stock of residential wealth by applying IPEA's methodology that involves:

- Using the hedonic model to impute the rents of non-rental units. This would be done just by "plugging in" the values of the independent variables for these non-rental units.
- Employ the standard equation to estimate housing price: $P = R/i$, where i is the monthly discount rate. We could use the same the monthly discount rate of 0.75% used by IPEA initially, but could do a sensitivity analysis on the impact of using a lower discount rate.
- Estimate the stock of residential capital with these housing prices.
- Simulate the impacts of improvements in the sense of security of crime (e.g., increase by one standard deviation or all households at the median sense of security level).

Following Tafner and Carvalho (2007), we could also do the estimates of residential capital for household income groups to estimate the impacts of crime on the distribution of residential wealth. In summary, through hedonic pricing, residential home price can become our *numéraire* for a set of the indicators on fear of crime and crime victimization, as well as other housing and neighborhood characteristics.

Further Work on the Hedonic Models

Further work to estimate the individual household bid-rent functions for different housing attributes including security from crime that underlie the hedonic function estimated here. As Brueckner (2012) points out, "Since the bid-rent functions reveal the structure of

preferences for housing attributes, estimating them allows recovery of the parameters of the household utility function. The most common estimation approach is the Rosen (1979) two-step method, where the hedonic function is estimated first and the bid-rent functions estimated in a second step. The approach exploits the fact that the slope of the hedonic price function, evaluated at a particular combination of housing attributes, equals the slope of the bid-rent function (the marginal valuation of attributes) for the household occupying that particular house. This slope equality reflects the upper-envelope property of the hedonic function. Therefore, regressing the hedonic slope (the marginal attribute prices) on the levels of the attributes and on the characteristics of the occupying household allows the researcher to recover the parameters of the bid-rent function and thus of preferences." Quigley (1982) is a good example of a study applying the Rosen two-step method.

Final Note

In summary, we think that the 2009 PNAD can provide the data necessary to develop a systematic, robust, and comprehensive way of analyzing the costs of crime and violence in Brazil, including the hedonic model of residential rent. Furthermore, the hedonic methodology could be applied at relatively low cost by other countries in Latin America that do household sample surveys.

An additional advantage of this methodology is that it can be used to improve the design of public policies in a number of sectors beyond the impact of crime. Tafner and Carvalho (2007) argue that this hedonic method of analyzing housing prices and residential capital is "more than just a statistical refinement, can and should be used to better target and design public policies to reduce the risk of homelessness and increase access to housing wealth, especially for the most deprived segments of society."

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Appendix A: Tables

Table A1. 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	
Household income	Natural log of household income
Type of housing unit	1, if apartment; 0, if otherwise
Type of materials used in walls	1, if masonry; 0, otherwise
Rooms	
Number of bathrooms	Number of bathrooms
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
Conventional phone line	1, yes; 0, otherwise
PC used to access internet	1, yes; 0, otherwise
Car	1, yes; 0, otherwise
Sense of security from crime	
Household: All persons 10 years of age or more in the household feel secure from crime	1, if all persons of 10 years of age or more feel secure from crime; 0, otherwise
Sector: % of all households in a sector secure in which all persons feel secure	Sector: % of all households in a sector in which all persons 10 years of age or more in the household feel secure from crime
Sector level for each household	
Median sector household income	Median monthly income of all households in the sector
Median commute time: All occupied persons in the sector	Median commute to work in minutes of all occupied persons in all households of the sector; All others = 0

Table A.2. Variables for the Principal Components Analysis

Sense of Security from Crime in the Home, Neighborhood and City	
Do you feel secure from crime: For persons of 10 or more years of age	
Variable label	**Description**
Household level: Binary variables	
Household: All household members feel secure at home:	All household members 10+ years old feel secure in home: Yes = 1, No = 0
Household: Reference person feels secure at home:	The reference person feels secure at home: Yes = 1, No = 0
Household: All household members feel secure in their neighborhood:	All household members 10+ years old feel secure in their neighborhood: Yes = 1, No = 0
Household: Reference person feels secure in their neighborhood:	The reference person feels secure in their neighborhood: Yes = 1, No = 0
Household: All household members feel secure in their city:	All household members 10+ years old feel secure in their city: Yes = 1, No = 0
Household: Reference person feels secure in their city:	The reference person feels secure in their city: Yes = 1, No = 0
Sector level: Percentage of households in the sector	
Sector: All household members feel secure at home:	% households in the sector in which all members 10+ years old feel secure in home
Sector: Reference person feels secure at home:	% households in the sector in which the reference person feels secure at home:
Sector: All household members feel secure in their neighborhood:	% households in the sector in which all members 10+ years old feel secure in their neighborhood
Sector: Reference person feels secure in their neighborhood:	% households in the sector in which the reference person feels secure in their neighborhood
Sector: All household members feel secure in their city:	% households in the sector in which all members 10+ years old feel secure in their city
Sector: Reference person feels secure in their city:	% households in the sector in which the reference person feels secure in their city
Crime Victimization Indicators: Robbery, Theft and Physical Aggression	
Victim of robbery: For persons of 10 or more years of age	
Variable label	**Description**
Household level: Binary variables	
Household: Robbery victim	At least one person in the household was robbed during the last year: Yes = 1, No = 0
Household: More than 1 robbery	More than one person in the household was robbed or one person was robbed more than once during the last year: Yes = 1, No = 0
Household: Robbery of car	A car was stolen in the last robbery: Yes = 1, No = 0
Household: Last robbery in the home	Robbery in own home or home of others: Yes = 1, No = 0
Household: Did you report the last robbery to the police	Yes = 1, No = 0
Household: Principal reason for not informing the robbery to police	No confidence in police: Yes = 1, No = 0
	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
Household: Was last robbery registered by the police or on the internet	Yes = 1, No = 0
Household: Why was the last robbery	No confidence in police: Yes = 1, No = 0

