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Evidence from Colombia

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Abstract

The effects of urban transport policies on household welfare are a broadly understudied topic in developing countries. This paper analyzes the distributional effects of a newly established bus rapid transit system in Barranquilla, Colombia. The paper uses pooled cross-sectional household survey data, analyzed by block, over 2008–15 and a difference-in-differences approach. The analysis shows that, in proximity to newly opened stations, poor households were replaced by households in the middle and upper socioeconomic strata. These results suggest that the designers of the system, despite the generally positive assessment of the system, may have overlooked the distributional consequences. Moreover, the paper shows that any results on outcomes that may be directly affected by the related policy will be biased due to urban displacement.

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Urban Transport Infrastructure and Household Welfare: Evidence from Colombia[1]

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1. Introduction

Rapid urbanization is one of the defining characteristics of the development process experience in many low- and middle-income countries. Infrastructure development is usually unable to keep pace with urban population growth, thereby generating the inefficient provision of essential services. Transportation is a particularly relevant example. A lack of planning gives rise to inadequate infrastructure, leading to saturated roads and low rates of mobility. In such a setting, public transportation is mostly provided by private actors who rely on the same overburdened roads. Experience indicates that only if the population pressure abates are more serious efforts at improving urban infrastructure and public services undertaken. This must happen under the additional constraints imposed by the existing urban structure. Latin America is a case in point. According to World Bank data, the region's population growth rate, including the Caribbean, peaked at 2.8 percent in 1961 and had declined to 1.0 percent by 2015.[2] The corresponding numbers for Colombia are a high of 3.0 percent in 1962 and a subsequent decrease to 0.9 percent in 2015. The urban population growth rate reached 4.4 percent in Latin America and the Caribbean in 1963 and stands currently at 1.4 percent, whereas Colombia exhibited a steady drop from 5.9 percent in 1960 to 1.4 percent. Today, 80 percent of Latin Americans and 77 percent of Colombians live in urban areas, up from 49 percent and 45 percent, respectively, in 1960. However, only recently have governments begun to improve urban infrastructure and services, particularly in poorer neighborhoods.

In this context, bus rapid transit (BRT) systems have shown dramatic growth over the recent decade. This urban mass transport, usually based on dedicated lanes that allow buses rapid mobility, has been implemented in 205 cities across the world and transports 34 million passengers daily over 5,600 kilometers.[3] Case studies point to the benefits of BRT systems, including in reduced travel time, improved air quality, curtailed greenhouse gas emissions, and the prevention of road accidents (Carrigan et al. 2013). However, research on outcomes such as employment, economic activity, or school attendance is almost nonexistent. One may attribute the gap in knowledge to a lack of appropriate data. Because households and firms may relocate in response to transportation infrastructure, one would need proper longitudinal data to assess the direct effects of infrastructure satisfactorily. Employing pooled cross-sections, as is often done in policy evaluation on other topics, runs the risk of confounding causal effects and changes in the underlying population in answer to a policy. Longitudinal data that are representative of a city or metropolitan area, however, are rarely available. In a recent review of the evidence on the impact of transportation infrastructure on economic growth, Deng (2013) discusses no evidence on urban transportation. All 18 studies discussed conduct their analyses at higher levels of aggregation (counties, states, provinces, or nations).

The present study analyzes the distributional effects of Barranquilla's BRT system, Transmetro, first inaugurated in 2010. It shows that, even though the system was planned to target poorer households, it effectively led to a displacement of households in the city's two lowest income quintiles by those in

[2] See Population Growth (annual %) (database), World Bank, Washington, DC, http://data.worldbank.org/indicator/SP.POP.GROW.
[3] See Global BRT Data (database), World Resources Institute–Ross Center, Brasil Sustainable Cities, Porto Alegre, Brazil, https://brtdata.org/.

the top three quintiles. As a result, households living in proximity to new bus stations became richer and more well educated and had fewer children. Moreover, home values and rents also rose. However, these increases are fully explained by improved home characteristics, and no separate direct effect on proximity can be found. These results matter for several reasons. Not only is this study an example of the still relatively few studies on public transportation in middle-income countries, but also it appears to be the first such study to focus on distributional effects as a result of displacement and neighborhood composition. As discussed below, a few studies exist that attempt to determine the effect of transport infrastructure on outcomes among households, such as employment or income. Because most such studies rely on pooled cross-sectional data, similar to this one, they are based on the implicit and often unstated assumption that households do not relocate in response to the policy. The findings of this study show that the assumption is likely to be violated. Consequently, the study shows that, in the absence of proper longitudinal data, the identification of proper causal effects on incomes among households or individuals is impossible.

Investment in transportation may have implications in a variety of dimensions, such as the spatial distribution of population, wages, and trade and the composition of industry. To fix ideas, Redding and Turner (2015) propose a general equilibrium model to assess the implications of transport infrastructure improvements within and between locations on the distribution of economic activity and then review empirical evidence. An important issue, as highlighted in the study, lies in distinguishing whether a change in transport infrastructure has an effect on growth, or whether it simply leads to a reallocation of existing economic activity. The results presented here strongly suggest that a large part of the changes in economic characteristics are caused by mere reallocation, rather than growth.

This paper has six sections: The next section offers an extensive review of the existing empirical literature on BRT systems. This is followed by a brief overview of Barranquilla's Transmetro. Section 4 explains the data and empirical strategy. Section 5 shows the results, and section 6 concludes.

2. Existing Literature

The existing empirical literature on the economics of public transportation is still sparse and mostly focused on documenting achievements of direct effects of the investments in terms of number of passengers, congestion or traffic rather than their impacts on the welfare and behavior of the population. Most studies focus on performance metrics, such as operating costs, financial sustainability, or total changes in ridership. For example, Alpkokin and Ergun (2012) discuss the BRT system in Istanbul and report significant ridership attracted from among prior car users or users of other modes of public transportation. Deng and Nelson (2013) evaluate a BRT system in Beijing and find positive effects on travel time and travel behavior, while they question the current fare structure. A number of studies compare the performance of BRT systems to other transport infrastructure in travel time, comfort, safety, environmental impact, cost, and quality of service; see, for example, Cervero (2013). Some studies examine those same dimensions through an equity lens, in addition to assessing the impact of BRT systems on employment, the distribution of ridership, accessibility, and health.[4]

Few studies look at labor market outcomes. Two exceptions are Heres, Jack, and Salon (2014) and Olarte Bacares (2013), which both look at Colombia's first BRT system, the TransMilenio system in the capital, Bogotá. Olarte Bacares estimates ordinary least squares and two-stage least squares models of the effect of TransMilenio according to the exposure of Bogotá's 112 planning zones to the system. He finds that jobs became more accessible and that employment increased in areas with higher exposure. However, income was unaffected in most specifications. While the study considers exposure a potentially endogenous variable, it does not take into account the degree to which the outcomes may be driven by changes in the composition of resident households and firms.

Heres, Jack, and Salon (2014) employ data similar to the data of the present study. They find that income rose among households in proximity, but not immediately adjacent to TransMilenio stations. However, because the data used are pooled cross-sections, the authors admit that their results are likely driven by changes in household composition.

In terms of job creation, Hidalgo et al. (2013) find a positive balance after the implementation of TransMilenio whereby the creation of new jobs overcompensated for the jobs lost through the phasing out of traditional buses. Venter, Hidalgo, and Valderrama Pineda (2013) assert that new jobs are more likely to be created if there are specific policies, such as in Johannesburg, providing that minibus drivers were retrained and employed as bus drivers or station staff.

