Urban Transport Infrastructure and Household Welfare: Evidence from Colombia*

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Abstract

The effects of urban transport policies on household welfare is a broadly understudied topic in developing countries. This paper analyzes the distributional effects of a newly established bus rapid transit (BRT) system in Barranquilla, Colombia. Using pooled cross-sectional household survey data, analyzed by block, over 2008-15 and a difference in differences approach, it 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 such systems, despite the generally positive assessment of the systems, may have overlooked distributional consequences. Moreover, it shows that any results on outcomes that may be directly affected by the related policy will be biased due to changes in composition.

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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 an inefficient provision of essential services. Transportation is a particularly relevant example. 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 when 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. 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[1]. 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 **?**. 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 conducted their analyses at higher levels of aggregation (counties, states, provinces, or nations).

The present study analyzes the distributional effects of Barranquilla's BRT system, Trans-

[1]See Global BRT Data (database), World Resources Institute's Ross Center, Brasil Sustainable Cities, Porto Alegre, Brazil, https://brtdata.org/.

metro, first inaugurated in 2010. It employs difference-in-differences methods on survey data collected in quarterly rounds over an eight-year period. 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 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. The overall welfare impact of the system are, therefore, ambiguous. While better-off households largely benefitted, poorer ones were displaced. Most importantly, a naive analysis that does not take these compositional effects into account would largely overestimate welfare gains. As discussed below, a few studies exist that attempt to determine the effect of transport infrastructure on household-level outcomes, 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. Our study also contributes to the literature by being one of the still relatively few on public transportation in middle-income countries- among which it also appears to be the first to focus on distributional effects as a result of displacement and neighborhood composition.

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. Redding & Turner (2016) 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 by 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 one provides a review on the existing empirical literature on BRT systems. This is followed by a brief overview of Barranquilla's Transmetro. Section four then explains our data and empirical strategy. Section five presents results, and section six concludes.

2 Existing Literature

Research on the economic impacts of transport infrastructure concentrates on studies analyzing intra-city mass transportation infrastructure, such as subways and BRT systems, and inter-city or region transportation infrastructure, such as road and railroad networks. Redding & Turner (2016) reviewed this literature extensively[2]. The main aspect that the present research is concerned with is the distributional impact of BRT systems. Most papers that focused on the effects of urban transport programs, however, do not take compositional impacts into account, such as whether households relocated in response to the implementation or expansion of a BRT system **?**. This is important as changes in household economic characteristics may be caused by reallocation-rather than growth-, thus empirical results may capture compositional effects, rather than causal effects[3]. Below we present an overview of the literature on BRT's and other transit systems, with a focus on displacement of residents (gentrification). Wherever possible, we reviewed evidence specifically for Colombia and other middle-income countries.

This paper contributes to several strands of this literature. First, our work is related to the empirical literature that examines the distributional impacts of transport infrastructure within a city, specifically BRT systems. Second, this research contributes to the scant empirical literature that attempts to causally measures the effects of BRT systems on socioeconomic outcomes. Third, this paper contributes to the research that examines the relationship between land and housing value uplift and BRT systems[4]. This has important implications as our results -in line with the empirical literature- finds evidence of compositional effects, suggesting a gentrification process is occurring, likely due to increases in property values.

[2]Papers that studied intra-city transport infrastructures, most notably include Gibbons & Machin (2005), Baum-Snow & Kahn (2005), Baum-Snow (2007), Billings (2011), Ahlfeldt, S., Sturm & Wolf (2015), J. (2017), Tsivanidis (2017), Scholl (2019), Heblich, Redding & Sturm (2020), Gaduh, Gracner & A. (2021), Balboni, Bryan, Morten & Siddiqi (2021), and Zarate (2021). Studies that examined these impacts with an inter-city or region lens include, Duranton, P.M. & Turner (2014), D. & R. (2016), Gonzalez-Navarro & Turner (2018), Fajgelbaum & Schaal (2017), D. (2018), Monte, Redding & Rossi-Hansberg (2018), Allen & Arkolakis (2019) and Baum-Snow, Henderson, Turner, Zhang & Brand (2020)

[3]This is similar to the attrition bias in randomized control trials.