was not registered by the police or on the internet	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
	Police did not want to register: Yes = 1, No = 0
Sector level: Percentage of households in the sector	
Sector: One robbery victim	% households in the in which at least one person in the household was robbed during the last year
Sector: More than 1 robbery victim	% households in the in which more than one person in the household was robbed or one person was robbed more than once during the last year
Sector: Robbery of car	% households in the in which a car was stolen in the last robbery
Sector: Last robbery in the home	% households in the in which robbery was in own home or home of others
Sector: Did you report the last robbery to the police	% households in the in which robbery was reported to police
Sector: Was last robbery registered by the police or on the internet	% households in the sector in which robbery was registered
Victim of theft: For persons of 10 or more years of age	
Household level: Binary variables	
Household: One theft victim	At least one person in the household was victim of theft during the last year: Yes = 1, No = 0
Household: More than 1 theft victim	More than one person in the household was victim of theft or one person was victim of theft more than once during the last year: Yes = 1, No = 0
Household: Theft of car	A car was stolen in the last theft: Yes = 1, No = 0
Household: Last theft in the home	Theft in own home or home of others: Yes = 1, No = 0
Household: Did you report the last theft to the police	Yes = 1, No = 0
Household: Principal reason for not informing the theft to police	No confidence in police: Yes = 1, No = 0
	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
Household: Was last theft registered by the police or on the internet	Yes = 1, No = 0
Household: Why was the last theft was not registered by the police or on the internet	No confidence in police: Yes = 1, No = 0
	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
	Police did not want to register: Yes = 1, No = 0
Sector level: Percentage of households in the sector	
Sector: Theft victim	% households in the in which at least one person in the household was victim of theft during the last year
Sector: More than 1 theft	% households in the in which more than one person in the household was victim of theft or one person was victim of theft more than once during the last year
Sector: Theft of car	% households in the in which a car was stolen in the last theft
Sector: Last theft in the home	% households in the in which theft was in own home or home of others
Sector: Did you report the last theft to the police	% households in the in which theft was reported to police
Sector: Was last theft registered by the police or on the internet	% households in the sector in which theft was registered

Victim of physical aggression: For persons of 18 or more years of age	
Household level: Binary variables	
Household: Physical aggression victim	At least one person in the household was victim of physical aggression during the last year: Yes = 1, No = 0
Household: More than 1 physical aggression victim	More than one person in the household was victim of physical aggression or one person was victim of physical aggression more than once during the last year: Yes = 1, No = 0
Household: The aggressor the last time	Unknown person: Yes = 1, No = 0
	Policeman or private security: Yes = 1, No = 0
	Spouse or ex-spouse: Yes = 1, No = 0
Household: Principal reason for not informing the physical aggression to police	No confidence in police: Yes = 1, No = 0
	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
Household: Was last physical aggression registered by the police or on the internet	Yes = 1, No = 0
Household: Why was the last physical aggression was not registered by the police or on the internet	No confidence in police: Yes = 1, No = 0
	Did not want to involve the police: Yes = 1, No = 0
	Fear of reprisal: Yes = 1, No = 0
	Police did not want to register: Yes = 1, No = 0
Sector level: Percentage of households in the sector	
Sector: Physical aggression victim	% households in the in which at least one person in the household was victim of physical aggression during the last year
Sector: More than 1 physical aggression	% households in the in which more than one person in the household was victim of physical aggression or one person was victim of physical aggression more than once during the last year
Sector: The aggressor the last time was an unknown person	% households in the in which a the aggressor was an unknown person
Sector: Last physical aggression in the home	% households in the in which physical aggression was in own home or home of others
Sector: Did you report the last physical aggression to the police	% households in the in which physical aggression was reported to police
Sector: Was last physical aggression registered by the police or on the internet	% households in the sector in which physical aggression was registered
Crime Victimization Indicators: Robbery, Theft and Physical Aggression	
Variable label	**Description**
Door viewer, door chain or intercom	1, if there is a door viewer, door chain or intercom; 0, otherwise
Extra or reinforced locks on doors or windows	1, if there are extra or reinforced locks on doors or windows; 0, otherwise
Bars on the windows or doors	1, if there are bars on the windows or doors; 0, otherwise
Electric fence or high walls	1, if there are electric fence or high walls; 0, otherwise
Video surveillance camera	1, if there is video camera; 0, otherwise
Private security guard or doorman	1, if there is private security guard; 0, otherwise
Guard dog	1, if there is a guard dog for security; 0, otherwise

Age and Gender of the Reference Person	
Variable label	**Description**
Household: Sex of the reference person	1, if female; 0, otherwise.
Household: Age of the reference person	Age in years
Metropolitan Areas	
Belém	1, If Belém; 0, otherwise
Fortaleza	1, If Fortaleza; 0, otherwise
Recife	1, If Recife; 0, otherwise
Salvador	1, If Salvador; 0, otherwise
Belo Horizonte	1, If Belo Horizonte; 0, otherwise
Rio de Janeiro	1, If Rio de Janeiro; 0, otherwise
Curitiba	1, If Curitiba; 0, otherwise
Porto Alegre	1, If Porto Alegre; 0, otherwise
Informal sector	
Informal settlement[17]	1, If household located in an informal settlement (i.e., *favela*); 0, otherwise

[17] Defined by IBGE as a *setor especial de aglomerado subnormal.* See Cavallieri (2010) for a discussion of this the IBGE definition.

Table A.3. Principal Components Analysis: The First 10 Components of the Rotated Component Matrix
(Loadings over .20 and less than -0.2 are highlighted)

Variables	High sector robbery	High sector theft	High household robbery	High household all persons and reference person feel secure in home	High household aggression	High sector security in home, neighborhood and city	High household income, camera, sector income	High income, apartment, security measures, security in the home (sector)	Household and sector secure in the neighborhood and city	High sector aggression
	1	2	3	4	5	6	7	8	9	10
Reference person: Sex	-.019	-.013	.000	.039	-.044	-.027	.172	-.106	.027	-.042
Reference person: Age	.006	.020	-.023	.141	-.048	-.022	.281	-.128	.020	-.003
Household: Monthly income	.015	.040	.047	.020	-.009	.047	.730	.235	-.021	-.005
Household: Apartment	.056	.050	-.001	.037	-.009	.088	.104	.763	-.097	.013
Household: Masonry walls	-.007	-.024	.024	-.004	.006	-.093	-.132	-.059	-.064	.032
Home protection: Door viewer or intercom	.046	.043	.019	.018	-.014	.025	.193	.664	-.042	.004
Home protection: Extra locks	.039	.035	.017	-.017	-.003	-.032	.167	.373	.000	.028
Home protection: Bars on windows and doors	.075	.045	.012	-.013	-.008	-.021	.044	-.065	-.072	-.041
Home protection: High walls or other barriers	.041	.049	.014	-.017	.000	-.014	.177	.288	.049	.004
Home protection: Surveillance camera	-.016	.019	.005	.016	-.009	.044	.221	.667	.002	-.029
Home protection: Security gate or person	.006	.047	.023	.012	-.003	.042	.188	.545	.008	-.045