Many recent studies on Bogotá's TransMilenio seek to evaluate whether the system had net positive effects on the welfare of users or the broader public. Relying on different specific assumptions, these exercises estimate or calibrate a user demand function to derive monetary values for time savings and greater convenience. Other factors, such as operator benefits, reduced air pollution, improved traffic conditions, or security are also included on the benefit side. These are then compared with total costs under various discount rates on the initial capital investment. In this respect, Chaparro (2002), focusing on the first phase of implementation, finds large positive welfare effects. However, these results are contradicted by Echeverry et al. (2005), who also focus on the first implementation phase and find positive effects among the direct beneficiaries of the system, but negative effects among users in areas away from the system within the same city. Hidalgo et al. (2013) also find that TransMilenio exerts a net positive effect, but point out that this is much smaller than the outcome envisaged in the ex ante evaluation, mostly because of cost overruns and delays during initial construction.

In a survey of BRT systems across the world, Hidalgo and Gutiérrez (2013) highlight the substantial associated positive externalities. Yet, as they point out, planning, implementation, and operation are not without issues, and, in many instances, the systems are viewed as second best relative to light rail. Other research has highlighted the negative externalities, such as the potential for the geographical

[4] Venter, Hidalgo, and Valderrama Pineda (2013) and Venter et al. (2017) provide an excellent review.

expansion of criminality associated with the greater mobility of criminals as a boomerang effect of Bogotá's BRT (Olarte Bacares 2014).

In addition, recent literature has begun to question the welfare impact of BRT systems, particularly through the effect of the systems on property values and urban land development. Various studies have associated the implementation of BRT systems with land value uplift (see below). Yet, as Stokenberga (2014) points out, more rigorous assessment is needed to understand the impact of the systems on land use and prices. For example, the majority of studies, which are predominantly cross-sectional, look at land prices rather than at changes in land prices. Stokenberga also highlights the importance of understanding whether BRT systems expand the accessibility of households previously living along the corridors or whether a price rise leads to displaced population segments. Indeed, as discussed in the next sections, the present paper finds evidence of composition effects that suggest that a gentrification process is occurring.

Some of the main research on BRT systems concentrates on impacts on housing markets. This constitutes the area of research that has received by far the most attention. Several studies have looked at the impact of the TransMilenio BRT system on the housing market in Bogotá. Thus, using spatial hedonic price functions, the cross-sectional analysis of Rodríguez and Targa (2004) suggests that land values decline as the walking distance to a BRT station becomes greater. The analysis of Munoz-Raskin (2010) on the impact of TransMilenio, also based on a hedonic analysis, uses Department of Housing Control data for 2000–04. His results indicate that property values are higher if properties are close to a feeder line. Furthermore, the prices of middle-income properties tend to be higher, the closer they are to the system, while the opposite is true of low-income housing. Rodríguez and Mojica (2009) use data before and after the expansion of the system to examine whether prices change. Their results suggest that values increased in locations already served by the system, while, in areas that previously did not have a BRT station, but that are now served by the extension, land values did not rise. Bocarejo, Portilla, and Pérez (2013) find that, in Bogotá, areas served by the BRT, particularly peripheral areas that have feeder bus routes, exhibit higher growth rates. Using a difference in differences methodology, they conclude that the BRT has contributed to densification. More recently, Rodríguez, Vergel-Tovara, and Camargo (2016) examine the impacts of BRT systems on the land market in Bogotá and Quito by comparing treatment and control corridors based on 10 years of data. Using a quasi-experimental research design, they consider outcomes such as changes in the use of land, property prices, and the built area added per year. Their results show mixed impacts in both cities. Overall, the pace of land development appears to have risen in areas with BRT stops relative to control areas, although market conditions and other factors also play a role. Comparing the results of propensity score matching and spatial hedonic pricing models, Perdomo Calvo (2011) finds that the average price of residential property associated with proximity to a TransMilenio station rose by US$59 using the former and US$50 with the latter method. Similarly, Perdomo Calvo (2017) uses an unbiased specification based on geographical information systems and various econometric techniques to estimate the impact of BRT systems in Barranquilla and Bogotá. Based on pooling cross-sections across time, structural change over time (2006, 2008, and 2011), hedonic price models, Box-Cox transformation, and spatial econometrics, his results confirm that the systems have a favorable impact on the market price of residential and commercial property prices in both cities.

Cervero and Kang (2011) document the impact of BRT systems on the value and use of land in Seoul. Their results, based on multilevel models, indicate that converting regular buses to a median-lane BRT system leads to higher-density housing (because property owners convert single-family homes to higher-density apartments). The price of land for both residential and commercial uses grew significantly around BRT stations. The study stresses the importance of zoning regulations and public financing in recovering the value that public infrastructure creates so private landowners may address inequities. Using an urban simulation model, Jun (2012) finds that the Seoul BRT attracts firms to urban centers. Residential areas, however, are less susceptible than nonresidential areas to the improvements in accessibility. Central business districts appear to benefit more from the property value gains, while the outer ring zones experience reduced property values.

Using longitudinal analysis of property price data, Deng and Nelson (2010) find that the improvements in accessibility associated with the BRT in Beijing have led to higher real estate prices. The prices of apartments near a BRT stop have increased more rapidly than the prices of apartments not serviced by the system. These effects are larger over time and in areas that previously lacked mobility opportunities. Deng and Nelson (2013) find improved accessibility among communities along the BRT route to the center of the city. They also mention a positive impact on property prices along the corridor after six years of service. In addition, a passenger survey found that 79 percent of the users of Beijing BRT Line 1 are low income or lower-middle income (Deng and Nelson 2012). Zhang et al. (2014) compare BRT systems to light rail and metro transit in terms of variations in housing market performance. Using hedonic price models, they find that transit impacts spread out one mile in the case of metro rail and a half mile in the case of light rail, but are indiscernible in the case of BRT. The premium associated with proximity to stops is higher among residents living close to a metro than among residents living close to light rail. While the technological features of transit are important, the study concludes that BRT systems seem to be more dependent on context relative to rail transit, which appears to be a more independent force.

Assessment of BRT systems in the cities of Brisbane and Sydney, Australia, find mixed effects on land values. Some studies conclude that the impact of BRT systems is less in developed countries than in developing countries and is also less relative to rail systems. Mulley and Tsai (2016) look at the effects of the Liverpool-Parramatta BRT in Sydney using a multilevel hedonic pricing model. They find that the BRT increases housing sales prices shortly after launch, but that the effect does not last.

Similarly, using repeat sales data from before and after the opening of the BRT system, Mulley and Tsai (2017) find little difference in prices between properties within and outside the BRT service coverage area. Their segmented hedonic models further stratify the sample by type of housing, finding that apartments benefit less in terms of locations that had good public transport accessibility before the BRT. Mulley et al. (2016) find greater land value uplift associated with the BRT in Brisbane than in Sydney, which may be explained by the greater network coverage of the Brisbane system. The authors use spatial modeling, followed by geographically weighted regression to study the spatial distribution of accessibility. Their results indicate that the rise in land values varies over the network and that the high-frequency feeder bus network seems to be a key factor behind the capitalization effects. Yet, overall, the degree of uplift is relatively low relative to the corresponding uplift in rail systems. Dubé et al. (2011) examine the impact of the introduction of the BRT in Quebec City on housing prices near the service corridor. The difference in differences analysis is based on real sales (transaction) prices rather than asking prices to estimate the market premium. Properties within walking distance of stops, but sufficiently far away to avoid the negative effects of greater bus traffic experienced a rise in sales price.

