Home Production, Expenditure, and Economic Geography*

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Abstract: This paper proposes a new microfoundation for the benefits of urban density. Market production of services is efficient because customers effectively share land and other factors of production, leaving them idle for less time. The paper develops a theory in which market-based sharing causes residents of dense areas to purchase services on the market that their suburban counterparts produce at home. The model predicts that residents of dense areas spend more on local services, home produce less, work more, and pay higher land prices - conditional on residents' productivity and proximity to work. The paper presents evidence that these predictions are consistent with the data.

Keywords: expenditure, home production, urban density, agglomeration, regional labor supply.

JEL: D13, J22, R12, R13, R23

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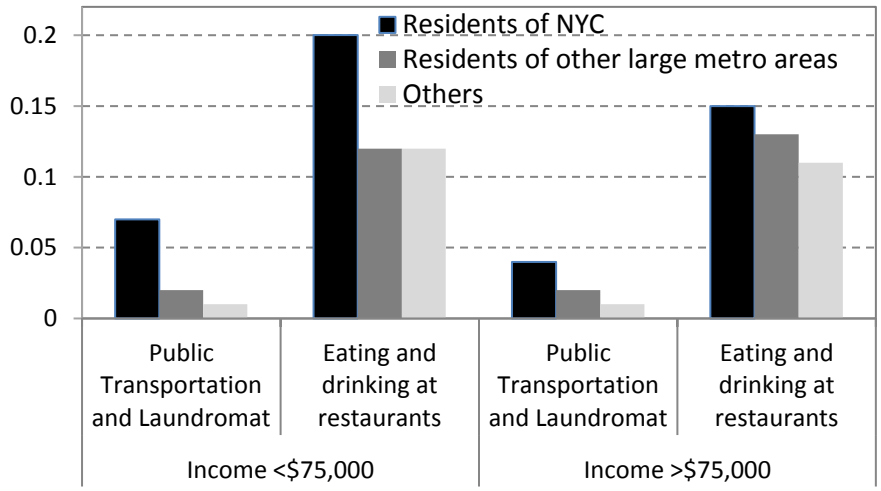
I. Introduction

Urbanization is a prominent feature of modern economic growth. A majority of the world's population lives in urban areas, many of which feature strong congestion-related disamenities such as poor sanitation, pollution, and housing shortages. Despite these apparent costs of congestion, urbanization rates are projected to continue rising (UN Habitat 2011, 2014). These trends raise a question about the benefits of urbanization that offset the costs of congestion: Why are populations increasingly urbanized in the face of congestion disamenities and falling transportation costs? Understanding the microfoundations of agglomeration is important for understanding economic growth and for designing policies to promote sustainable growth (e.g., Moretti 2011).

Traditional explanations for urbanization focus on cost efficiencies associated with industrialization, but modern cities have flourished in the absence of industrialization (Gollin, Jedwab, and Vollrath 2014). Recent work has shifted focus toward the consumption benefits of urban areas, such as variety of services (e.g., Glaeser, Kolko, and Saiz 2001; George and Waldfogel 2003; Ahlfeldt 2013). This paper explores a new benefit of urban living based on the margin between home and market production.

Figure 1: Expenditure shares on local services by city type



Data Source: 2010 Consumer Expenditure Survey, single respondents between 21 and 55 years of age

The insight in this paper is motivated by the observation that dense cities feature high expenditure shares on local services, such as laundromats, for which variety is less likely to be a driving factor (Figure 1). These services have strong home-production substitutes. This observation suggests that the home-production margin may be an important driver of consumption of differentiated services as well.

In this paper I propose an economically substantial benefit of urbanization by incorporating insights from a separate literature on the margin between home and market production. A large literature demonstrates that Becker's (1965) insights about the allocation of time can explain a number of economic phenomena.[1] Here I extend the work on time use to propose a new microfoundation for agglomeration that is based on sharing of factor inputs through market purchases.

The new market-based-sharing microfoundation of residential agglomeration proposes that in dense urban areas it is more efficient to obtain services on the market rather than through home production due to the scarcity of land and the relative efficiency with which service establishments use land. When urban consumers obtain services on the market, they effectively share the factors of production. For example, meal preparation at home requires each consumer to possess his or her own cooking supplies. A restaurant uses a certain amount of kitchen space, oven capacity, and other factor inputs to serve many customers in a day. By purchasing restaurant services, these customers share factor inputs such as land. The restaurant acts as an intermediary by collecting payments for services to pay the factors of production. Similarly, urban residents share automobiles and laundry machines (and the land on which to store them) when they ride taxis or patronize a laundromat.

To formalize this intuition, I present a baseline model consisting of a neighborhood populated by homogenous agents who work at a separate location (e.g., the central business district, or CBD) for an exogenous wage. When market production uses land relatively efficiently compared to home production, higher land prices are associated with an increase in the effective price of home production relative to the price of market production, which causes

[1]These economic phenomena include structural transformation (Buera and Kaboski 2012), life-cycle consumption and expenditure patterns (Ghez and Becker 1975, Aguiar and Hurst 2005), and labor supply over the business cycle (e.g., Benhabib, Rogerson, and Wright 1991). Aguiar, Hurst, and Karabarbounis (2012) survey the literature on the economics of time use.

production of services to shift toward the market. As a result, residents of neighborhoods with higher land prices purchase more services on the market and home produce less. With the time saved from home producing less, residents work more in the CBD, which helps pay for the higher expenditure.