Variables	High sector robbery	High sector theft	High household robbery	High household all persons and reference person feel secure in home	High household aggression	High sector security in home, neighborhood and city	High household income, camera, sector income	High income, apartment, security measures, security in the home (sector)	Household and sector secure in the neighborhood and city	High sector aggression
	1	2	3	4	5	6	7	8	9	10
Metro area: BELÉM	.220	-.023	.025	-.043	.011	-.126	.016	-.046	-.029	.029
Metro area: FORTALEZA	.133	.036	.023	-.020	.002	-.109	-.037	-.012	-.054	-.013
Metro area: RECIFE	.085	-.042	.020	.022	-.005	.002	-.282	.066	-.111	-.089
Metro area: SALVADOR	.093	-.003	.018	.005	.019	-.013	-.068	-.005	-.097	-.005
Metro area: BELO HORIZONTE	-.054	.065	-.011	-.007	.005	-.002	.007	-.021	.077	.098
Metro area: RIO DE JANEIRO	-.128	-.115	-.021	.018	-.009	.098	.053	-.033	-.008	-.073
Metro area: SÃO PAULO	-.052	-.018	-.012	.004	-.005	.038	.077	.034	.020	-.003
Metro area: CURITIBA	-.018	.102	-.011	-.006	.002	-.038	.086	-.023	.028	.019
Metro area: PORTO ALEGRE	-.037	.040	.003	.014	-.002	.055	-.126	.059	.036	.040
Metro area: DISTRITO FEDERAL	-.027	.050	.001	-.021	-.007	-.070	.231	-.056	.126	.052
Sector: median household income	.067	.129	-.001	.029	-.001	.132	.728	.421	-.046	.021
Sector: median per capita income	.039	.101	-.007	.037	-.002	.156	.684	.475	-.048	.012
Household: Feel secure in home	-.009	.005	-.022	.786	-.034	.142	.062	.083	-.048	.001
Household: Feel secure in neighborhood	-.045	-.002	-.041	.806	-.018	.096	.030	.012	.218	-.021
Household: Feel secure in city	-.035	-.008	-.036	.597	-.013	-.091	-.019	.018	.610	-.036
Reference Person: Feel secure in home	-.019	-.027	-.049	.721	-.034	.271	-.003	.041	-.121	.019
Reference Person: Feel secure in neighborhood	-.068	-.014	-.073	.720	-.017	.212	-.008	-.046	.198	.006
Reference Person: Feel secure in city	-.050	-.028	-.061	.491	-.013	-.030	-.035	-.034	.652	-.022

Variables	High sector robbery	High sector theft	High household robbery	High household all persons and reference person feel secure in home	High household aggression	High sector security in home, neighborhood and city	High household income, camera, sector income	High income, apartment, security measures, security in the home (sector)	Household and sector secure in the neighborhood and city	High sector aggression
	1	2	3	4	5	6	7	8	9	10
Sector: % all persons in households: Feel secure in home	-.033	.014	-.010	.178	-.012	.737	.186	.241	.007	-.054
Sector: % all persons in households: Feel secure in neighborhood	-.138	-.022	-.024	.153	-.014	.757	.097	.056	.349	-.073
Sector: % all persons in households: Feel secure in city	-.115	-.029	-.019	.029	-.014	.418	-.015	-.033	.774	-.061
Sector: % reference persons: Feel secure in home	-.100	-.094	-.016	.202	-.006	.799	.044	.088	-.003	.007
Sector: % reference persons: Feel secure in neighborhood	-.195	-.068	-.034	.158	-.007	.751	.003	-.078	.338	.002
Sector: % reference persons: Feel secure in city	-.152	-.079	-.025	.020	-.010	.370	-.064	-.121	.774	-.017
Sector: Households with one robbery	.868	.056	.120	-.037	.022	-.094	-.013	.048	-.096	.115
Sector: Households with more than 1 robbery	.687	.072	.101	-.050	.019	-.129	-.025	.034	-.032	.099
Sector: Car robbed	.525	.076	.079	.006	.011	-.034	.161	.055	-.015	.005
Sector: Robbery in home	.353	.065	-.020	-.017	.006	-.089	.008	-.014	.029	-.012
Sector: Robbery reported to police	.882	.068	.175	-.029	.016	-.058	.066	.001	-.044	.083
Sector: Robbery registered by police	.866	.061	.174	-.025	.013	-.051	.069	-.011	-.039	.075
Sector: Households with one Theft	.110	.832	.024	-.004	.012	-.032	.029	.087	-.058	.087
Sector: Households with more than 1 Theft	.050	.690	.015	-.005	-.005	-.054	-.024	.096	.005	.110
Sector: Theft of car	.035	.518	-.003	-.017	.008	.012	.091	.008	-.051	-.052
Sector: Theft in home	.048	.590	.022	-.007	-.004	-.075	-.058	-.023	.057	.092
Sector: Theft reported to police	.053	.866	.014	-.011	.015	-.025	.118	.029	-.035	.047
Sector: Theft registered by police	.066	.832	.013	-.012	.016	-.023	.113	.017	-.029	.025
Sector: Households with one Aggression	.868	.056	.120	-.037	.022	-.094	-.013	.048	-.096	.115
Sector: Households with more than 1 Aggression	.067	.110	.011	-.022	.098	-.059	-.027	.001	.009	.352