Perk and Catalá (2009) examine the effect of BRT stops along the Martin Luther King Jr. East Busway, in Pittsburgh, on the values of nearby single-family homes. Using a hedonic regression model, they find that property values increase the closer a residence is to a BRT stop. Case studies of BRT systems in other U.S. cities show a premium in real estate values among properties near a transit system. A study compiled by HR&A (2014) reports premiums on real estate values among properties close to the Boston Silver Line enhanced bus system, the BRT system of Eugene-Springfield (Metropolitan Area Express light rail), and Pittsburgh's Martin Luther King Jr. East Busway of 7.6 percent, 10.2 percent, and 11.0 percent, respectively, according to hedonic price regression analysis. In the case of the light rail system in Buffalo, New York, Hess and Almeida (2007) find that home prices within a quarter-mile of a station increase on average by 2 percent to 5 percent relative to the city's median home value. However, this effect is much larger in high-income neighborhoods and more negative in low-income neighborhoods.

None of the studies reviewed, however, appears to take into account the effect of the change in transport infrastructure on household composition, such as whether households relocate in response to the implementation or expansion of a BRT system. The rise in property and land prices in the corridors along BRT systems may be pricing out lower-income households. In a related finding, Duarte and Ultramari (2012) conclude that most of the passengers using the BRT in Curitiba, Brazil, do not live along the corridors, but rather in heavily populated peripheral districts. Having found that Bogotá's BRT has contributed to densification, Bocarejo, Portilla, and Pérez (2013) suggest that access to affordable land may be shrinking because rising property values are leading to densification. Delmelle and Casas (2012) examine accessibility to the Masivo Integrado de Occidente (western mass integrated) BRT implemented in Santiago de Cali, Colombia, in 2009. They use a multimodal approach, focusing on travel time and the transit system to examine the equity of the spatial accessibility setting under the BRT. Their results suggest that pedestrian access to the system is more limited in low- and high-income neighborhoods, but greater among middle-income groups. Also in the context of Cali's BRT, Jaramillo, Lizárraga, and Grindlay (2012) develop a theoretical framework to examine accessibility, social exclusion, and public transport. Their results indicate that, during the development of the BRT, accessibility had not improved in many districts in the periphery, while central districts appeared to enjoy overprovision. In a recent study, Wang et al. (2016) look at the effects of the metro in Shanghai using spatial quantile hedonic pricing models. Their results show that a rental premium is associated with geographical proximity to metro stations, although they find no evidence of transit-induced segmentation of the local private residential rental market.

Considering fixed-guideway systems more broadly, including heavy, light, or commuter rail, in addition to BRT systems, studies in the United States suggest that public transport has a gentrification effect on local housing markets. Immergluck (2009) finds that the public announcement and planning of a rail transit initiative in Atlanta had positive effects on the prices of homes located close to the development. In a similar line, Lin (2002) concludes that the presence of transit in Chicago had a gentrifying effect as evidenced by changes in residential property values close to transit stations. Looking at 14 large U.S. cities, Kahn (2007) finds that there is less gentrification in communities with greater access to park and ride stations—parking lots next to public transport connections for commuters—than in communities with growing access to walk and ride stations, that is, sole public transportation access.

The studies closest to the study described in this paper are probably those of Gleaser, Kahn, and Rappoport (2008) and Pollack, Bluestone, and Billingham (2010), which show results for the effects of public transportation investment on income and poverty rates. Gleaser, Kahn, and Rappoport hypothesize that the concentration of poverty in U.S. inner cities is caused by the better access to public transportation. They show, first, that areas in New York City's outer boroughs that are closer to subway stops are poorer than those farther away. They then look at rail expansions in 16 major cities and establish that the census tracts in these cities that were directly affected by an expansion became poorer. However, Pollack, Bluestone, and Billingham find results that are almost polar opposites: analyzing changes between 1990 and 2000 in 42 neighborhoods in 12 metropolitan areas that introduced rail transit, they show that, in directly affected neighborhoods, home prices have increased and residents have become wealthier and more likely to own cars. These changes were particularly pronounced in areas with a high stock of rental housing.

3. Barranquilla's Transmetro System

BRT systems have earned more recognition in recent years for their ability to mitigate urban congestion and inefficient public transportation. To qualify as a BRT system, a bus network must be able to use dedicated lanes to provide efficient speed and mobility for the buses. Latin America has been home to many such systems. Pioneered by Curitiba in Brazil and Quito in Ecuador, such systems have spread to other large capital cities, such as Bogotá and Mexico City, and farther on to smaller cities. In particular, Colombia has been avid in adopting BRT systems. The TransMilenio system was introduced in Bogotá in 2001, and the country's second and third largest cities, Medellín and Cali, followed suit in 2011 and 2009, respectively. Several other smaller cities have since implemented similar systems or are planning to do so in the near future. One of them is Barranquilla, which is the subject of the study described in this paper.

Barranquilla is of interest for several reasons. With over 2 million people, the Barranquilla metropolitan area, consisting of the municipalities of Barranquilla, Galapa, Malambo, Puerto Colombia, and Soledad, is Colombia's fourth largest population center. However, it is only about half the size of the second and third biggest metropolitan areas (Medellín and Cali). It therefore constitutes a good case study on the effect of BRT systems or, more generally, access to improved public transport in midsize cities. The second reason is that data are readily available on the transportation system of Barranquilla since it entered into service in 2010. This allows one to take advantage of the yearly progress in the implementation of the system to identify impacts. The third reason is that the topology of Barranquilla is entirely flat, unlike most other Colombian cities. This is important because it allows distances to bus stations along the city's street grid to be measured easily in comparative terms, which would be challenging in a city set into foothills or mountainous terrain.

The Council of National Economic and Social Policy described the equipment and infrastructure of the public transportation system in Colombia as obsolete and characterized the service as inadequate and generally poor (CONPES 2003). After the launch of Bogotá's TransMilenio, the government decided to promote mass rapid transit systems in cities with high population densities. One such location, the Barranquilla metropolitan area, is, according to the council, characterized by (a) the forced displacement of rural families toward urban areas, (b) an increase in the population share of the lowest socioeconomic strata, and (c) substantial dependency on the city of Barranquilla as the regional center of economic activity (CONPES 2004). In consequence, the Transmetro system was expected to benefit particularly the poorest households in the urban periphery through better connectivity and lower fares.

Map A.1 provides a visual overview of the Transmetro BRT system (see the appendix). The system serves the municipalities of Barranquilla and Soledad. The main lines consist of local and express stations. The local stations may be bypassed by express buses. Buses along the feeder lines either stop for connections with buses on the main lines, requiring passengers to change buses, or continue along the main routes once they reach the main lines. There are 18 stations on the main lines and over 600 stops along the feeders. The fare for a single trip was raised from Col$1,800 to Col$2,000 (around US$0.67) in 2016. The total number of passengers rose from 3,658,421 in 2010 to over 36,400,000 in 2016.[5] The system entered service on April 7, 2010, and, for the first three months, until July 9, it operated free of charge.

4. Data and Empirical Strategy

The ideal survey structure for the assessment of the effects of a transportation system on households or individuals would consist of longitudinal data to allow respondents to be followed if they move between survey rounds. The results in any study using data that fall short of this requirement may be suspect because of the possibility of picking up effects of urban displacement, rather than causal effects, on the outcomes of interest.

The aim of the present paper is to show how the implementation of Transmetro may have changed the composition of neighborhoods in proximity to new stations. To this end, the study relies on data from the 2008–15 rounds of the Gran Encuesta Integrada de Hogares—GEIH survey, the main labor

[5] For these and other data on the system, see "Te une a Barranquilla," Transmetro S.A., Barranquilla, Colombia, http://www.transmetro.gov.co/.

survey in Colombia similar to the Current Population Survey (CPS) in the United States. The GEIH survey is conducted by the National Administrative Department of Statistics (DANE). The current survey was first carried out in 2007 and has supplied consistent information in the current format since 2008, though it has been on a quarterly basis for 13 main metropolitan areas and on a semester basis for an additional 11 cities. Barranquilla-Soledad metropolitan area is covered by the survey on a quarterly basis. GEIH provides information on an ample set of welfare, housing and labor characteristics that are relevant for this study.