High land prices in dense regions may arise for a number of reasons, including proximity to the CBD (e.g., Mills 1967; Lucas and Rossi-Hansberg 2002) and urban amenities (Roback 1982). The substitution toward market purchases does not rely on a particular cause of high land prices. The theory is quite flexible and can be modified to accommodate different causes of high land prices. However, in a simple setup, the theory offers a new microfoundation for high land prices in dense areas. Specifically, when land-market clearing is imposed within a neighborhood, land prices are increasing in neighborhood density, holding constant proximity to the CBD and other location amenities.[2] Therefore, the model predicts that residents of denser neighborhoods spend more on local services, home produce less, work more, and pay higher land prices.

The model adds to a list of sharing-based microfoundations for agglomeration, which Duranton and Puga (2004) classify as sharing indivisible facilities, sharing gains from a wider variety of inputs, sharing gains from specialization, and sharing risks. The home-production microfoundation is perhaps most similar to the sharing of indivisible facilities that require large fixed costs, such as ice rinks and museums (Buchanan 1965). The distinction between the two microfoundations is that substitution between home and market production does not rely on strong indivisibilities or substantial fixed costs: individuals often have laundry machines and automobiles, whereas they do not tend to own ice rinks.

This paper presents new evidence that time use, expenditure, and labor supply depend on economic geography across regions of the United States. Consistent with the model's predictions, residents of larger, denser regions allocate less time to home production and spend more of their income on market services. The geographic dimension of time use is economically substantial. Living in a central city is associated with 16.9 fewer minutes of home production per

[2] The appendices demonstrate that the predictions of the baseline model are robust to model extensions, including permitting resident mobility and spatial equilibrium. I examine zoning restrictions as an example of a cause of variation in density across neighborhoods based on the evidence that historical land use regulations cause intra-city variation in density (e.g., Brooks and Lutz 2014). When some neighborhoods restrict market production relative to the level obtained in a homogenous density equilibrium (and thus enforce higher land use for home production), the unrestricted neighborhoods are denser and feature higher land prices. Residents of the unrestricted dense neighborhoods work more, spend more on local services, and home produce less.

day, conditional on a range of individual characteristics (24.5 fewer minutes unconditionally), which is equivalent to 3.5% of an eight-hour workday (5.1% unconditionally). Likewise, residents of the densest cities spend over six percentage points more of their income on local services such as laundromats, restaurants, and transportation.

I explore the additional predictions of the theory (high labor supply and high land prices in dense neighborhoods) by exploiting detailed Census data. The theory predicts that, conditional on these standard mechanisms (e.g., productivity, proximity to the CBD), denser areas should feature higher work hours and potentially higher land prices. The results are consistent with these predictions. Residents of dense areas allocate more time to work and pay higher land prices, conditional on their wage, education, occupation, location of work, proximity to work, and other characteristics.

The richness of the Census data allows me to include controls that help condition on variation in work hours and land prices that are driven by existing theoretical mechanisms. The analysis does not contain an instrument for density and therefore cannot entirely rule out alternative explanations for high work hours and land prices in dense areas. However, the rich set of controls helps condition on many of the leading theoretical alternative explanations for high land prices and work hours in dense areas. Location of work fixed effects help control for location-related productivity and income. Controls for industry and education further help control for respondents' productivity and likelihood to work hard to compete with peers (Rosenthal and Strange 2008). I do not directly observe the amenity value of each residential neighborhood, so it remains a possibility that hard-working individuals select into areas with high amenitiy value (and hence high land prices). However, the dependence of work hours on establishment density is just as strong when omitting from the sample respondents in industries with the longest work hours (finance and law), which suggests an additional role for the home production margin in driving work hours, above and beyond individual preferences for work/leisure.

This paper contributes to a number of streams of the literature. First, the paper expands the reach of the time use literature by demonstrating that the home-production margin can also influence agglomeration. In linking these two previously disparate strands of the literature, it also

contributes to an extensive body of work devoted to understanding agglomeration mechanisms (Duranton and Puga 2004 provide a review).

Second, this paper contributes to literature on cross-region variation in labor supply. High work hours in cities have been shown to depend on proximity to other workers through a rat-race effect (Rosenthal and Strange 2008) and metropolitan area commuting time (Black, Kolesnikova, and Taylor 2014). This paper suggests that substitution between home and market production of to services can also contribute to labor supply variation.

Third, the home-production margin is relevant for work that examines regional variation in inequality (e.g., Moretti 2013; Handbury 2013). One implication of this paper is that regional variation in consumption inequality depends on regional variation in home production. It also suggests that high prices charged to low-income consumers at convenience stores (e.g., Broda, Leibtag, and Weinstein 2009) may be due to land scarcity in dense areas. If residents are compensated for the high price of convenience by having more time to work and/or needing less space, then high service prices need not reflect lower well-being. The ability to save on space through market-based sharing of land and other factors is potentially relevant for quantitative estimates of the consumption benefits of density (e.g., Couture 2014).