[4]The remainder of the literature on BRT systems focuses on performance metrics, such as operating costs, financial sustainability, or changes in ridership (e.g. see Alpkokin & Ergun (2012); and Deng & Nelson (2013)). A number of studies compared the performance of BRT systems to other transport infrastructure considering these factors (see, for instance, Cervero (2013)). Studies in this line have found positive impacts of Bogotá?s TransMilenio system in Colombia (Chaparro (2002); Hidalgo, Liliana, Estpiñán & Jiménez (2013); while others found negative effects among users in areas further away **?**), as well as negative externalities-specifically, the expansion of criminality associated with the greater mobility of criminals, as a boomerang effect of the BRT **?**. Alternatively, in a survey of BRT systems across the world, Hidalgo & Gutiérrez (2013) highlighted the substantial associated positive externalities. Other research took an equity lens, in addition to assessing the impact of BRT systems on employment, ridership distribution, accessibility, and health. Venter, Jennings, Hidalgo & Valderrama-Pineda (forthcoming) and Venter, Hidalgo & Valderrama-Pineda (2013) provide excellent reviews.

First, this paper contributes to the small albeit growing literature that examines the distributional impacts of transport infrastructure (D. (2018); Tsivanidis (2017); Allen & Arkolakis (2019); Fajgelbaum & Schaal (2017); Balboni et al. (2021); Gaduh et al. (2021) and Zarate (2021)). This work is closely related to Tsivanidis (2017)), who analyzed Bogota?s TransMilenio BRT system using a general equilibrium model allowing for the sorting of workers. The author found that the transit system triggered residential segregation across worker groups; and, even though welfare increased by 1.49 percent and output overall by 1.09 percent, gains were accrued disproportionately to high-skilled workers. Similarly, Balboni et al. (2021) and Gaduh et al. (2021) analyzed the distributional effects of BRT systems in Dar es Saalam, Tanzania and Jakarta, Indonesia respectively, through general equilibrium models. Balboni et al. (2021) estimated a welfare gain at 3 percent for incumbent low-income residents living near the BRT, compared to a 2.5 percent gain for incumbent high-income residents. Alternative, Gaduh et al. (2021) found smaller welfare gains at 0.03 percent, and evidence that the BRT system increased congestion in Jakarta. For Argentina, Warnes (2020) finds that the BRT in Buenos Aires increased the welfare of high skilled and low skilled incumbents, by 1.04% and 0.94%, respectively.

Second, our work is also related to the thin literature that focuses on the impact of transport infrastructure on socioeconomic outcomes such as employment and educational attainment. Causal studies of this nature in Latin America are scant (Yañez Pagans, Martínez, Mitnik, Scholl & Vázquez (2019); Scholl, Martínez, Mitnik, Ovied & Yañez Pagans (2018)). In Bogota, income appears to have increased among households in proximity to BRT stations, although-as pointed out by the authors-results are likely driven by changes in household composition, as the data used are pooled cross-sections **?**. Employment also appears to have increased in areas with higher exposure to the BRT system **?**. In Lima, Peru, Scholl et al. (2018) examined the effects of the Metropolitano BRT system on the labor market, and found significant impacts on employment, hours worked and labor earnings for those individuals that live close to BRT stations. Alternatively, the authors found no causal evidence of impacts for individuals living in low income areas. Lastly, to the best of our knowledge, our paper is one of the few that attempts to measure the causal effects of BRT systems on educational attainment.