Information on exposure to the Transmetro system has been collected using official maps and appropriately geo-coded in a geographic information system. The system's operators also supplied information on the date each station entered into service - both main line stations and feeder stops, which represent time varying information of the geographical expansion of the BRT system within Barranquilla MA. Such time variability allows us to control for the unobserved block-specific characteristics that are correlated with the decision to give access to the public transport system.

To protect the privacy of respondents, the publicly available GEIH microdata censored geographical location. Since we need a detailed localization of households to match households with the nearest stations/stops of the BRT system, we relied on DANE's data lab (similar to RDC in the United States).

Because of its stratified design, the GEIH furnishes a sample of randomly drawn blocks. Within each block, around half of all households are entered in the survey, so it is reasonable to say that we have a large sample size within each block. However, the exact location of each household within the block is not provided. Partly for this reason, but also to be able to take into account changes in the total number of households and dwelling types in each block, the analysis was conducted based on the blocks, aggregating over all observed households in a given year. The distance to stations of the Transmetro system is calculated from each block's centroid and following the street grid.

The final sample is restricted to blocks that are within a distance of one kilometer to a main line or a feeder line station in 2016. This restriction excludes remote areas of the city that may confound the results. To arrive at an easier interpretation of the parameters, the negative distance to a station is used in the estimation so that a positive parameter corresponds to a positive effect of closer proximity. When the system first opened in 2010, several blocks that ended up within the 1-kilometer radius to a station by 2016 were far from the first stations, close to 10 kilometers at the maximum. For this reason, the distance values for 2008 and 2009 are normalized at a value of 10 kilometers.

The empirical model in its most basic specification has the following form:

$$y_{b,t} = \beta_0 + \beta_1 Distance_{b,t} + \beta_2 Distance\ 2016_b + \alpha' \mathbf{X_{b,t}} + \theta_t + \varepsilon_{b,t} \qquad (1)$$

which denotes block *b* observed in year *t*. This is a standard presentation for a difference in differences estimation with pooled cross-sections and more than two time periods. The parameter of interest is β_1. The year-specific error term, θ_t, is operationalized through a set of year-specific binary variables. Given that, in each year, there is an independently drawn sample of blocks, one may not directly control for block fixed effects. Instead, *Distance 2016* is included as a block-specific, time-invariant variable measuring the distance to the closest station/stop in 2016.[6] This variable captures all unobserved block-specific characteristics that are systematically correlated with proximity to a station. As in any difference in differences framework, the identification resides in the assumption of parallel trends, that is, had Transmetro or any other improvement to the public transit system not been implemented, there would be no systematic difference in the trends in the outcomes under study as a function of the treatment variable (*Distance*). Lastly, the term $\alpha X_{b,t}$ denotes additional control variables and is only included for a few specifications. For each outcome, the results are presented for two treatment variables, that is, distance to the closest station independent of the type of station and a second specification that estimates the effects of distance to either a main line station or a feeder stop separately. The error term $\varepsilon_{b,t}$ is allowed to suffer from heteroskedasticity in the regressions.

Table A.1 shows a list of all variables used. The distances from the block centroid to the station range from a maximum of 10 kilometers, for observations in 2008 and 2009, down to 2 meters among feeder lines and 32 meters among main lines. In 2016, the centroids of some blocks coincided with stations. After the cutoff for inclusion in the sample was set at 1 kilometer, the maximum distance became 999 meters. If a block is closest to a main line station, the distance values to feeder lines are normalized to 10 kilometers and vice-versa in the case of the distance value for blocks closest to a feeder line station. The total sample consists of 2,964 block-year observations. Each year, blocks are randomly sampled, but some are repeated over the eight years under study. In total, 2,088 blocks were observed, among which 1,419 enter only once; 509 are sampled twice; 160, three times or more.[7]. The number of blocks oscillates between 334 and 473 blocks across the different years. The aggregates are based on a total of 57,330 households, resulting in an average of 19.34 households per block. Of these, more than half (10.70) represent homeowners, 2.62 live in usufruct, and 5.89 rent.[8] If the sample is split into owners-usufruct and renters-other, some observations are dropped for the average variables because of the lack of observations in the category; see the bottom of table A.1.

The rest of table A.1 should be mostly self-explanatory; it does not contain any surprising results. For clarity, the variables old age, prime age, youth, and children refer to the number of individuals ages 65 or above, 23–64, 16–22, and 15 or less, respectively. An average of only 0.78 household per block-year (around 4 percent of the total observed) are extremely poor, while almost a quarter of the total (4.72) are considered poor. Household income is monthly and shown in constant Colombian pesos per capita. Here, average per capita incomes are reported with and without imputed rent for homeowner households and households in usufruct. The latter is an outcome of interest; the former is used to calculate income quintiles (following the official definition). The block averages on home values and rents are based on various survey questions. Homeowners and usufructuaries are asked for their estimates of the price at which they could sell the property or how they estimated the rent they

[6] The 2016 round of the GEIH was not yet available in December, but other information on the transportation network was available and allows us to control for the characteristics of the neighborhoods that are close to a station.

[7] To be more specific, 124 are sampled three times; 27, four times; 7, five times; and 2, six times.

[8] The number of households in some other arrangement is negligible, at an average 0.13.

might have to pay for it. There is a much larger number of missing values across households in the case of the first question than in the case of the second. Renters are asked about the actual rent paid, but there is also a fair quantity of missing values. This implies that the averages are based on fewer observations for home values and rents than for hypothetical rents.

5. Results

5.1. The results on housing characteristics

The first step is to examine the effect of Transmetro on the total number of households in proximity to a station according to dwelling ownership status. One may distinguish among owners, including those who are still paying mortgages, households living in usufruct, renters, and other arrangements. Table A.2 shows that proximity to a main line station reduces the number of households living in their own homes or in usufruct and, as a result, also the total number of households. No effect is found for the number of households that rent or live under different arrangements. The point estimates imply that living next to a main line station relative to living at a 1-kilometer distance lowered the number of owner households by 0.739 and those in usufruct by 0.511. Put in relation to the mean number of households of each type shown in table A.1 (10.7 for owners and 2.62 for usufruct), this suggests that there is an effect of a significant magnitude and raises the question of what happened to these dwellings, given the absence of an increase in rental properties.

Table A.3 provides a partial answer. It shows results on all households and then divides the sample into two groups: Following the official distinction used by DANE, the first group includes owner households and households living in usufruct. The second group includes renters and households with other arrangements. This division is followed throughout. The observable outcomes of interest are the number of households in apartments, homes with solid walls, homes with solid floors, and households with exclusive toilets. To be consistent with the other outcomes, the number of rooms is measured as the total number of rooms in each block. The results show a strong effect on the quality of the housing stock: a general increase in the number of apartments, more rooms, and exclusive toilets. There is no strong positive effect on the number of homes with solid walls and floors, expect for a small effect at 10 percent significance for solid floors in rental homes close to main line stations. Noteworthy is the consistently negative effect on both outcomes revolving around the number of owner-occupied dwellings, which is highly statistically significant in the case of solid walls and proximity to main line stations. The magnitude of the latter also accounts almost fully for the effects found in table A.2. The implication is that owner-occupiers of low-quality housing were likely bought out to construct higher-quality housing, often in multi-unit buildings. The improvements in housing quality may also be observed in the proximity to feeder lines among owner-occupied housing and rental housing alike. Farther from the city's main arteries, these areas permitted additional construction without a reduction in the overall number of households. Moreover, while the point estimates for renters and owners are of similar magnitude, there are more than twice as many households in the former group. Thus, the relative magnitude of the identified effects is twice as large for renters relative to owners.