Finally, the home-production microfoundation contributes to the literature on the theoretical determinants of land prices. High land prices in dense residential areas are traditionally attributed to proximity to a business district due to transportation costs associated with commuting to work (e.g., Mills 1967; Lucas and Rossi-Hansberg 2002). The home-production microfoundation suggests an additional factor contributing to high land prices. Specifically, in dense areas, land is the relatively efficient factor of production because residents share land by purchasing services on the market. As a result, this paper has implications for the interpretation of estimates of regional quality of life.

This paper proceeds as follows. Section 2 presents the theoretical model. Section 3 presents the evidence on time use, expenditure, work hours, and land prices across regions. Section 4 concludes.

2. A Theory of Home Production, Expenditure, and Density

Before diving directly into the formal model, let me begin with an informal story that illustrates the distinction between urban and suburban living. The purpose is to demonstrate that equally productive individuals may enjoy equal consumption, but through different means based on their residential location.

Consider first a woman living in a small apartment in a dense area of Manhattan. She does not own a car or a washing machine, and her kitchen is small enough that cooking is limited to only basic meals. She likely commutes by taxi or subway rather than owning a car that would be expensive to park given the high cost of land. She gives her laundry to the cleaners at the end of the block, and eats out at the myriad restaurants within a minute's walk from her apartment. If she does cook at home, she likely shops at a food market that day rather than storing groceries in her apartment for long periods of time. In other words, she purchases on the market many of the services that she consumes.

Now consider a man living and working in an isolated suburban community elsewhere in the country. He owns a car, a washing machine, and a large kitchen. He cooks at home often and stores groceries in his spacious pantry. He also drives himself to work and washes his clothes himself, so that many of the services he consumes are produced using his own labor within his own home. If income in the suburbs is low due to the lower market labor supply, why does the man not simply move to Manhattan, earn a higher income, and purchase services on the market? One possibility is that the man may not need a higher income since he purchases less on the market. In other words, his total consumption is the same as if he lived in Manhattan because he is compensated for lower income with more time to produce at home. The tradeoff for a higher income in Manhattan is higher land and service prices. In the model developed below, higher land prices in the denser area will induce residents to work more, home produce less, and purchase more services on the market.

2.1. Theory

The objective of this section is to formalize the dependence of time use and expenditure on residential density. To do so, I will examine a setting that is both simple (in that it abstracts from many features of the urban environment) and rich enough to provide a number of new insights.

In particular, the model takes as given residents' wages, commuting costs, and unit costs of local services.

The model features a neighborhood populated by identical agents who work in a separate location for an exogenous wage. Residents choose how to allocate their time between working and home production. I derive the implications of density by examining the effect of changes in neighborhood land size, holding constant the population (or equivalently, comparing otherwise identical neighborhoods that differ in land size). Land scarcity induces higher land prices, which shifts production toward the sector that uses land more efficiently. Market-based production uses land more efficiently than home production due to the ability to share space, as discussed in the Introduction.

It should be noted that the baseline model abstracts from choice of residential location by holding fixed population in each neighborhood. Therefore it does not impose spatial equilibrium. In this sense, the model can be thought of as comparing different neighborhoods in which residents have preferences for their location relative to other locations. The key predictions of the theory hold when residents are mobile, as demonstrated in Appendix A.

2.1.1. Baseline Model

Consider a neighborhood populated by a unit mass of identical residents who work in a tradable sector at a different location (perhaps the CBD) for an exogenous wage w. Land L is a fixed quantity in the neighborhood. Residents use their income to purchase land (for housing services/home production) and market-based services from establishments located in the neighborhood. Ownership of durables is omitted from the model for simplicity and because the intuition with respect to sharing of durables can be captured in the model by the sharing of productive land through market purchases. For simplicity, rents from land are assumed to accrue to agents outside of the city.

Service establishments use labor from workers outside the neighborhood to produce local services (in addition to land). The unit labor cost of market-based services is exogenous. This treatment of the service sector limits the focus of the model to market outcomes for people who work in similar industries. The qualitative predictions of the model are robust to alternative setups in which neighborhood residents work in the service sector.

Residents have utility over services produced at home and those produced on the market:[3]

$$U = \left(M^{\frac{\sigma-1}{\sigma}} + H^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where M is the bundle of market-based services and H is the bundle of services produced at home. M includes meals purchased at food establishments, laundromat services, and public transportation, while H includes home-produced counterparts (e.g., cooking and cleaning at home and driving oneself for transportation). One can also think of M as including market-based storage services in the form of convenience stores (consumers have the option of stockpiling groceries at home or purchasing them at convenience stores on an as-needed basis). For simplicity, I also assume that agents do not purchase local services from neighborhoods other than the one in which they reside.

Each resident is endowed with t units of time, which she allocates to working in the tradable sector t^W and home production t^H. I abstract from additional uses of time to focus on the work/home-production margin.

Technology. Home and market production use a Leontief technology that takes time/labor and land as inputs. The home-production function is

$$H = \min\left(t^H, \frac{1}{b_H} l^H\right), \tag{2}$$

where l_H is the amount of land devoted to home production and b_H is the amount of land required to home produce a unit. Cost minimization implies that the effective cost of home production is

$$p^H = w + b_H r, \tag{3}$$

where w is a resident's wage in the tradable sector (and therefore the opportunity cost of home production) and r is the price of land. The wage w is exogenous and the land price r is endogenous.