Third, this research also contributes to the literature that studies the implementation of BRT systems and land and housing value uplift. There is evidence from Bogota?s TransMilenio system that land values declined as the walking distance to a BRT station increased **?**; that property values were higher if close to a feeder line ?; and that an extension of the system increased land value[5] ?. BRT systems also appear to have had a favorable impact on the market price of residential ? and commercial property prices in both Bogota and Barranquilla ?. Most recently, Guzman, H.D. & Hessel (2021) found that in Bogota, the BRT had a positive effect on land value across low-income neighborhood compared to medium- and high-income neighborhoods[6]. Furthermore, the pace of land development appears to have risen in areas with BRT stops (in addition to other factors) in Bogota and Quito ?. Assessments of BRT systems in cities outside Colombia also found positive effects on the real estate market (Jun (2012); Deng & Nelson (2010); Cervero & Kang (2011); Dubé, Des-Rosiers, Thériault & Dib (2011); Perk & Catalá (2009); Hess & M. (2007); Deng & Nelson (2010); Zhang, Meng, Wang & Xu (2014)), with some exceptions (Mulley & Tsai (2016); Mulley, Ma, Clifton, Yen & Burke (2016); Mulley & Tsai (2017)).

Further research is necessary to better understand whether BRT systems expand the accessibility of households previously living along the bus corridors, and whether a price rise leads to displaced population segments, found by Stokenberga (2014) and by this paper. Evidence form the U.S. also points to residential segregation as a result from public infrastructure (Glaeser, Kahn & Rappaport (2008); Severen (2018)), however these are not specific to BRT systems. The results of our paper are aligned with this strand of the literate, as we found evidence of low-income households living in proximity to new BRT stations being replaced by households in the middle-and upper-income end of the distribution.

The literature on the economic effects of changes public transportation gained momentum in recent years. However, most studies have relied on cross-sectional data, and are thus based on the on the implicit and often unstated assumption that households do not relocate in response to the policy being studied. This assumption is likely to be violated as reported by other empirical studies as well as the findings from this study (Scholl et al. (2018); Heres, Jack & Deborah (2014)). One way to overcome this limitation is by incorporating longitudinal panel-data, enabling researchers to know the residence of each individual across time, thus fully determining treatment and control groups. In recent years, scholars have implemented general equilibrium frameworks[7] to overcome the limitations from successfully identifying treatment

[5] This effect is found in locations already serviced; values did not rise in areas previously lacking a BRT station but that are now serviced by the extension.

[6] The effect of BRT infrastructure was not significant and, negative in some cases.

[7] Redding & Rossi-Hansberg (2017) provide a comprehensive review of this literature.

and control groups ?. Despite recent advancements, findings on the economic impacts of BRT systems are mixed and as it will be shown in this paper, should be treated with caution given the data limitations mentioned. Thus, making the identification of causal effects on socioeconomic outcomes difficult.

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 Bogota 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 Bogota in 2001, and the country's second and third largest cities, Medellin 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 (Medellin 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 Bogota's Trans-

Milenio, 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 1 provides a visual overview of the Transmetro BRT system. The system serves the municipalities of Barranquilla and Soledad. The main lines, with a total length of 14 kilometers, consist of local and express stations. The local stations may be bypassed by express buses. Buses along the feeder lines, which comprise another 190 kilometers, 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[8]. The total number of trips rose from 3,658,421 in 2010 to over 36,400,000 in 2016. 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 compositional effects, 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 of the 2008-15 rounds of the Gran Encuesta Integrada de Hogares-GEIH survey, the main labor survey of Colombia similar to Current Population Survey-CPS in United States, the survey is conducted by the National Administrative Department of Statistics (DANE by its Spanish acronym). The current survey was first carried out in 2007 and has supplied consistent

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

information in the current format since 2008. Barranquilla-Soledad metropolitan area is covered by the survey on a quarterly basis[9]. 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 feeders 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 household with the nearest stations/stops of the BRT system we relied on DANE's data lab (similar to Research Data Centers common 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 median block in our sample has 25 households[10]. Sincearound half of households in each block were sampled, this implies that the typical block has about 50 households. The distance to main line stations and feeder stops of the Transmetro system is calculated from each block's centroid and following the street grid. Figure 2 provides a graphical illustration of this process.