Variables	High sector robbery	High sector theft	High household robbery	High household all persons and reference person feel secure in home	High household aggression	High sector security in home, neighborhood and city	High household income, camera, sector income	High income, apartment, security measures, security in the home (sector)	Household and sector secure in the neighborhood and city	High sector aggression
	1	2	3	4	5	6	7	8	9	10
Sector: Aggression by unknown person	.205	.122	.012	-.007	.086	-.034	.005	-.002	-.056	.694
Sector: Aggression by police	.000	-.029	.007	.000	-.017	-.022	-.013	-.022	-.025	.076
Sector: Aggression by spouse or ex-spouse	.012	.020	.016	-.012	.082	-.035	-.018	-.019	-.008	.077
Sector: Aggression in home	.040	.014	.011	-.012	.094	-.038	-.036	-.010	.006	.214
Sector: Aggression reported to police	.118	.088	.015	.001	.071	-.024	.001	-.022	-.027	.802
Sector: Aggression registered by Police	.140	.056	.023	.001	.083	-.018	-.006	-.037	-.028	.774
Household: Households with one robbery	.182	.010	.788	-.078	.070	.000	-.010	.024	-.043	.036
Household: Households with more than 1 robbery	.120	.019	.592	-.073	.074	-.003	-.011	.029	.010	.023
Household: Car robbed	.080	.018	.523	.004	.004	-.063	.067	.019	-.005	-.014
Household: Robbery in home	-.023	-.003	.285	-.024	.012	.004	-.004	.000	-.029	.010
Household: Robbery reported to police	.140	.016	.920	-.026	.046	-.010	.026	-.005	-.026	.016
Household: Robbery registered by police	.134	.013	.912	-.020	.041	-.012	.028	-.011	-.024	.012
Household: Households with one Theft	.035	.138	.032	-.042	.041	.003	.025	.021	-.039	.021
Household: Households with more than 1 Theft	.003	.115	.033	-.037	.044	-.006	.020	.020	-.004	.023
Household: Theft of car	.011	.077	.013	-.012	-.010	.001	-.008	.023	.001	-.020
Household: Theft in home	.008	.065	-.007	-.048	.024	-.010	.023	-.039	.004	.016
Household: Theft reported to police	.015	.114	.044	-.008	.011	-.009	.027	.014	-.013	.018
Household: Theft registered by police	.015	.112	.047	-.005	.009	-.008	.023	.016	-.010	.013
Household: Households with one Aggression	.018	.016	.092	-.042	.850	-.024	-.025	.007	.020	.251
Household: Households with more than 1 Aggression	.016	.022	.018	-.025	.704	-.008	.005	-.015	.003	-.018
Household: Aggression by unknown person	-.001	.022	.137	-.035	.553	-.047	-.016	.028	.057	.420
Household: Aggression by police	.016	.008	-.011	-.014	.136	.006	.001	-.001	.007	-.025
Household: Aggression by spouse or ex-spouse	.042	-.010	-.031	.003	.617	.029	.008	-.035	-.075	-.251
Household: Aggression in home	.034	-.011	-.015	.000	.703	.017	-.001	-.021	-.057	-.178
Household: Aggression reported to police	.001	.003	.115	-.022	.713	-.017	-.009	.003	.010	.276

Sources: Authors' calculations with data from the 2009 PNAD

Table A.4. Descriptive Statistics of the Variables

Variables	*Mean*	*Standard Deviation*
Reference person: Sex	59.2%	49.2%
Reference person: Age	48.0	15.3
Household: Monthly income	2,543	3,660
Household: Apartment	18.2%	38.6%
Household: Masonry walls	8.6%	28.1%
Home protection: Door viewer or intercom	29.9%	45.8%
Home protection: Extra locks	23.4%	42.3%
Home protection: Bars on windows and doors	46.2%	49.9%
Home protection: High walls or other barriers	22.8%	41.9%
Home protection: Surveillance camera	6.7%	24.9%
Home protection: Security gate or person	9.0%	28.7%
Metro area: BELÉM	2.9%	16.7%
Metro area: FORTALEZA	5.7%	23.1%
Metro area: RECIFE	6.4%	24.5%
Metro area: SALVADOR	6.6%	24.8%
Metro area: BELO HORIZONTE	9.1%	28.8%
Metro area: RIO DE JANEIRO	21.4%	41.0%
Metro area: SÃO PAULO	31.5%	46.4%
Metro area: CURITIBA	5.6%	23.0%
Metro area: PORTO ALEGRE	7.0%	25.5%
Metro area: DISTRITO FEDERAL	3.9%	19.4%
Sector: median household income	2,018	1,751
Sector: median per capita income	755	752
Household: Feel secure in home	47.6%	49.9%
Household: Feel secure in neighborhood	32.7%	46.9%
Household: Feel secure in city	18.0%	38.4%
Reference Person: Feel secure in home	75.1%	43.2%
Reference Person: Feel secure in neighborhood	56.0%	49.6%
Reference Person: Feel secure in city	33.0%	47.0%
Sector: % all persons in households: Feel secure in home	40.3%	18.3%
Sector: % all persons in households: Feel secure in neighborhood	27.0%	17.4%
Sector: % all persons in households: Feel secure in city	14.4%	15.2%
Sector: % reference persons: Feel secure in home	74.7%	17.6%
Sector: % reference persons: Feel secure in neighborhood	55.8%	23.0%
Sector: % reference persons: Feel secure in city	32.8%	24.4%
Sector: Households with one robbery	16.5%	14.5%
Sector: Households with more than 1 robbery	5.6%	8.4%
Sector: Car robbed	1.5%	4.2%
Sector: Robbery in home	1.3%	3.6%
Sector: Robbery reported to police	7.4%	8.2%
Sector: Robbery registered by police	6.8%	7.8%
Sector: Households with one Theft	10.0%	10.7%
Sector: Households with more than 1 Theft	2.8%	5.5%
Sector: Theft of car	0.8%	2.7%
Sector: Theft in home	3.0%	5.5%
Sector: Theft reported to police	3.9%	6.5%
Sector: Theft registered by police	3.3%	5.3%
Sector: Households with one Aggression	16.5%	14.5%
Sector: Households with more than 1 Aggression	1.3%	3.7%