Market production uses a Leontief technology over land and labor from workers outside the neighborhood,

[3] Preferences are assumed to be of the constant-elasticity variety for simplicity and generality. The results discussed below hold for any $\sigma > 0$. As an alternative to assuming imperfect substitutability between home and market, Appendix B assumes that each of a set of distinct services has perfect home and market substitutes. If there is some heterogeneity in services (e.g., in time costs of home production), then some services will be home produced and others purchased on the market, just as predicted by the setup with imperfect substitutability between home and market bundles.

$$q_i^M = \min\left(n^0, \frac{1}{b_M} l^M\right), \tag{4}$$

where l^M is the land used to produce service i on the market, n^0 is effective labor from workers outside the neighborhood, and b_M is the amount of land required to produce a unit of any good on the market. Cost minimization in the market sector implies that the market price is

$$p^M = a + rb_M, \tag{5}$$

where a is the unit cost of outside labor.

Leontief technology serves two purposes. First, it simplifies the analysis, and second, it embodies complementarity in production between labor and land. I impose $b_M < b_H$ to capture the notion that market production of services uses land more efficiently than home production. For example, a household kitchen generally uses space to feed a single family, while a restaurant kitchen may use comparable space to feed hundreds of customers in a day. Likewise, driving oneself to work requires owning space for a car, while using a taxi or ride-sharing service does not.

Consumer Problem. A resident maximizes

$$U = \left(M^{\frac{\sigma-1}{\sigma}} + H^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{6}$$

subject to

$$wt^W = rl^H + p^M M, \tag{7}$$

$$t = t^W + t^H, \tag{8}$$

$$t^H = H, \tag{9}$$

$$l^H = b_H H. \tag{10}$$

Equation (7) is the budget constraint that states that agents supply labor to the tradable sector (located outside their neighborhood) and use the income to purchase land for home production and to purchase local services. Equation (8) is the agent's time constraint, which states that agents allocate their time endowment to working on the market and home production. Equation

(9) is the home-production time constraint, and equation (10) is the home-production land constraint. Combining the constraints and substituting in for the price of home production yields

$$wt = p^M M + p^H H, \tag{11}$$

which simply states that the value of consumers' time is allocated between the effective cost of market purchases and home production.

The consumer's first-order condition can be written as

$$\left(\frac{H}{M}\right)^{\frac{1}{\sigma}} = \frac{a + b_M r}{w + b_H r}, \tag{12}$$

where I have substituted $a + b_M r$ for p_M and $w + b_H r$ for p_H. Differentiation of (12) implies that $d\left(\frac{H}{M}\right)/dr < 0$ if and only if

$$\frac{b_M}{b_H} < \frac{a}{w}. \tag{13}$$

Equations (12) and (13) state that an increase in the price of land r causes substitution toward market purchases when the price of home production p_H increases faster than that of market purchases p_M. This occurs when the relative efficiency of land in market production (b_M is low) exceeds the relative efficiency of local labor in obtinaing market services (a is high relative to w). Intuitively, higher land prices push up the cost of home production more quickly than they push up the price of market production because market production uses land relatively efficiently.

Market-Based Sharing of Land and the Effect of Density. We can close the model by noting that land-market clearing, $L = l_H + l_M$, and the production functions imply a simple expression for the relationship between H and M: $H = (L - b_M M)/b_H$. Substituting for H in the first-order condition (12) yields

$$\left(\frac{L - b_M M}{b_H M}\right)^{\frac{1}{\sigma}} = \frac{a + b_M r}{w + b_H r}. \tag{14}$$

To derive a second equilibrium condition in (M, r)-space, we can substitute for H in the budget constraint (11) and rearrange to obtain

$$wt = \left(\frac{w}{b_H} + r\right) L + \left(a - \frac{b_M}{b_H} w\right) M. \tag{15}$$

Equations (14) and (15) represent the equilibrium.

Equation (14) unambigusouly depicts a positive relationship between r and M and equation (15) depicts a negative relationship when condition (13) holds. Uniqueness of the equilibrium follows from the different slopes of the first-order condition and budget-constraint schedules in (M, r) space. Equilibrium is the intersection of lines (14) and (15) in (M, r)-space.

Proposition 1: Lower density (higher L) is associated with lower land prices, higher home production, and less time devoted to working on the market.

Proof: Density is captured by decreases in the land size L, which unambiguously shifts both curves down (Figure 2). The first-order condition (14) shifts down because L increases the amount of land available for home production, and r must fall (for any given M) to induce the household to want to home-produce more. The budget constraint (15) shifts down because the hosehold can only afford addional land if r falls (holding M fixed). The proof that L is inversely related to r in equilibrium follows immediately from that fact that either shift alone is associated with a fall in the land price r.

The shift toward home production is associated with a decrease in labor supply. To see this, note that the time constraint (8) can be written as $t = t^W + H$, which implies that $dt^W = -dH$. Therefore it suffices for $\frac{dt^W}{dL} < 0$ to demonstrate that $\frac{dH}{dL} > 0$. The land market clearing condition, $L = b_H H + b_M M$, implies that increases in L are associated with increases in H or M or both. The fact that $d(H/M)/dL > 0$ implies that $dH/dL > 0$, which is sufficient for $\frac{dt^W}{dL} < 0$.