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 this restriction allows for a better comparison by excluding areas that were never to be targeted by the public transit system. 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

[9]The survey covers all of the country's 13 major metropolitan areas on a quarterly basis

[10]While a few blocks enter with a single household, the maximum number of households per block is 77. The average is close to the median at 25.66.

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:

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

The outcome variable $y_{b,t}$ are either the total number of households/individuals or averages for block b observed in year t. The parameter of interest is β_1 which captures the effect of closer proximity to a station on the outcome $y_{b,t}$. This is a standard presentation for a difference in differences (DD) estimation with pooled cross-sections and more than two time periods. The general philosophy behind DD estimation frameworks is to regress changes in outcomes on changes in the treatment of interest. Any time-invariant unobservable characteristics that may act as omitted variables, and whose effect on the outcome would otherwise be wrongly attributed to the treatment, can hence be directly controlled for. Since data from several time periods need to be employed, one also needs to control for time-period specific factors that may affect the outcome, but could also be correlated with the treatment. The year-specific error term, θ_t, implemented through a set of year-specific binary variables, takes care of the latter concern. If longitudinal data were at hand, one could similarly control for time-invariant and block-level characteristics with a set of block-specific binary variables. In the case of pooled cross-sections this is not possible. Instead, we use the distance to the closest station in 2016 when the system had been fully implemented, $Distance\ 2016_b$, which captures any block-specific characteristics that are correlated not only with the outcome, but also its proximity to a station. [11]

As in any DD 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*). In practical terms, we need to rule out that unobserved year-specific changes at the block level simultaneously affected its connection to Transmetro and the outcome of interest. Lastly, the term $\alpha' X_{b,t}$ denotes additional control

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

variables and is only included for a few specifications. For each outcome, 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 stations or a feeder stops separately. The error term $\varepsilon_{b,t}$ is fully robust to heteroskedasticity.

Table 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[12]. 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 19.34 households per block. Of these, more than half (10.70) represent homeowners, 2.62 live in usufruct, and 5.89 rent[13]. 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 1.

The rest of table 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 households (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 the estimated rent they might have to pay for it. There is a much larger number of

[12]To be more specific 124 are sampled three times; 27, four times; 7, five times; and 2, six times.
[13]The number of households in some other arrangement is negligible, at an average 0.13

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

From a perspective of economic theory, the opening of a public transit station (like other forms of public infrastructure) should have an ex-ante undefined impact on property values in the surrounding areas. To the extent that existing or prospective benefit from the service the valuation of close real estate should go up. If the opening of the stations increases undesirable features of the location, such as traffic congestion or crime, it would have the opposite effect. The area may also simultaneously become less attractive for housing, but more attractive for commercial activities. A change in value, or in relative attractiveness for different activities, will of course trigger other changes, such as new construction, investment in the existing stocks, and changes in the ownership structure. In what follows, we will walk through these effects step by step to understand the nature of the observed changes. We will first look at housing characteristics, followed by time-invariant characteristics of resident households, and finally at changes their time-variant economic characteristics[14].

5.1 Results on housing characteristics

Changes in home values can be the result of changes dwelling characteristics or the value of the location. Investment in (or deterioration of) a housing unit will also be determined by its ownership status. So the first step in understanding the effect of Transmetro on real estate values is to determine if it changed the ownership structure at the block-level. One can distinguish among owners, including those who are still paying mortgages, households living in usufruct, renters, and other arrangements. Table 2 shows that proximity to a main line station reduced the number of households living in their own homes or in usufruct and, as a result, also the total number of households. No effect was 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

[14] All estimations shown here were implemented in Stata.

and those in usufruct by 0.511. Put in relation to the mean number of households of each type shown in table 1 (10.7 for owners and 2.62 for usufruct) suggest effects of significant magnitude. This raises the question as to what happened to these housing units.