Sector: Aggression by unknown person	2.2%	4.9%
Sector: Aggression by police	0.2%	1.4%
Sector: Aggression by spouse or ex-spouse	0.5%	2.2%
Sector: Aggression in home	0.9%	2.9%
Sector: Aggression reported to police	1.9%	4.5%
Sector: Aggression registered by Police	1.4%	3.2%
Household: Households with one robbery	14.6%	35.3%
Household: Households with more than 1 robbery	4.8%	21.4%
Household: Car robbed	1.4%	11.6%
Household: Robbery in home	1.2%	11.0%
Household: Robbery reported to police	7.4%	26.1%
Household: Robbery registered by police	6.7%	25.1%
Household: Households with one Theft	9.2%	28.8%
Household: Households with more than 1 Theft	2.4%	15.4%
Household: Theft of car	0.7%	8.3%
Household: Theft in home	2.9%	16.9%
Household: Theft reported to police	3.6%	18.6%
Household: Theft registered by police	3.3%	17.9%
Household: Households with one Aggression	3.8%	19.0%
Household: Households with more than 1 Aggression	1.1%	10.3%
Household: Aggression by unknown person	1.9%	13.5%
Household: Aggression by police	0.2%	4.1%
Household: Aggression by spouse or ex-spouse	0.4%	6.6%
Household: Aggression in home	0.8%	8.9%
Household: Aggression reported to police	1.6%	12.6%
Observations	40,095	

Sources: Authors' calculations with data from the 2009 PNAD

Table A.5. Value of the Upper Limit of the Per Capita Household Income Groups in Minimum Salaries (MS) Used in the 2009 PNAD in Reais (R$) and US$

	Per capita household income in Minimum Salaries (MS)					
	Up to 1/4 MS	> 1/4 thru 1/2 MS	> 1/2 thru 1 MS	> 1 thru 2 MS	> 2 thru 3 MS	> 3 thru 5 MS
R$	116	233	465	930	1,395	2,325
US$	58	116	233	465	698	1,163
Family of 4 (US$)	233	465	930	1,860	2,790	4,650

Notes: 2009 PNAD used the value of the minimum salary used in September of 2009: R$465.00.
The exchange rate used in the table is the average commercial sell rate for 2009: US$1 = R$2.00
Sources: Authors' calculations with data from the 2009 PNAD and Banco Central do Brasil, Boletim, Seção Balanço de Pagamentos from IPEAdata.

Appendix B. The Hedonic Housing Price Methodology and Its Use in Brazil

In the hedonic price methodology as applied to the housing market, the price of housing is a function of its characteristics and those of its neighborhood, as well as access to work and other opportunities. The hedonic housing price methodology is widely used and generally accepted. Garner (2004) of the US Bureau of Labor Statistics argues 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." The use of PNAD data is cost effective because it provides all the needed data for the hedonic analysis from IBGE's long established and credible annual survey. As we will discuss below, Brazil's Instituto de Pesquisa Econômica Aplicada (IPEA) uses the hedonic method to estimate the stock of residential capital using census and PNAD data (including the census sector level data).

Methodological Issues for Hedonic Housing Models

There is a massive literature on the theory and methodological issues of hedonic housing models and many reviews of their use in general and for specific ends such as measuring environmental amenities (e.g., parks and green space) and problems (e.g., pollution, hazard waste sites, crime, location of sex offenders, etc.). Of these reviews, Follain and Jimenez (1985 a) and Sheppard (1999) discuss in detail the theoretical and econometric issues involved in these models. Palmquist (2005) reviews these issues for the use of property value models in environmental economics. Malpezzi's (2002) complements these reviews by focusing on the issues facing the applied economist in estimating these models (e.g., multicollinearity, and heteroscedasticity) and providing suggestions on how to ameliorate them. As the hedonic price method involves estimating the impact of specific factors on housing prices, it has often been used to measure the impact of amenities (e.g., green space) and negative ones (e.g., crime and pollution) on housing price (Baranzini et al. 2008).

Brueckner (2012) explains quite clearly that the hedonic price function is the upper envelop of the collected bid-rent functions for housing characteristics in the market: "As is well known from hedonic price theory, households in a housing market compete for the

available dwellings, with each dwelling occupied by its highest bidder. Household bids are generated from bid-rent functions, which give the rental payment (as a function of dwelling characteristics) consistent with achievement of a particular utility level for the household. As a result of the bidding process, the equilibrium rent for a given dwelling lies on the highest of the bid-rent functions from among the competing households. The implication is that the hedonic price function (which connects rent to dwelling characteristics) is then the upper envelope of the collection of bid-rent functions for the households competing in the market." Brueckner notes that most research seeks to estimate just the hedonic price or rent function per se (as is the case of our research).

Although there are usually many potential housing and neighborhood characteristics that could be included on the right hand side of a hedonic regression model, one can really never expect to cover all the aspects of these complex housing markets. Furthermore, many of the characteristics that can be measure are inter-correlated, as one would expect when neighborhood effects are so important in determining housing price. Although the research indicates that coefficient estimates are not robust to the omitted variables problem (Butler, 1982; Ozanne and Malpezzi, 1985), Malpezzi (2003) shows that 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 coefficients must be interpreted more cautiously." In our case, we will focus on the overall impact of the variables including the crime related ones to obtain a robust model of rent payment, rather than the coefficients of the individual variables.

As discussed in the text, many authors have discussed the problem of multicollinearity in hedonic price models and some authors have used factor analysis in seeking to address this problem and also identify the complex relationships among the indicators.