■

Intuitively, an increase in the supply of land is associated with a decline in its price. Since home production uses land less efficiently, its price drops by more than does the price of market production, which induces a substitution toward home production. To accommodate the higher input of time into home production, agents must work less on the market.

These strong and clear predictions emerge from a relatively simple framework. A benefit of the current approach with exogenous wages is that it clearly isolates the effect of density on

time use and expenditure conditional on how density relates to productivity or proximity to the city center.

There are, of course, a number of dimensions of reality that could be added to the current framework, including agents with heterogeneous efficiencies in market-based work and home production. For example, higher-wage workers will purchase more on the market, all else equal. One could also incorporate this framework into a Rosen-Roback model in which nominal wages are endogenous to locational differences in amenities and productivities in the tradable and nontradable sectors. In that case, land prices would be jointly determined with local tradable-sector wages.

Other location advantages such as proximity to work could be captured by permitting the time endowment to vary with time required to travel to work. In particular, consider a situation in which all residents choose to work at the CBD (there is no variation in the extensitve margin of labor supply), and the total time available is decreasing the the amount of time spent commuting to work. Then the total time endowment can be rewritten as $t - c$, where c is commuting time. We can examine the effects of changes in c by modifying the budget constraint to incorporate commuting costs:

$$w(t - c) = (r + w)L + (a - b_M w)M. \tag{16}$$

Then the equilibrium is represented by the intersection of equations (14) and (16). It is straightforward to demonstrate that as c falls (and residents are effectively closer to work), land prices, work time, and M/H all rise. With a larger time endowment, residents can afford to work more and therefore have higher incomes, which bids up land prices. As in monocentric city models, proximity to the CBD is associated with higher land prices.

Additional extensions to the model are explored in appendices. Appendix A demonstrates that the model's predictions are robust to permitting resident mobility and spatial equilibrium across regions of different density. Appendix B demonstrates the model's predictions when services are modeled as discreet, satiable wants that can be satisfied through home production or market purchases. The model also incorporates costs of housing and other intermediate inputs into home and market production.

3. Evidence

When examining the data through the lens of the theory (either the baseline model or the model with spatial equilibrium in Appendix A), we are effectively comparing outcomes in a low-density neighborhood with outcomes in a high-density neighborhood. The theory predicts that, among neighborhoods with identical resident characteristics (e.g., home and market productivity, etc.), residents of the denser neighborhoods purchase more goods on the market and home produce less. They also work more and pay higher land prices. Below I examine the empirical support for these predictions. The theory abstracts from a number of additional potential determinants of the outcome variables, so the analysis conditions on available observable respondent characteristics to help isolate the mechanism in the model. For example, information on education and industry helps control for variation in worker productivity. Information on family size helps control for differences in preferences between home and market production that may be driven by household characteristics from which the theory abstracts.

I first explore the predictions with respect to home production and expenditure using data from the ATUS and CEX. I then examine detailed Census data to examine the dependence of work hours and land prices on density.

3.1 Time Use, Expenditure, and Economic Geography.

Here I document that, conditional on observable characteristics, residents of larger, denser regions spend less time on home production and spend more of their income on local services.

Home production and economic geography.

The data on home production is from the 2003–2015 waves of the American Time Use Survey (ATUS). The Bureau of Labor Statistics (BLS), which administers the ATUS, tracks respondents' time use over 24-hour intervals. The BLS categorizes time use into broad categories, including home production, work-related activities, leisure, and purchasing goods and services. The BLS home production category, which I use in this study, consists of time spent on food preparation, home and appliance maintenance, and laundry and other chores.

The most detailed respondent-level geographic data in the ATUS is the Consolidated Metropolitan Statistical Area (CMSA). These metropolitan areas can span metropolitan

statistical areas (MSAs) of varying size and density. The U.S. Census Bureau, which administers the ATUS, provides additional geographic information on the size of the MSA in which residents live and, for respondents who live in a metropolitan area, whether the resident lives in the central city. Table 1 shows the distribution of the ATUS sample by city size (which is defined categorically) and central city status. While the largest MSAs feature the largest share of respondents living in the central city, there is substantial variation in central-city status across MSAs.

Table 2 shows the main results for the dependence of home production on economic geography. MSA size (column 1) and central-city status (column 4) are associated with substantially less time devoted to home production. Residents of large MSAs (central cities) spend 17.5 (24.5) fewer minutes per day on household activities compared to nonmetropolitan counterparts. These estimates are only slightly smaller when conditioning on education (columns 2 and 5), suggesting that the higher proportion of educated workers in urban areas cannot alone explain the geographic variation in home production. The specifications in columns (3) and (6) include a range of additional respondent-level characteristics, including age, marital status, sex, employment status, and MSA fixed effects. Conditionally, residents of large MSAs (central cities) spend 19.0 (16.9) fewer minutes on home production per day. This dependence is larger at the end of the sample period (column 8) than in the early 2000s (column 7).

These estimates are economically substantial, especially considering that the conditional dependence of home production on education falls drastically when including the additional controls. For example, having a bachelor's degree (relative to no high school diploma) is associated with 7.7 fewer home-production minutes per day, while living in a central city (relative to a nonmetropolitan area) is associated with 16.9 fewer minutes per day. Considering the large documented dependence of time use on education (Aguiar and Hurst 2007), the twice-as-large dependence of home production on geography (relative to education) is both substantial and surprising. The welfare implications of geographic differences in home production are also large. Fifteen minutes is 3.13% of an eight-hour workday and 20% of the median number of minutes allocated per day to household activities.