Table 3 provides a partial answer by looking at the quality of homes. As a location becomes more attractive to higher-income households the quality of the housing stock is expected to increase. It first shows results on all households and then divides the sample into two groups: Owner-occupied households and households living in usufruct, and renters and households with other arrangements [15]. This division will be followed in the remainder of this paper. The observable outcomes of interest are the number of households living in apartments, homes with solid walls, homes with solid floors, and homes 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 showed a strong effect on the quality of the housing stock: a general increase in the number of apartments, more rooms, and more homes with exclusive toilets. There was no strong positive effect on the number of homes with solid walls and floors, except for a small effect (significant at the 10 percent level) 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 was highly statistically significant in the case of solid walls and proximity to main line stations. The magnitude of the latter also accounted almost fully for the effects found in table 2. The implication is that owner-occupiers of low-quality housing were likely bought out to construct higher-quality housing, often apartments. The improvements in housing quality were also present in the proximity to feeder lines. 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 were of similar magnitude, there were more than twice as many households in the former group. Thus, the relative magnitude of the identified effects was twice as large for renters relative to owners.

The next logical step is to explore if home values increased and, if they did, the extent to which this reflected better quality or improved location. This is answered in table 4. Three outcomes were examined. Respondents who owned their home were asked at which price they believed they could sell or rent. The latter outcome is called hypothetical rent. The summary

[15]These categories follow the official definitions used by DANE, putting homes inhabited in usufruct into the same broader category as homeowners.

statistics showed that the average hypothetical rent is about twice as large as reported actual average rents. Homeowners either systematically overestimated the rental value of their homes or they interpreted the question as asking for their reservation price. The dependent variables in table 4 are average rents and valuations at the block-level. To assess the importance of improved home characteristics, we ran the estimations first without control variables, followed by the inclusion of the characteristics examined in table 3. The results are instructive. If no controls for home quality were included, estimated home values and both types of rents increased significantly with closer proximity to a station. Home values were scaled to millions of Colombian pesos, and rents to thousands of pesos. The results implied that moving from a 1 kilometer distance to a place directly adjacent to a station increased 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 for feeder lines and main lines, respectively. The most important result here may be that these effects vanished once home characteristics are controlled for. The increases thus merely captured improved quality, but that there was no additional premium 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 argued that homeowners simply do not factor in the added value derived from station proximity in their estimated home values. However, we found the same effect for actual (though self-reported) rents. One 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 better-off households who do not need public transportation are drawn to station proximity because of secondary effects. These effects might include public investments related to Transmetro, such as better maintained roads or more police on the beat. Alternatively, it may also be the case that public investments are simply taken as a signal for a greater commitment of local authorities to certain areas of the city. Private housing investments would then coordinate on such areas, which would act as focal points, even if the public BRT service is not directly valued by future residents.

5.2 Results on time-invariant household characteristics

The results in the previous subsection showed that in response to the Transmetro system an improved and more expensive housing stock developed around stations. This could either have been the case because the existing residents became better-off and could afford these improvements, or, alternatively, that many of the existing residents were replaced by newcomers who could afford the new housing. The next three tables (5-7) show evidence for the latter. The strategy here was to focus on probably time-invariant household characteristics that indicate socio-economic status. Any systematic change in these could then be interpreted as evidence for displacement.

Table 5 shows results for the number of households that were female headed and that fell within three different profiles of household composition. Negative effects were found throughout among owners in proximity to main line stations. Given that the magnitude of the effects among owners was similar to the magnitude of the effects shown in table 2, these can be 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 were all significant at 5 percent.

Table 6 examines the characteristics of individuals across age-groups and by gender. As expected in light of the earlier results, 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, as well as, in the number of individuals aged 16-22 (young) among homeowner households close to feeder lines. Taken together, these results explained most of the changes in household size shown in table 5.