These results raise the issue of the extent to which the improvements are reflected in housing prices. This is answered in table A.4. Three outcomes are examined. DANE chooses to group homes inhabited in usufruct into the same broader category as homeowners. The respondents in the group were asked the prices at which they would sell or rent their homes. The latter outcome is called hypothetical rent. The summary statistics make clear that the average hypothetical rent is about twice as large as reported actual average rents, which are only observed among homeowners who choose to take in renters. This outcome may reflect the fact that either homeowners systematically overestimate the rental value of their homes, or they report only their initial rental price, rather than the minimum at which they would rent or an estimated equilibrium price. Moreover, owner-occupiers would probably experience higher opportunity costs associated with the rentals compared with owners already on the rental market. Table A.4, in contrast to the previous tables, illustrates block averages rather than totals. Specifications are also included that control for dwelling characteristics that are outcome variables in table A.3. The results are instructive. If no controls are applied for dwelling characteristics, home values and both types of rents increase significantly with closer proximity to a station. Among home values, this effect is only found associated with feeder stations, whereas, for rental properties, a statistically significant effect is found for either type of station, albeit only at 10 percent for feeder lines and actual rents. Home values are scaled to millions of Colombian pesos, and rents to thousands of pesos. The results imply that moving from a 1-kilometer distance to a place directly adjacent to a station increases the average home value by a little over Col$11 million (around US$5,500 during the period under study, and US$3,700 as of the drafting of this paper). Actual monthly rents increased by Col$45,732 and Col$31,310 according to the same metric of feeder lines and main lines, respectively. The more important result here may be that these effects vanish once controls are applied for home characteristics. This implies that the increases merely reflect the greater quality of homes, but that there is no additional premium paid for proximity to stations. In the case of main lines, average home values even fell by over Col$4 million, possibly reflecting the additional nuisance imposed by living next to a busy bus station.

These results merit deeper analysis. It may be the case that homeowners simply do not factor in the added value derived from station proximity. The study only observed estimates of home purchase values, but not selling market prices. However, the study did observe rental market prices and did find the same effect even if the values are self-reported and some observations are missing. A possible explanation is that the construction of Transmetro resulted in an oversupply of improved housing around stations that, at least in the short run, exerted downward pressure on prices. A more intriguing possibility is that more well-off households that can afford improved dwellings and may not need public transportation are drawn to station proximity because of secondary effects. These effects might include public investments related to Transmetro, such as more well-maintained roads or the greater presence of new and better housing near eventual station sites. Alternatively, it may also be the case that public investments are simply taken as a signal of the greater commitment of local authorities to certain areas of the city. Private housing investments would then coordinate on such areas even if the public BRT service is not directly valued by future residents.

In sum, the results on home characteristics are in line with much of the literature on the topic. There was a statistically significant increase in home values and rents, a rise in the number of apartments, and improvements in quality. That the last two results fully account for the first one appears to be a new result.

5.2. The results on time-invariant household characteristics

The above results indicate that, in response to the Transmetro system, a better and more expensive housing stock developed around stations. This also suggests that a change occurred in household composition as more well-off individuals and families replaced poorer ones. The next three tables (A.5–A.7) show that this was indeed the case. A number of household characteristics are examined that are unlikely to be directly and causally affected by Transmetro, so that any systematic effects may be attributed to changes in the composition of households, rather than causal effects of the system on household welfare.

Table A.5 shows the number of households that are woman headed and that fall within three size profiles. Negative effects are found throughout among owners in proximity to main line stations. Given that the magnitude of the effects among owners is similar to the magnitude of the effects shown in table A.2, these are attributed to the overall decrease in the number of such households. Among owners and renters alike, proximity to feeder stations raised the number of smaller households (one or two members) and reduced the number of large households (more than five members), while there were no effects on the number of households with three to five members. These effects are all significant at 5 percent.

Tables A.6 and A.7 illustrate the characteristics of the individuals in each group. Table A.6 examines the characteristics of individuals across age-groups and women. As expected, there was a consistent decline in the number of individuals in each group living in owner households in proximity to main line stations. In addition, there was a statistically significant decrease in the number of children across all specification, though only at 10 percent among renters in proximity to feeder stations. There was also a significant drop-off in the number of individuals ages 16–22 (young) among homeowner households close to feeder lines. Taken together, these results explain, even if not completely, the changes in household size shown in table A.5.

Table A.7 exhibits the results on the total number of adults according to educational attainment. To rule out any direct effects of Transmetro on observed educational attainment, the data are restricted to totals on individuals older than 22 years, that is, individuals who can be expected to have completed their educational careers. The goal is to gauge the effects of education on the composition of households living close to newly opened stations. In all specifications, there is a strong and statistically significant negative effect, often at 1 percent, on the number of individuals who have completed less than mid-secondary education (high school), that is, none, only primary, or only basic secondary education. There is no effect on the number of individuals who have completed high school, but who did not go further, except for owners close to main line stations. This may only reflect the overall decrease in such households. The negative effect among the less well educated is offset by an increase in the number of adults achieving higher education. Except among owners close to main line stations among whom the total number of individuals in the households declined, the sum of the statistically significant negative effects up to basic secondary education roughly corresponds to the increase in the more highly educated. This shows that there is a replacement of the former by the latter. Considering the results on the housing stock, these results also lend strong support for a replacement of poorer households by richer ones moving into new, higher-quality homes.

5.3. The results on household income and wealth

The findings on the effects on household economic characteristics should be interpreted in light of the results discussed above because a less than careful reading may attribute the results to a direct effect of better access to public transportation on household economic opportunities. Table A.8 looks at household poverty status, ownership of motor vehicles (as a proxy for ownership of durable consumption goods), and per capita income. The first three outcomes are the total number of households in each block, while income is measured as an average. There was an important reduction in the number of poor households and in the number of renters among the extremely poor living in proximity to main lines. The number of households owning a motor vehicle increased among owners and renters alike if they were living close to feeder stations. The average per capita income rose among all specifications except owners close to main line stations. This last result indicates that the total decline in the number of such households found throughout is not only derived among relatively poorer households.

Table A.9 analyzes the total number of households in each income quintile. The quintiles are calculated based on household per capita incomes that, unlike the outcome used in table A.8, includes imputed rents received among homeowners as well as households living in usufruct. (One could also carry out an analysis with this income measure that would be similar to the analysis in the last two columns on the right of table A.8, with the expected result of an additional rise in per capita income among owners.) The results largely mirror the results on adult educational attainment exhibited in table A.7. There was a strong and significant drop-off in the number of households in the bottom two quintiles among renters and the bottom three quintiles among owners. At the same time, the number of households in the fifth quintile rose significantly except among owners close to main line stations, which is offset by the overall decline in numbers. The fourth quintile was largely unaffected except for an increase among renters living close to main line stations. The results in tables A.8 and A.9 support the general finding that Transmetro led to a replacement of poorer, more vulnerable households by richer households.

6. Conclusions

Since the turn of the millennium, BRT systems have become a popular addition to public transportation infrastructure in cities especially, but not exclusively, in middle-income countries. In particular, government leaders in Colombia have been eager to launch such systems in second-tier cities following the implementation and perceived success of the TransMilenio BRT in Bogotá. While TransMilenio has received considerable attention among researchers, few studies exist on BRT systems in smaller cities. Moreover, the existing BRT literature is focused on efficiency metrics, cost-benefit analyses, and the effects on real estate markets. Few studies have concentrated on variables associated with individuals or households.