The fact that home production depends more on urban status (central city versus suburbs versus nonurban) than on MSA size suggests that the underlying mechanism relies on more than

agglomeration forces that operate solely at the metropolitan level. In particular, variation in urban status within MSAs predicts time use. The model developed above provides an interpretation of this variation based on density.

What types of activities account for the low home production in urban areas? Table 3 shows the subcategories of home production with the strongest dependence on geography. Urban residents spend less time on food prep and general housework (including laundry), less time on home maintenance, and less time working on cars and appliances. They spend slightly more time on household management, which includes paying bills. Somewhat unsurprisingly, the dependence of housework/food prep on urban status is stronger when limiting the sample to respondents interviewed on weekdays.

Table 4 shows how alternative categories of time depend on geography. Each of the time-use categories in the table is based on the BLS-provided aggregates. The first three categories displayed are combinations of two distinct BLS categories (work and education; leisure and socializing; purchasing goods/services and eating). Unconditionally, urban residents spend more time working, less time on leisure, more time purchasing services, and more time on personal care (including sleeping). When conditioning on respondent-level covariates, only purchasing/eating remains significant. Therefore, while much of the variation in work and leisure can be explained by nongeographic factors, urban status independently predicts lower home production and more time shopping/eating.

Expenditure and economic geography.

The Consumer Expenditure Survey (CEX) provides detailed expenditure data for respondents across the U.S. along with some information on the size of the respondent's Primary Sampling Unit (PSU). PSUs are groups of counties that correspond to MSAs when the population of the PSU exceeds 1.5 million. For approximately half of the sample, the CEX provides information on the exact MSA, and in the case of residents of the New York Metropolitan Statistical Area, the CEX distinguishes between residents of New York City (NYC) and residents of suburbs of NYC.

I classify laundromats, restaurants, taxis, and public transportation as local services that have strong home-production substitutes. Laundromat and restaurant services are clear

substitutes for doing laundry and cooking at home. Taxis (or ride-share services such as Uber) and public transportation are substitutes for self-driving.

Table 5 shows that service expenditure shares are 2.0 percentage points higher in large cities (PSUs with more than 4 million residents), which is 23% of the average expenditure share in nonlarge PSUs (column 1). The estimate is nearly identical when conditioning on individual characteristics, which include age, race, sex, education, marital status, and employment status (column 2). Column 3 shows that the estimates fall slightly when dropping NYC from the sample, but that service expenditure shares remain high in large cities (excluding NYC) compared to nonlarge cities.

The fact that the CEX provides information on whether respondents from the New York area live in NYC or the New Jersey/Connecticut suburbs allows us to shed some light on whether higher expenditure shares in large cities are due to an MSA-wide phenomenon or whether there is variation in expenditure shares within MSAs. Column 4 shows that conditional expenditure shares are substantially higher (6 percentage points) in NYC than are expenditure shares elsewhere, including the NYC suburbs. Therefore, within metropolitan areas, service expenditure shares are higher in denser areas. Columns 5 through 8 demonstrate that the dependence of total quarterly expenditure on economic geography is similar to the dependence of expenditure shares. Each of the different categories of local services contributes to the higher expenditure shares in large, dense cities. Table 6 shows that conditional expenditure shares on laundry services, restaurants, and transportation services are higher in big cities, and even higher in NYC.

3.2. Evidence on Labor Supply and Land Prices from U.S. Census

Here I examine detailed Census data evidence to explore the theory's predictions with respect to labor supply and land prices. The richness of the data allows me to include controls that help condition on variation in work hours and land prices that are driven by existing theoretical mechanisms. The theory predicts that, conditional on these standard mechanisms (e.g., productivity and proximity to the CBD), denser areas should feature higher work hours and potentially higher land prices.

The 2000 U.S. Census provides data on respondents' hours worked, as well as location of residence and location of work at the Public Use Microdata Area (PUMA) level. To be classified

as a PUMA, a geographical region must contain at least 100,000 people. Therefore, the Census data identify location of work and residence within a small area of land for respondents living in dense areas.

The detailed geographic information in the U.S. Census allows a precise measure of proximity between respondents and service establishments, and the detailed respondent-level data help control for factors that are associated with traditional determinants of agglomeration and labor supply, including occupation, wage, and proximity to work. This detailed demographic information allows me to compare the labor supply of observationally similar workers who live in neighborhoods of different density. Importantly, the data permit controlling for a number of potential determinants of work hours, including occupation, wages, age, and proximity to work.

Measures of density are based on the number of service establishments per square mile. The Zip Code Business Patterns dataset at the U.S. Census provides the number of establishments within a zip code by NAICS industry definition. I match zip codes to locations (central cities of metro areas or PUMAs) using the geocorr2k software maintained by the Missouri Census Data Center, and I total the number of service establishments in a location to construct a measure of establishment density for each location. Measures of service-establishment density are highly correlated with population-based measures.

My definition of service establishments includes those services for which consumers can produce at home or on the market. Specifically, I classify all restaurants, laundromats, convenience stores, and fruit, fish, meat, and vegetable markets as service establishments.[4] The results presented below are robust to alternative classifications that include a broader range of service establishments, since high-density areas tend to have high concentrations of all types of service establishments.