Table 7 exhibits results for the total number of adults according to educational attainment. To rule out any direct effects of Transmetro on observed educational attainment, the data were restricted to individuals older than 22 years and could thus be expected to have completed their educational careers. All specifications showed a strong and statistically significant negative effect on the number of individuals who had completed less than mid-secondary education (high school). There was almost no effect on the number of individuals who had completed high school, but did not go further. The one exception here was for owners close to main line stations. For this group only, the total number of individuals declined. For all other groups, the sum of the statistically significant negative effects up to basic secondary education roughly corresponds to the increase in the more highly educated (keep in mind that we are looking at the number of adults, not all individuals or households). This shows the existence of a replacement effect.

5.3 Results on household income and wealth

Given these compositional effects on education and household demographics, one would also expect a compositional improvement in households' average economic characteristics. The question is then if access to public transportation, in addition, provided households with better economic opportunities, and thus increased the income of households who stayed on the block. Table 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 were measured as the total number of households in each block, while income was calculated 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 close to feeder stations. The average per capita income rose among all specifications except owners close to main line stations. This last result reflects findings other tables for this group.

Table 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 8, include imputed rents for homeowners and households living in usufruct. The results largely mirror those on adult educational attainment shown in table 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 8 and 9 support the general finding that Transmetro led to a replacement of poorer, more vulnerable households by richer households. The magnitudes of these effects is similar to what we had found in tables (5-7), which suggest no direct positive economic effect of Transmetro.

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 Bogota. 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 of households.

This paper presented a study on the effects of Transmetro, the BRT system in Barranquilla, on the composition of households in the neighborhoods around stations in the newly established system. In line with a large part of the existing literature, the study finds that home values, their quality, household incomes and other welfare indicators increased in proximity to new stations. Unlike most other studies, it also finds that 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 important result 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 hold in other settings and seek a causal relationship. The results described in this paper suggested that the more highly educated and better-off households that moved into the improved homes close to the stations did probably not value the service itself. However, they may have been attracted by other, related public investments. Alternatively, these public investments may have acted as a focal point for private investment by signaling by signaling the local government's commitment to the development of certain areas. None of these possibilities can be tested based on the data available to this study.

The results implied strongly negative distributional impacts among poor renters. In contrast, poor owners may either have choosen to stay in their homes or reap the capital gains by moving to less expensive locations. The results were 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. Other studies presented similar findings.

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 the 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 suggested 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 showed 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.

Figure 1: Transmetro system map with main and feeder lines.