This paper presents a study on the effects of Transmetro, the BRT system in Barranquilla, on the composition of households in the neighborhoods around the stations of the newly established system. In line with a large part of the existing literature, the study finds that home values, rents, and the quality of homes increased in proximity to new stations. As a result, poor households are being replaced by households in middle- and upper-income strata. The households located near new stations became richer and more well educated and had fewer children. One result of the research is that the entire rise in home values and rents was driven by better housing quality, without any additional premium on access to public transportation. Future research should explore whether similar results or partially similar results hold in other settings and seek a causal relationship. The results described in this paper suggest that the more highly educated, more well-off households that move into the improved homes close to new public transport stations are probably too well off to prefer the proximity to the service. However, they may be attracted by other, related public investments. Alternatively, the investments may represent a signal of the greater commitment of local governments that help coordinate private investment in certain areas. None of these possibilities can be tested based on the data available to this study.

The results imply strongly negative distributional impacts among poor renters. In contrast, poor owners may either choose to stay in their homes or reap the capital gains by moving to less expensive locations. The results are also stronger in the case of feeder lines relative to main lines. This may be associated with particular characteristics of households close to the city's main arteries or with negative amenity effects linked to main line stations, such as the greater foot traffic, noise, and commercial activity next to new stations. This is not the only study to produce this finding.

These results are important for several reasons. First, they point to the potential distributional effects of BRT systems that have been overlooked until now. Even though welfare enhancing in aggregate, the effects on the poorest socioeconomic strata are far from clear. This is especially important because improved public transportation is often aimed at benefiting the poor. The study results suggest that improved public transportation may mostly benefit the middle and higher strata at least in places with wealth and income distribution similar to Colombia. These and other outcomes among households, such as employment, income, or school attendance, should be studied further. The results here also show that concerns about the validity of studies based on pooled cross-sectional household data are entirely warranted. Given the scarcity of surveys characterized by a longitudinal design and representativeness at the level of cities, future research should find new, innovative ways to answer these questions. Finally, future work should also consider the importance of evaluating the joint distributional effects of complementary policies to an investment in BRTs systems, such as targeted transport subsidies for the poor, public space improvements and land use planning.

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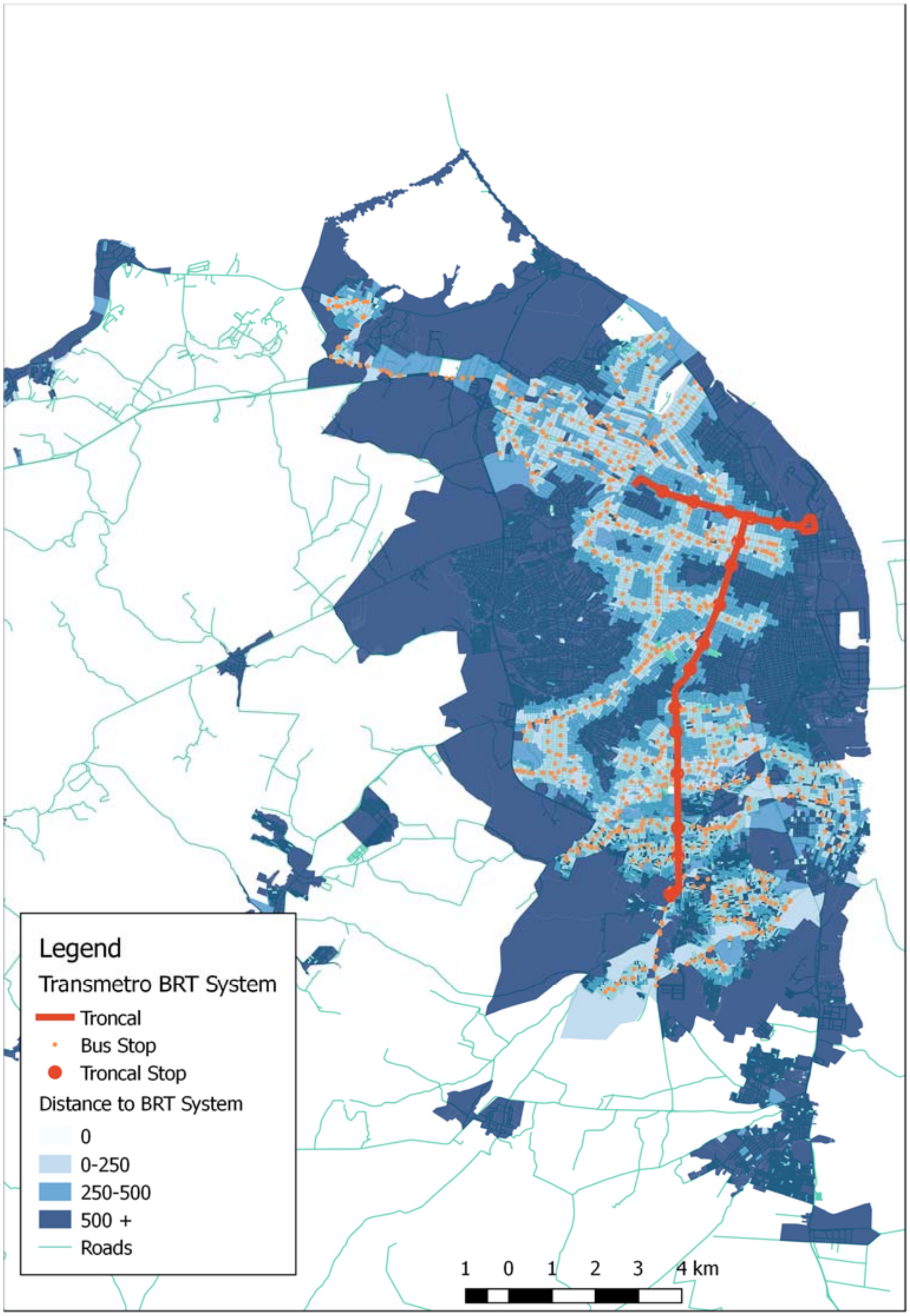
Appendix A. Figures and Tables

Map A.1. Transmetro BRT System



Note: Each segment of the T (in red) is one of the three main lines. The total length of the three main lines (*troncales*) is 14 kilometers. The 21 feeder lines (*alimentadoras*) are shown as roads with bus stops. The total length of these feeder lines was 190 kilometers in 2016.

Table A.1. Summary Statistics

	Num. Obs.	Mean	Std. Dev.	Min.	Max.
Treatment Variables:					
Distance	2,964	-3.33	4.19	-10	-0.002
Distance Feeder	2,964	-4.93	4.75	-10	-0.002
Distance Main	2,964	-8.41	3.34	-10	-0.032
Distance 2016	2,964	-0.34	0.23	-0.999	0
Distance Feeder 2016	2,964	-2.16	3.80	-10	0
Distance Main 2016	2,964	-8.11	3.90	-10	0
Summed Household-Level Variables:					
Number Households	2,964	19.34	11.06	1	77
Home Owners	2,964	10.70	6.54	0	45
In Usofruct	2,964	2.62	2.99	0	28
Renters	2,964	5.89	4.55	0	32
Other Status	2,964	0.13	0.62	0	14
Apartment	2,964	7.97	7.69	0	72
Solid Walls	2,964	18.42	10.54	0	72
Solid Floors	2,964	18.27	10.49	0	72
Number Rooms	2,964	68.08	40.07	1	283
Private Water Toilet	2,964	16.87	10.35	0	72
Female Headed	2,964	6.36	4.47	0	34
Household 1 or 2 Members	2,964	3.97	3.59	0	32
Household 3-5 Members	2,964	11.83	7.13	0	55
Household with >5 Members	2,964	3.54	3.13	0	24
Extremely Poor	2,964	0.78	1.33	0	12
Poor	2,964	4.72	4.90	0	40
Has Motor Vehicle	2,964	4.37	5.00	0	48
1 st Quintile	2,964	2.43	3.19	0	27
2nd Quintile	2,964	2.64	3.01	0	18
3rd Quintile	2,964	3.05	3.13	0	22
4th Quintile	2,964	3.73	3.58	0	20
5th Quintile	2,964	5.06	7.02	0	54
Summed Individual-Level Variables:					
Female	2964	40.05	23.97	0	175
Old Age	2964	6.19	5.63	0	40
Prime Age	2964	41.51	24.44	0	173
Young	2964	10.24	7.07	0	46
Children	2964	17.39	14.35	0	89
No Education	2,964	1.59	2.20	0	25
Primary Education	2,964	9.71	8.04	0	58
Secondary Education	2,964	6.92	5.58	0	45
Upper Secondary Education	2,964	14.74	9.87	0	68
Higher Education	2,964	14.70	14.74	0	106
Averaged Household-Level Variables:					
Home Value	2,836	58.49	63.03	0.45	800
Rent Paid	2,821	332.15	265.29	25	4500
Hypothetical Rent	2,939	643.82	2899.13	20	63588
Per-Capita Income Without Imputed Rent	2,964	345.68	358.42	0	3232
Per-Capita Income With Imputed Rent	2,491	615.77	520.43	79	4223