Density Classifications. I allow for a categorical dependence of outcomes on density by classifying PUMAs as highest, high, medium, and low density. As Table 7 demonstrates, there are distinct differences in density across the groups. The highest-density neighborhoods are primarily in Manhattan and San Francisco. High-density neighborhoods are in New York,

[4] The data identifies industries at the detailed NAICS 6 level. I include food markets under the assumption that they provide food-storage services for consumers. Urban consumers visit food markets more frequently and store less food at home, while suburban consumers visit grocery stores infrequently but purchase more for storage in each visit. Hence urban consumers effectively share the land used by food markets for storage.

Philadelphia, and San Francisco. Medium-density PUMAs are located in New York; San Francisco; Boston; Chicago; Washington, DC; and Los Angeles. Figure 3 shows the geographic layout of these PUMAs in the NYC metropolitan area.

3.2.1. U.S. Census Empirical Tests

Dependence of Work Hours on Density. Table 8 shows that living in highest-density (high-density) PUMAs is unconditionally associated with 3.56 additional hours per week relative to living in low-density areas (column 1). Of course, the higher work hours may be associated with a host of factors other than density. For example, highly productive individuals who work long hours may select into dense areas. To help condition on alternative factors, column 2 includes a rich set of controls that proxy for individual productivity and other determinants of time use, including education, wage, transportation time to work, PUMA of work, occupation, age, and marital status. Including wage in the regression limits the sample to individuals who are currently employed. The work-PUMA fixed effects help absorb agglomeration forces that may affect worker productivity.

The thought experiment when introducing these controls is that we are comparing observationally equivalent individuals (in terms of productivity, occupation, and proximity to work) who differ in the density of their residential neighborhood. According to column 2, there remains a strong dependence of work hours on density (3.6 and 2.0 additional hours per week in highest- and high-density areas). One may wonder whether family-related factors that are not captured in the controls could account for higher work hours. Column 3 limits the sample to single individuals with no kids, thus ensuring that the results are not driven by concerns over school quality or the desire to share durables among family members for home production. The results are very similar. Therefore, additional factors can explain some but not most of the dependence of time use on economic geography.

One possibility for high work hours in dense areas is the rat-race effect among professional workers whereby proximity to peer workers causes more work effort. Rosenthal and Strange (2008) postulate that the rat-race effect operates through proximity to workers in similar occupations and demonstrate that the rat race is particularly evident among high-paid professionals such as lawyers. Part of the rat-race effect on hours in Table 8 is captured by

occupation, wage, and work-PUMA controls. To further isolate the residential-density effect from the rat-race effect in the data, column 4 excludes finance and legal professionals from the sample. The estimates are of similar magnitudes, suggesting a role for neighborhood density in determining work hours beyond the rat-race effect of proximity to peer employees.

Dependence of Land Prices on Density. High land prices in dense areas may arise for a number of reasons, including agglomeration-based productivity, proximity to the CBD, and amenities (e.g., Roback 1982, Mills 1967, Muth 1969). Consistent with agglomeration-based theories of land price determination, empirical work has documented higher land prices in larger, denser cities (e.g., Colwell and Munneke 1997; Davis and Palumbo 2008; Combes, Duranton , and Gobillon 2016; Albouy, Ehrlich, and Shin 2017). The theory developed above implies that the efficient use of land in dense areas through market-based sharing can also contribute to high land prices. Here I present suggestive evidence that is consistent with the theory's implication. The analysis does not condition on all alternative causes of high land prices (for example, some local services may be amenities rather than simply substitutes for home production). Rather, it conditions on the obvious alternatives permitted by the data. Hence the results should be interpreted as suggestive support for the theory.

The data and sample are the same as in the test for labor supply. A key feature of the data is that it includes respondents' PUMA of work, which controls for a number of determinants of land prices, including agglomeration forces that operate within the location where residents work. The information on transportation time to work also controls for land value based on residents' proximity to work (Mills 1967; Lucas and Rossi-Hansberg 2002). The information on land prices is based on housing cost residuals. Following Albouy (2012), I obtain the housing-cost differential for individual j using a regression of gross rents, r_j, on controls (Y_j) for size, rooms, commercial use, kitchen and plumbing facilities, age of building, home ownership, and the number of residents per room.

$$\log(r_j) = Y_j\beta + \epsilon_j. \tag{17}$$

Rents for homeowners are imputed using a discount rate of 7.85% (Peiser and Smith 1985). The residuals ϵ_j are the rent differentials that represent the amount individual j pays for her apartment/home relative to the average cost of a similar apartment/home in the NYC metro area.

I estimate the dependence of rent differentials on indicators of urban density using the following specification:

$$\epsilon_j = \alpha + \gamma_1 Density + X_j\gamma + e_j,$$

where X_j is a vector of individual-specific controls, including the log of the number of minutes spent traveling to work and work-PUMA fixed effects. Table 9 shows that rent residuals are unconditionally increasing in density (column 1). The same pattern holds when conditioning on location benefits such as proximity to work and work-PUMA fixed effects (column 2), respondent demographics (column 3), and wage and occupation (column 4). Columns (5) and (6) show that these results are robust to assuming a log-linear, rather than categorical, dependence on residential PUMA establishment density.