Brazilian Hedonic Studies of the Impact of Crime on Property Prices

In the international literature using hedonic pricing related to crime, the units of analysis are most often spatial units (e.g., neighborhoods or census tracts) rather than individual households. There are a number of Brazilian hedonic studies that use data on different sources to measure the impact of different types of crime on housing and commercial rents or prices in Brazilian municipalities. All of the studies use data from police

reports in developing their estimates of crime victimization. For example, based on the results of their hedonic model in the Municipality of Belo Horizonte, Rondon and Andrade (2005) estimated that a reduction of 50% in armed robbery would increase rents by 22% in the city center, if other crime rates remained constant. Pontes and et al. (2011) confirm this impact of armed street robbery for Belo Horizonte using data on apartment prices from the real estate transfer tax (ITBI). They estimate that a 50% reduction in armed street robbery in the city center would increase apartment prices by 22.5%. Paixão (2009) finds statistically significant impacts of homicide and armed street robbery on prices of commercial properties (shops and offices) in Belo Horizonte. The authors attribute the higher impact of street robbery on property values than homicide on the higher frequency of the former. Another interpretation would be that people may generally realize that most homicides involve people who know one another, whereas armed street robbery is usually by unknown assailants. Teixeira and Serra (2006) also show higher impacts for robbery/ theft than homicide rates on apartment rents in the Municipality of Curitiba. In their hedonic analysis of the impact of amenities on land values in the Municipality of São Paulo, Hermann and Haddad (2005) found that crime as measured by the homicide rate had a high and significant negative impact on rent paid. According to the hedonic models developed by Carvalho and Lemme (2005) for a neighborhood in the Municipality of Rio de Janeiro, the price of property drops by about 1.2% for every crime in the area and about US$9,000 for each kilometer closer to a slum area (i.e., *favela*). In summary, the findings on the negative impact of crime of property values seem robust for Brazil, as they have been confirmed in several cities using data from different sources and different methodologies. However, none of these studies uses household survey data of the type collected by the 2009 PNAD.

We did, however, find one model of the probability of being a victim of crime using the PNAD crime supplement data. Souza and Cunha (2012) develop a profile of the victims of theft, robbery and aggression using a logit model with data from the 1988 and 2009 PNADs. The results show that socio-economic characteristics of an individual have significant impacts of the probability of being the victim that support our finding that higher Theft and Robbery victimization are associated with higher educational levels that are associated with higher income levels, as summarized below for 2009:

Characteristic	Probability of being a victim	
	Theft or Robbery	**Aggression**
Gender	Higher for males	Higher for males
Age	Highest for 20 to 24	Highest for 20 to 24
Educational level	Higher for higher levels	Lower for higher levels
Employment status	Higher for occupied	Higher for occupied
Living in metropolitan region	Higher	Higher
Living in urban area	Higher	Higher
By great region	Highest in Northeast	Highest in Northeast

Brazilian Hedonic Price Studies Using Household Survey Data

There are a number of interesting studies that use census and PNAD micro data that do not include analysis of the sense of security from crime or crime victimization. For example, Cruz and Morais (2000) estimate hedonic prices for housing and urban services in nine Brazilian metropolitan areas and the Federal District (DF/ Brasília) using 1997 PNAD micro data. They argue that this kind of study helps "policy makers to obtain more detailed information on the nature of housing demand – regarding the consumers' preferences for the different attributes of the house and levels of provision of urban services, as well as on the capacity of cost-recovery, and the social impacts of the different housing, sanitation and urban development programs."

As they assume a stable relationship between property price (P) and the value of the monthly rent (R),[18] they use the standard hedonic price methodology in which the dependent variable is monthly rent and the independent variables are housing characteristics available in the PNAD (equation 2), including: The type of materials used in the walls and roof, size of the dwelling unit (number of bedrooms and other rooms), access to public services (water, sewerage, solid waste collection, phone connection and electricity); "quality" of the neighborhood (household per capita income), living conditions (density per bedroom and exclusive bathrooms) and characteristics of the local housing markets (the Metropolitan Region where the property is located).

As discussed in the text, one advantage of using rent as the measure of value in Brazil is that a national Tenant Law (Lei do Inquilinato, Lei nº 8.245, de 18 de outubro de 1991) provides a common legal framework for all aspects of renting and leases for all urban areas, including the rights and duties of the renter and the property owner, the length of the

[18] As with the estimates of residential capital below, P = R/ i, where is the monthly discount rate.

rental contract, eviction, and civil and criminal penalties. There appear to be no strong reasons for the PNAD respondent not to provide the rent accurately. This is not the case for the property register data in which the value provided determines the amount of the real estate transfer tax (ITBI). Using the asking prices (as is the case for data collected from realtors, newspapers, etc.) would also appear to reflect less accurately the prices in the real estate market than actual rents being paid, as they do not show the final sale price of the property. In summary, the PNAD rent data provides a reasonably reliable source of information on the real estate market for a large, carefully selected sample of households.

Cruz and Morais use per capita household income per capita "to capture the quality of the neighborhood, because one expects that people with lower per capita income live in poor neighborhoods and vice-versa." In other words, they use the income of the individual household as a proxy for the quality of the neighborhood in which the household is located. Although residential segregation by household income is quite high in Brazil (Lago 2000, Vetter 1981b and Massena 1986), income of the household per se is not a strong proxy for neighborhood quality. As we shall see below, later studies have used census sector data to overcome this shortcoming. Other problems were the "absence of a measure of accessibility of the residence in the model, despite its relevance in explaining urban land prices, and consequently, housing unit values" and the age of the housing unit. Later PNADs and the 2010 population census have effectively collected data on commuting time to work. They calibrated their model using weighted least squares. As is often the case with hedonic models, the log-linear form provided the best fit with an R-square of 0.59.

In a paper of the Bank for International Settlements (BIS), Reiff and Barbosa (2005) estimate the residential capital value of Brazil's housing stock from 1970 to 1999 using a hedonic price methodology. Their study was part of a broader project on the Estimates of the Stock of Capital and Wealth of Brazil. Overall, their methodology is quite similar to that of Cruz and Morais (2000) with monthly rent as the dependent variable. However, one interesting change introduced by Reiff and Barbosa was that they use the median household income of the census sector (*setor censitário*) in which the household is located as their measure of neighborhood quality, a significant improvement over the income of the individual household income per se as the indicator of neighborhood quality. IPEA uses this census sector data in its estimates of Brazil's stock of residential, as we discuss below.