Note: Each observation represents a block-year. However, blocks may be randomly repeated across years. The treatment variables are only observed among blocks. The summed household-level variables represent totals among households in each block. The summed individual-level variables represent totals among individuals. Average household-level variables represent averages across all households in each block.

Table A.2. The Results by Ownership Status

	Households		Owners		In Usufruct		Renters		Other Status	
Distance	-0.654*		-0.495**		-0.274***		0.167		-0.051	
	0.396		0.218		0.092		0.146		0.042	
Distance Feeder		-0.037		-0.161		-0.032		0.184		-0.028
		0.602		0.367		0.162		0.234		0.027
Distance Main		-1.187***		-0.739***		-0.511***		0.137		-0.074
		0.457		0.253		0.105		0.171		0.053
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.047	0.046	0.024	0.025	0.049	0.044	0.049	0.053	0.033	0.036
F	19.69	15.56	9.624	7.904	12.59	9.947	22.07	18.69	4.416	4.250

Note: The outcome variables are the total number of households in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.3. The Results by Dwelling Characteristics

	Apartment		Walls		IFloors		Rooms		Toilet	
Distance	1.074***		0.196		0.253*		1.820***		0.710***	
	0.194		0.167		0.148		0.518		0.164	
Distance Feeder		0.867***		0.146		0.170		3.001***		0.658**
		0.315		0.265		0.265		0.986		0.282
Distance Main		1.145***		0.183		0.267		1.577***		0.866***
		0.229		0.196		0.169		0.554		0.199
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.356	0.362	0.793	0.794	0.791	0.792	0.816	0.818	0.728	0.730
F	80.35	67.69	862.1	717.8	870.7	726.7	963.4	805.6	640.8	541.4
OWNERS & USUFRUCT:										
Distance	0.323**		-0.605**		-0.547**		0.672*		0.306***	
	0.159		0.252		0.238		0.351		0.085	
Distance Feeder		0.437**		-0.229		-0.028		1.639***		0.309**
		0.212		0.419		0.113		0.562		0.142
Distance Main		0.189		-0.928***		-0.025		0.286		0.371***
		0.193		0.287		0.073		0.408		0.104
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.031	0.033	0.037	0.036	0.036	0.921	0.895	0.895	0.855	0.856
F	11.19	9.236	13.81	11.16	13.62	1920	1578	1319	1335	1136
RENTERs & OTHER:										
Distance	0.425***		0.105		0.109		1.148***		0.404***	
	0.110		0.171		0.172		0.428		0.124	
Distance Feeder		0.324*		0.148		0.198		1.363**		0.349*
		0.190		0.224		0.209		0.633		0.200
Distance Main		0.467***		0.071		0.292*		1.291**		0.495***
		0.128		0.210		0.174		0.520		0.149
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.054	0.060	0.060	0.062	0.060	0.238	0.259	0.262	0.229	0.235
F	21.44	18.41	25.40	21.33	25.50	64.21	79.35	66.60	71.45	60.82

Note: The outcome variables are the total number of households in each block that inhabit apartments, have solid walls and roofs, or have toilets in the residence. Rooms is the total number of rooms observed in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.

Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.4. The Results by Home Values and Rents

	Home Owners & In Usufruct								Renters & Other Status			
	Home Value				Hypothetical Rent				Rent			
Distance	4.502**		-2.100		123.937***		36.246		31.370***		1.061	
	1.990		1.670		46.923		37.221		9.077		8.177	
Distance Feeder		11.295***		1.746		287.224**		177.642		45.732*		11.447
		1.928		1.664		120.392		109.397		24.790		23.391
Distance Main		3.248		-4.285**		75.576**		-26.686		31.310***		-5.034
		2.463		2.165		34.916		34.622		6.776		5.900
Additional Controls	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes
Observations	2,836	2,836	2,836	2,836	2,938	2,938	2,936	2,936	2,821	2,821	2,820	2,820
R-squared	0.062	0.063	0.409	0.409	0.006	0.006	0.029	0.029	0.056	0.056	0.360	0.360
F	17.97	18.37	63.25	59.84	2.963	2.580	4.432	3.867	22.46	18.07	70.65	62.74

Note: The outcome variables are block averages of households that either own the dwellings, live in usufruct, rent, or have other arrangements. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.

Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.5. The Results by Household Characteristics

	Female Headed		1 or 2 Members		3-5 Members		> 5 Members	
Distance	-0.094		0.165		-0.560**		-0.259***	
	0.152		0.109		0.261		0.097	
Distance Feeder		0.094		0.466***		-0.079		-0.423**
		0.245		0.176		0.373		0.172
Distance Main		-0.253		-0.008		-0.862***		-0.317***
		0.173		0.121		0.305		0.114
Observations	2964	2964	2964	2964	2964	2964	2964	2964
R-squared	0.042	0.042	0.029	0.032	0.042	0.043	0.033	0.029
F	18.1	14.77	12.4	10.89	18.09	14.63	9.203	6.871
OWNS HOME:								
Distance	-0.185*		0.02		-0.575***		-0.213***	
	0.109		0.067		0.181		0.082	
Distance Feeder		0.006		0.287**		-0.187		-0.292**
		0.194		0.123		0.279		0.148
Distance Main		-0.337***		-0.136*		-0.835***		-0.280***
		0.123		0.072		0.21		0.097
Observations	2964	2964	2964	2964	2964	2964	2964	2964
R-squared	0.031	0.031	0.021	0.022	0.035	0.035	0.028	0.025
F	11.64	9.594	8.69	7.449	12.29	10.09	8.101	6.06
RENTS HOME:								
Distance	0.091		0.146**		0.015		-0.045	
	0.07		0.058		0.11		0.037	
Distance Feeder		0.089		0.179**		0.108		-0.131**
		0.095		0.09		0.16		0.062
Distance Main		0.084		0.127*		-0.027		-0.036
		0.086		0.069		0.131		0.043
Observations	2964	2964	2964	2964	2964	2964	2964	2964
R-squared	0.039	0.043	0.022	0.028	0.044	0.045	0.026	0.025
F	16.12	13.63	9.182	8.918	18.56	15.42	9.334	7.167

Note: The outcome variables are the total number of households in each category in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.6. The Results by Age-Group among Household Members