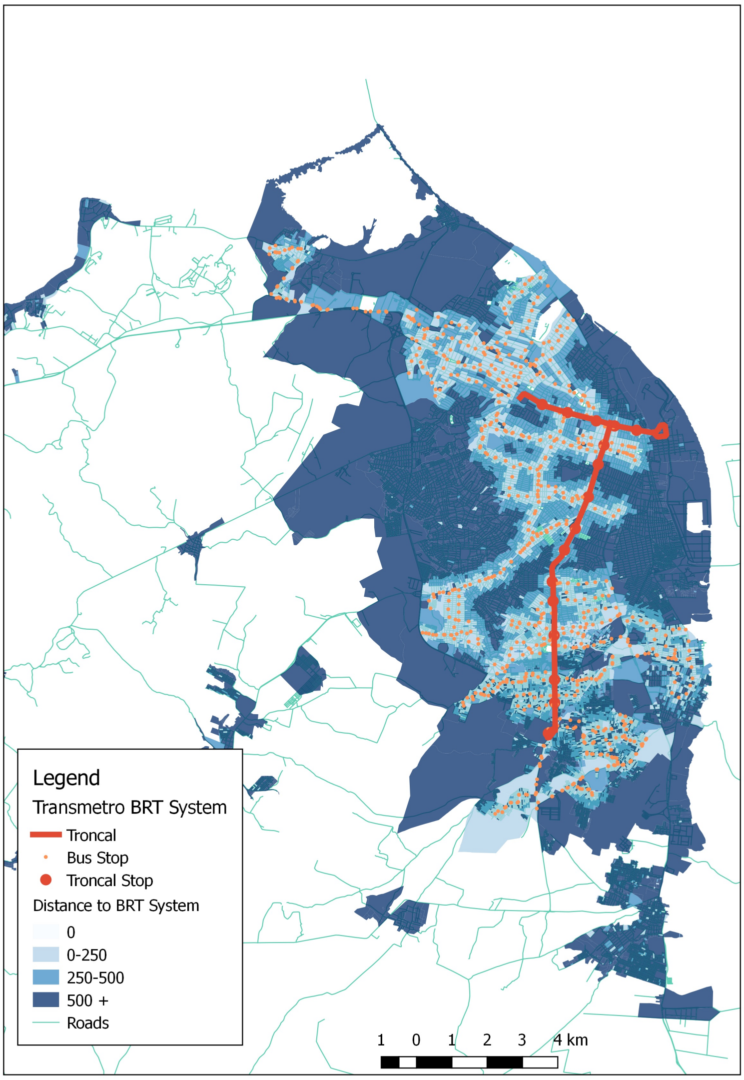

Figure 2: Illustration of distance calculations.