In an interesting extension of this previous work, Tafner and Carvalho (2007) do an analysis of the distribution of the stock of residential capital by household income groups and other household characteristics using PNAD data. Such estimates can be done for any of the other characteristics covered by PNAD, such as household income groups , tenure, characteristics of the reference person (e.g., employment status, age, sex, color, etc.), and household composition (e.g., size and number of children).

Using the Hedonic Price Method to Calculate Residential Capital

Using a methodology similar to that of Reiff and Barbosa (2005), IpeaData (the excellent online database of IPEA) provides estimates of Residential Capital at the municipal level for urban and rural areas using census micro data for 1970, 1980, 1991 and 2000.[19] For non-census years, national estimates using the PNAD data are available. In this methodology, they first estimated hedonic price functions for rental units with 1999 data on housing characteristics and neighborhood characteristics measured by the median household income of the census sector. Then, they use the model to impute the rents of non-rental units at 1999 prices. They then estimate residential property values using the present value of perpetual flow of the monthly rents[20] discounted at the rate of 0.75% per month (9.38% per year). Given that IPEA uses the 1999 estimates of hedonic prices for all years, the estimates show the value of the change in the characteristics of the stock of housing at 1999 prices. Table B.1 shows that the total stock of residential capital rose by US$453 billion (56.2%) over the 1991/2000 period or about 5.1% (US$51.1 billion) per year just due to changes in the housing stock, as prices are fixed at the 1999 level. 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.

[19] See *Capital Residencial* in the Regional section on http://www.ipeadata.gov.br.
[20] R/i, where i is the monthly discount rate.

Table B.1. Brazil: Total Stock of Urban Residential Capital Estimated Using the Hedonic Price Method in US$ of Constant 2009 Value

	1991	2000	Change 1991-2000		
			Absolute	%	Annual %
Total (US$ billions)	806.5	1,259.5	453.0	56.2%	5.1%
Per capita US$	7,267	10,234	2,967	40.8%	3.9%
Total population (millions)	111.0	123.1	12.1	10.9%	1.2%
% of GDP	92.9%	122.8%	29.9%	32.1%	3.1%

Note: Transformed into R$ of constant average 2009 value using the Implicit GDP Deflator and into US$ using the average annual commercial exchange rate for buyers and seller in 2009: US$1 = R$2.00.

Sources: Authors' calculations with data from IPEAdata.

Appendix C. The PNAD Sample

The Sampling Methodology

This will be a concise overview of the PNAD sampling procedure. For a more detailed description, see Silva et al. (2002). PNAD uses a three-stage sampling procedure involving the selection of: (1) municipalities, (2) census sectors and (3) households.

In the first stage, municipalities are classified into two categories: automatically selected (selection probability = 1) and non-automatically selected. Municipalities in the second category were stratified using population size in 2000. In each stratum, municipalities are selected with replacement and probability proportional to population obtained from the 2000 Demographic Census.

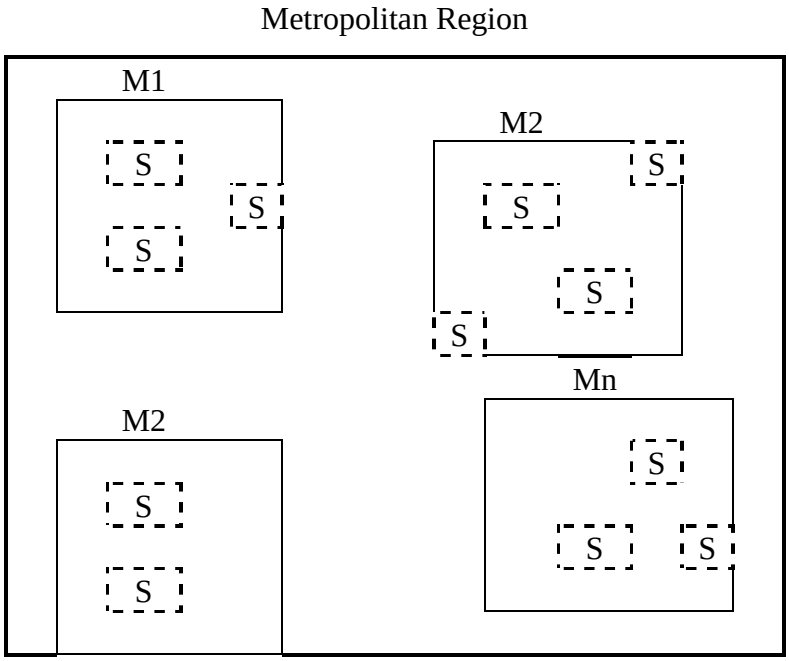
In the second stage, census sectors are selected in each of the selected municipality with replacement and selection probability proportional to the number of households in 2000. IBGE's census sector is an operational unit based on the area that one survey taker can cover during the census or survey period. There are usually between 250 and 350 households in each sector. Variations in the sample sizes of the sectors are adjusted over the inter-census period in responses to population shifts noted in the annual updating of the listing of households.

In the third stage, households within each census sector are selected systematically from an updated listing of households with equal likelihood of selection to allow for statistical analysis of the characteristics of the households and their members. Figure C.1 provides a schematic overview of how the sampling selection procedure with a metropolitan region in which the municipalities (M) and the sectors (S) are selected as described in the first two stages of the sampling procedure. Thus, we have a systematic selection of households within each of these census sectors.

As IBGE currently also collects information on the GPS coordinates for each household surveyed, we know the precise spatial location of each housing unit. Although these coordinates would be available only to IBGE officials due to confidentiality rules, they do offer the potential for matching these survey data with other datasets for eventual monitoring etc. This could also allow calibration of models using a Geographical Information System (GIS), as discussed by Ismail and Macgregor (2006) and Ceccato and

Wilhelmsson (2011). However, IBGE would, of course, need to develop a strategy for avoiding confidentiality issues with such a GIS system.