	Female		Old Age		Prime Age		Young		Children	
Distance	-1.402*		-0.138		-1.175		-0.613**		-1.417***	
	0.732		0.167		0.803		0.247		0.327	
Distance Feeder		-0.844		0.189		-0.031		-0.880**		-2.553***
		1.343		0.260		1.315		0.420		0.840
Distance Main		-2.261***		-0.336*		-2.198**		-0.703**		-1.445***
		0.817		0.196		0.921		0.294		0.291
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.055	0.053	0.021	0.025	0.034	0.033	0.037	0.035	0.243	0.244
F	19.11	15.30	7.519	7.032	13.21	10.46	13.05	10.30	212.3	179.0
OWNS HOME:										
Distance	-1.462***		-0.189		-1.399**		-0.566***		-1.114***	
	0.548		0.159		0.601		0.189		0.259	
Distance Feeder		-0.783		0.108		-0.180		-0.708**		-1.973***
		1.059		0.242		1.048		0.333		0.653
Distance Main		-2.323***		-0.385**		-2.412***		-0.684***		-1.150***
		0.618		0.190		0.685		0.226		0.236
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.037	0.036	0.017	0.019	0.025	0.024	0.035	0.033	0.184	0.187
F	12.01	9.633	6.160	5.420	8.246	6.663	9.931	7.970	142.5	119.5
RENTS HOME:										
Distance	0.060		0.051		0.225		-0.046		-0.303**	
	0.296		0.040		0.316		0.099		0.122	
Distance Feeder		-0.061		0.081		0.149		-0.173		-0.579*
		0.473		0.051		0.462		0.161		0.327
Distance Main		0.062		0.049		0.213		-0.018		-0.296***
		0.350		0.051		0.380		0.118		0.103
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.076	0.077	0.021	0.029	0.049	0.052	0.034	0.034	0.209	0.209
F	28.38	23.39	6.681	7.257	20.35	17.07	15.40	12.56	173.3	145.2

Note: The outcome variables are the total number of individuals in each age-group in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.7. The Results by Educational Attainment among Adults

	No Education		Primary		Secondary		High School		Higher	
Distance	-0.396***		-1.326***		-0.805***		-0.393		1.605***	
	0.076		0.245		0.199		0.330		0.408	
Distance Feeder		-0.458***		-1.453***		-0.795**		-0.271		3.133***
		0.155		0.459		0.334		0.549		0.541
Distance Main		-0.512***		-1.673***		-1.027***		-0.587		1.260**
		0.093		0.283		0.235		0.376		0.501
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.065	0.053	0.060	0.054	0.047	0.043	0.029	0.028	0.030	0.036
F	16.77	10.97	16.21	12.17	14.41	10.84	11.86	9.545	11.30	13.50
OWNS HOME:										
Distance	-0.329***		-1.060***		-0.642***		-0.486**		0.926***	
	0.069		0.210		0.165		0.240		0.299	
Distance Feeder		-0.378***		-1.014***		-0.518*		-0.308		2.145***
		0.144		0.387		0.272		0.431		0.399
Distance Main		-0.422***		-1.399***		-0.859***		-0.703***		0.583
		0.080		0.244		0.198		0.268		0.366
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.054	0.046	0.051	0.048	0.038	0.036	0.020	0.019	0.022	0.027
F	13.89	9.384	14.35	11.36	10.46	8.401	6.923	5.516	7.861	10.39
RENTS HOME:										
Distance	-0.067***		-0.266***		-0.163***		0.093		0.679***	
	0.019		0.075		0.060		0.168		0.144	
Distance Feeder		-0.080**		-0.439***		-0.277**		0.037		0.989***
		0.038		0.141		0.117		0.197		0.213
Distance Main		-0.090***		-0.275***		-0.168**		0.117		0.677***
		0.026		0.084		0.067		0.211		0.176
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.027	0.020	0.037	0.033	0.037	0.035	0.041	0.041	0.036	0.042
F	6.569	4.612	9.679	7.000	13.25	10.48	17.75	14.63	14.29	13.45

Note: The outcome variables are the total number of adults (over age 22) in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.8. The Results by Household Economic Characteristics

	Extremely Poor		Poor		Motor Vehicle		Per-Capita Income	
Distance	-0.171***		-1.146***		0.293**		32.863***	
	0.045		0.196		0.132		10.046	
Distance Feeder		-0.063		-1.005***		0.799***		103.069***
		0.069		0.285		0.186		14.969
Distance Main		-0.300***		-1.482***		0.097		10.916
		0.061		0.240		0.165		11.292
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.091	0.080	0.109	0.106	0.024	0.026	0.033	0.037
F	24.27	18.78	31.63	25.97	8.746	9.308	11.03	12.33
OWNS HOME:								
Distance	-0.123***		-0.840***		0.191*		25.903***	
	0.033		0.130		0.100		9.803	
Distance Feeder		-0.046		-0.715***		0.606***		85.000***
		0.057		0.219		0.143		13.834
Distance Main		-0.212***		-1.109***		0.014		7.244
		0.046		0.160		0.128		11.374
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,949	2,949
R-squared	0.082	0.076	0.117	0.113	0.019	0.021	0.030	0.033
F	20.29	15.82	35.75	29.59	7.099	7.688	9.217	10.21
RENTS HOME:								
Distance	-0.047		-0.306***		0.102**		53.841***	
	0.031		0.090		0.050		12.381	
Distance Feeder		-0.017		-0.290***		0.192***		129.126***
		0.034		0.110		0.073		25.003
Distance Main		-0.088**		-0.373***		0.083		27.656**
		0.039		0.110		0.059		11.281
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,837	2,837
R-squared	0.031	0.026	0.042	0.041	0.024	0.025	0.023	0.026
F	9.293	6.440	11.50	9.090	8.152	7.505	7.862	8.610

Note: The outcome variables are the total number of households that fall into each group in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.

Table A.9. The Results by Household Income Quintile

	1st		2nd		3rd		4th		5th	
Distance	-0.709***		-0.684***		-0.243**		0.088		0.881***	
	0.109		0.118		0.104		0.107		0.198	
Distance Feeder		-0.797***		-0.758***		-0.485***		0.200		1.819***
		0.183		0.184		0.173		0.154		0.253
Distance Main		-0.857***		-0.753***		-0.209*		0.054		0.576**
		0.136		0.139		0.121		0.129		0.242
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.179	0.174	0.189	0.188	0.194	0.194	0.210	0.213	0.106	0.113
F	201.4	169.4	295.5	244.7	379.6	314.8	455.3	374.2	195.1	161.5
OWNS HOME:										
Distance	-0.496***		-0.554***		-0.237***		-0.025		0.513***	
	0.076		0.087		0.075		0.085		0.147	
Distance Feeder		-0.595***		-0.603***		-0.425***		0.145		1.229***
		0.133		0.152		0.137		0.123		0.182
Distance Main		-0.585***		-0.619***		-0.206**		-0.095		0.261
		0.095		0.100		0.085		0.101		0.182
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.150	0.145	0.156	0.155	0.158	0.159	0.183	0.184	0.102	0.108
F	135.7	114.7	212.3	176.3	289.0	239.1	383.1	314.4	193.5	158.9
RENTS HOME:										
Distance	-0.213***		-0.130***		-0.006		0.113***		0.368***	
	0.054		0.046		0.050		0.042		0.067	
Distance Feeder		-0.202**		-0.154**		-0.060		0.055		0.590***
		0.086		0.068		0.070		0.068		0.100
Distance Main		-0.272***		-0.135**		-0.003		0.149***		0.316***
		0.063		0.055		0.061		0.053		0.079
Observations	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964	2,964
R-squared	0.119	0.117	0.116	0.116	0.115	0.114	0.113	0.123	0.079	0.084
F	161.9	133.6	193.0	158.6	203.1	167.3	202.1	167.0	124.8	104.1

Note: The outcome variables are the total number of households in each quintile in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables. Standard errors are robust to heteroskedasticity.
Significance level: * = 10 percent, ** = 5 percent, *** = 1 percent.