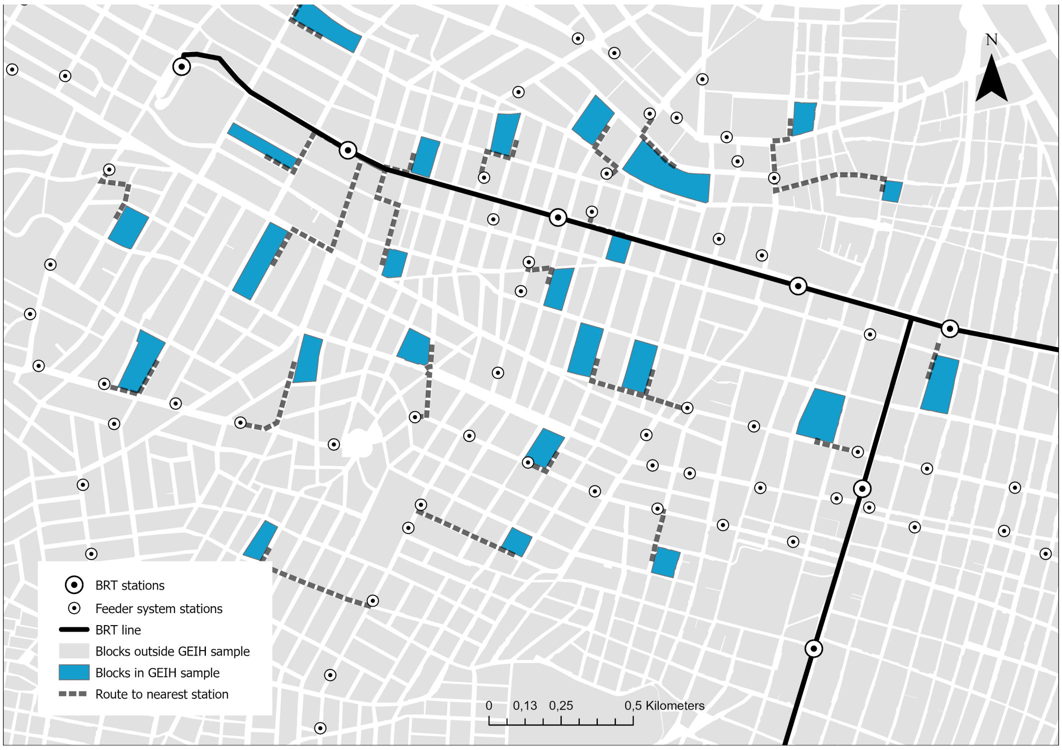

Table 1: Summary Statistics

	Num. Obs.	Mean	Std. Dev.	Min.	Max
Treatment Variables:					
Distance to closest station	2,964	-3.33	4.19	-10	-0.002
Distance to closest feeder line station	2,964	-4.93	4.75	-10	-0.002
Distance to closest main line station	2,964	-8.41	3.34	-10	-0.032
Distance to closest station in 2016	2,964	-0.34	0.23	-0.999	0
Distance to closest feeder line station in 2016	2,964	-2.16	3.80	-10	0
Distance to closest main line station in 2016	2,964	-8.11	3.90	-10	0
Outcomes and control variables					
Number of households on block	2,964	19.34	11.06	1	77
Total number of rooms on block	2,964	68.08	40.07	1	283
Number of households/homes with the following characteristics on block:					
Home owners	2,964	10.70	6.54	0	45
Living in usufruct	2,964	2.62	2.99	0	28
Renters	2,964	5.89	4.55	0	32
Living in other occupancy status	2,964	0.13	0.62	0	14
Apartment	2,964	7.97	7.69	0	72
With solid walls	2,964	18.42	10.54	0	72
With solid floors	2,964	18.27	10.49	0	72
With private water toilet	2,964	16.87	10.35	0	72
Female headed	2,964	6.36	4.47	0	34
With 1 or 2 members	2,964	3.97	3.59	0	32
With 3-5 members	2,964	11.83	7.13	0	55
With >5 members	2,964	3.54	3.13	0	24
Being extremely poor	2,964	0.78	1.33	0	12
Being poor	2,964	4.72	4.90	0	40
Has motor vehicle	2,964	4.37	5.00	0	48
In 1 st quintile	2,964	2.43	3.19	0	27
In 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
Number of individuals with the following characteristics on block:					
Female	2,964	40.05	23.97	0	175
Old age	2,964	6.19	5.63	0	40
Prime age	2,964	41.51	24.44	0	173
young	2,964	10.24	7.07	0	46
child	2,964	17.39	14.35	0	89
Adult with no education	2,964	1.59	2.20	0	25
Adult with primary education	2,964	9.71	8.04	0	58
Adult with secondary education	2,964	6.92	5.58	0	45
Adult with upper secondary education	2,964	14.74	9.87	0	68
Adult with higher education	2,964	14.70	14.74	0	106
Averages values foe households with the following characteristics on block:					
Estimated home value	2,836	58.49	63.03	0.45	800
Rent raid	2,821	332.15	265.29	25	4500
Estimated rent	2,939	643.82	2899.13	20	63588
Per-capita income:					
Without imputed rent	2,964	345.68	358.42	0	3232
With imputed rent	2,491	615.77	520.43	79	4223

Notes: Each observation represents a block/year (however, blocks may be randomly repeated over years). The treatment variables are only observed at the block level. The "summed household-level variables" represent totals of households in each block, the :summed Individual-level variables" represent totals of individuals. Lastly "averaged household-level variables" represent averages over all households in each block.

Table 2: Results for total number of households and 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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable 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.

Table 3: Results for dwelling characteristics showing total numbers

	Apartments		Homes with Solid Walls		Homes with Solid Floors		Rooms		Homes with Exclusive 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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable are the total number of households in each block that live in apartments, have solid walls, roofs, or have their own toilet. 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.

Table 4: Results for average home values & Rents.

	Home Owners & In Usufruct								Renters & Other Status			
	Average Home Value				Average Hypothetical Rent				Average 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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable are block-level averages of households that either own their dwelling or live in usufruct, or rent/have other arrangements. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables.

Table 5: Results for total number of households by gender of head and number of members.

	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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable 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.

Table 6: Results for total number of females and members of different age groups.

	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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable 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.

Table 7: Results for total number of adults with different educational attainments.

	No Education		**Primary**		**Secondary**		**High School**		**Higher Education**	
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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable are the total number of adult individuals with each educational level, in each block. All models include the corresponding distance variables in year 2016 and year (survey round) specific fixed effects as control variables.

Table 8: Results for total number of households in poverty, with a motor vehicle, and average of per-capita income.

	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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable 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.

Table 9: Results for total number of households in each 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

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are robust to heteroskedasticity. The outcome variable are the total number of households that fall into 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.

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