Figure C.1. Schematic Overview of the Municipalities (M) and Census Sectors (S) In the PNAD Sampling Methodology for a Metropolitan Region



Source: Developed by the authors

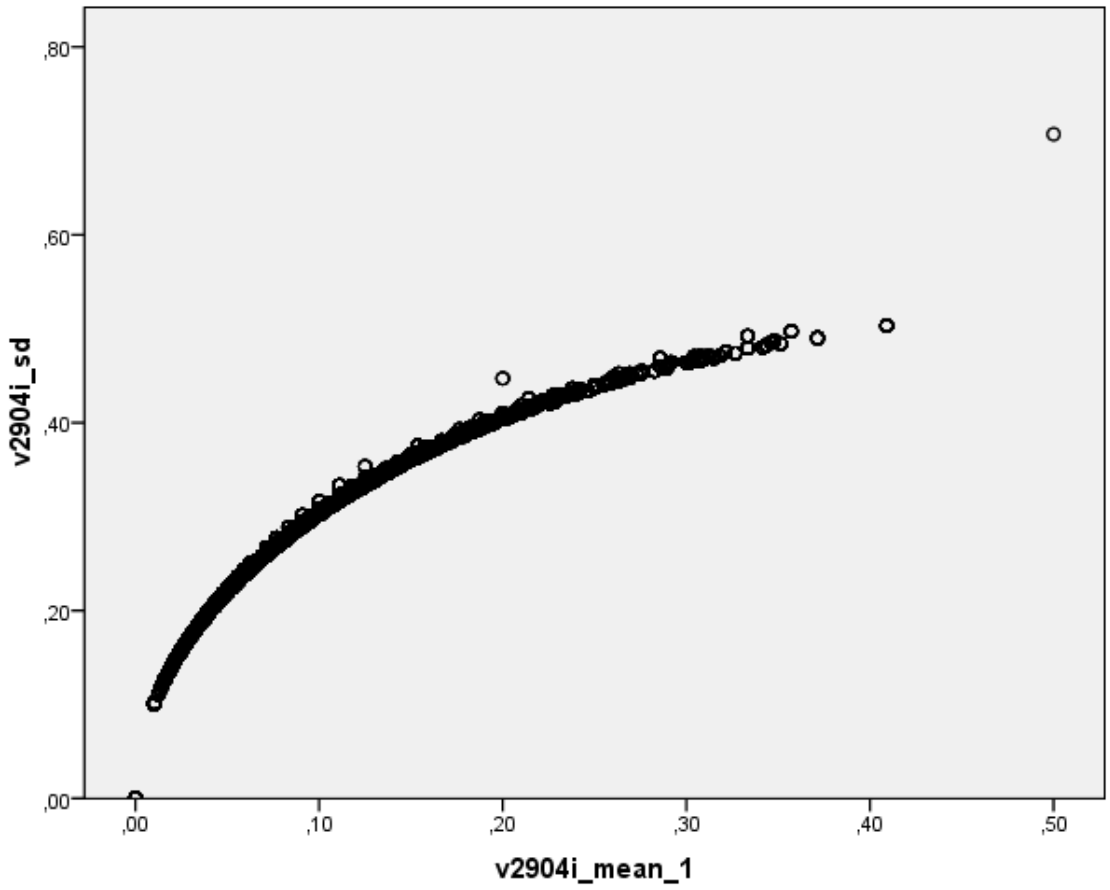
How adequate is the sample size at the census sector level for the questions on sense of security from crime and crime victimization? To address this question, we analyzed:

- The distribution of the population of 10 or more years of age in the sector, as the questions on security from crime and victimization were addressed to this age group.
- The distribution of the means and standard deviations of the indicators on security from crime and victimization at the sector level.
- The statistical significance of the correlation coefficients among the key variables.

As the basic questions on sense of security from crime and crime victimization are asked of all those 10 years of age or more, we focus on this age group. Our total sample of persons 10 or more years of age is 118,286 who are distributed among a total of 2,784 sectors in the urban areas defined above. For the reason discussed below, we eliminated sectors with less than 20 persons 10+ years old. The mean number of persons 10+ years of age in the sample is 42.5, and the median is 42.

To assess the adequacy of this sample size at the sector level, we analyzed the distribution of the individual indicators. This issue is, of course, less important for the sense of security from crime variable, where the average percentage of households who feel secure is about 41%, than for the crime victimization measures where the means are lower. For example, Figure C.2 shows a scattergram of the sector means and standard deviations of the percentage of households in which at least one person was robbed in the previous year where the mean is about 17%. The tight relationship between the sector means and standard deviations indicates a level of consistency for this this indicator among the sectors. We did this type of analysis for many of the crime victimization indicators.

Figure C.2. The Census Sector Means (Horizontal Axis) And Standard Deviations (Vertical Axis) Of The Percentage Of Households In Which One Person Was Robbed During The Reference Year.



Sources: Authors' calculations with data from the 2009 PNAD.

Finally, we reviewed the statistical significance of the coefficients for the sense of security from crime and crime victimization equations in our regression equations. Silva et al. (2002) of IBGE note that it is common to use PNAD data in the construction and calibration of regression models. As discussed above, IPEA uses hedonic models to estimate the stock of residential capital. These models use median household income for the sector. Moraes et al. (2012) develop ordinal logistic models of self-rated health status using PNAD 2008 data, including indicators calculated for census sectors. We found statistically significant relationships among key sector level variables for the sense of security from crime and several of the crime victimization indicators (e.g., victim of robbery, theft or physical aggression). When the coefficients at the sector level are not statistically significant, we can still analyze these variables at the household level, but not at the sector level.

Although the PNAD micro data available on the internet does not identify the census sector to protect confidentiality, there is a control code that can be used as a unique identification number for each sector without violating confidentiality. However, as we know only that the sector is in a particular metropolitan region or state, this control code does not invade the privacy of the informants.

The way in which the newly constructed housing units identified during the annual update are coded on the micro data file generates an issue. These newly constructed units that are selected for the sample are coded separately without coding on the internet file that would permit integrating them with the existing sectors in which they were constructed. As a result, some of these separately coded "sectors" may have just one or two households. As it would make little sense to calculate our sector level indicators with so few households, we decided to cut the 0.4% of households living in these added "sectors" with less than 20 persons of 10 or more years of age, as we think that this solution will have little impact on the results. IBGE could, of course, eventually generate a recoded micro data file in which the new households are integrated with the existing sectors.