Overview and discussion of Census evidence. The empirical analysis focuses on the United States due to data availability. However, the theory is likely to be relevant to the many cities in other countries that are far denser and that are home to a large portion of the world's population.

The detail in the Census data helps control for factors that are traditionally associated with labor supply and land prices across regions. However, without a source of exogenous, independent variation in density, the analysis here cannot entirely rule out alternative explanations for high conditional labor supply and land prices in dense neighborhoods.
Here I briefly discuss some alternative possible forces and implications for interpretations of the data.

One possibility is that hardworking employees have preferences for dense neighborhoods containing laundromats and other services that substitute for home production. While unobserved preferences for work and density could explain patterns of expenditure and time use, it is less clear how such an explanation alone could account for high land prices in dense areas. The denser areas would need to be more expensive because the residents have higher income (and hence bid up land prices) or because the dense areas are valuable for additional reasons such as amenities or proximity to the CBD. The land-price regressions show that land prices are higher in dense areas even conditional on resident income, occupation, proximity to work, and location of work. Hence there appears to be an additional factor causing high land prices in dense areas even if dense neighborhoods are populated by residents with preferences for hard work and

density. The baseline model provides one interpretation of this additional variation in land prices that can also account for the variation in expenditure and time use.

An alternative leading candidate for the theory's key predictions is heterogeneity in locations' productive endowments. If highly productive locations attract high-income, hardworking employees, then it is the location's endowments, rather than land scarcity, that is the causal force behind variation in hours and work effort. The empirical specifications help control for this through metropolitan fixed effects (in the case of the time-use data) and work-PUMA fixed effects (in the case of Census data). Indeed, the dependence of hours and land prices on density falls when conditioning on work-PUMA fixed effects, consistent with traditional theories of agglomeration. However, there remains an economically and statistically significant dependence of land prices and work hours even after including the fixed effects. The theory provides a lens through which to understand this strong and otherwise unexplained variation in the data while also rationalizing the patterns with respect to home production and expenditure in Section 3.1.

4. Conclusion

This paper presents a new microfoundation for residential neighborhood agglomeration. Urban residents share land by purchasing services on the market that their suburban counterparts produce at home. In this paper's analysis, urban residential areas are dense economic regions in which the most efficient manner for consumers to satisfy their wants is for firms to provide services for consumers to purchase. Suburban areas are sparsely populated economic regions in which consumers most efficiently satisfy their wants by producing them at home.

A model incorporating this mechanism predicts that residents of denser neighborhoods home produce less, spend more on local services, work more, and face higher land prices. Empricial evidence from a range of data sources demonstrates support for these predictions, even conditional on a host of factors associated with traditional forces of agglomeration and variation in time use and land prices.

Despite the somewhat intuitive nature of the empirical and theoretical results presented here, this paper is the first to explicitly model the density-dependent tradeoff between home and market production and its implications for market prices and quantities. The theory can be

extended to incorporate additional important features of urban economies, including differences in amenities, productivity, and proximity to the CBD. The mechanisms highlighted here are likely to be particularly relevant for welfare analysis and structural estimation of models of economic geography.

The substitution toward market production in dense areas has a number of implications for additional areas of inquiry. From a public-policy perspective, it is important that consumers and service establishments are able to collocate within localized areas in order to generate the benefits of sharing factor inputs. The home-production margin may also be relevant for understanding regional differences in business cycles and for understanding the interactions between household size and urbanization.

References

Aguiar, Mark and Erik Hurst. 2005. "Consumption versus Expenditure." *Journal of Political Economy*, 113: 919-948.

Ahlfeldt, Gabriel M. "Urbanity." LSE. Mimeo.

Albouy, David. 2012. "Are Big Cities Bad Places to Live? Estimating Quality-of-Life across Metropolitan Areas." University of Michigan.

Albouy, David, Gabriel Ehrlich, and Minchul Shin. "Metropolitan Land Values," forthcoming, *Review of Economics and Statistics.*

Benhabib, Jess, Richard Rogerson, and Randall Wright. 1991. "Homework in Macroeconomics: Household Production and Aggregate Fluctuations." *Journal of Political Economy*, 99(6): 1166-1187.

Becker, Gary. 1965. "A Theory of the Allocation of Time." *The Economic Journal* 75(299): 493-517.

Black, Dan A., Natalia Kolesnikova, and Lowell J. Taylor. 2014. "Why do so few women work in New York (and so many in Minneapolis)? Labor supply of married women across U.S. cities." *Journal of Urban Economics* 79:59-71.

Broda, Christian, Ephraim Leibtag, and David E. Weinstein. 2009. “The Role of Prices in Measuring the Poor’s Living Standards.” *Journal of Economic Perspectives* 23: 77-97.

Brooks, Leah and Byron Lutz. 2014. “Vestiges of Transit: Urban Persistence at the Micro Scale.” Mimeo.

Buchanan, James M. 1965. “An Economic Theory of Clubs.” *Economica* 32(125):1-14.

Buera, J. and J. Kaboski. 2012. “The Rise of the Service Economy.” *American Economic Review* 102: 2540-2569.

Combes, Pierre-Philippe, Gilles Duranton, and Laurent Gobillon. 2016. “The Costs of Agglomeration: Land Prices in French Cities." Mimeo

Colwell , Peter F. and Henry J. Munneke. 1997. “The structure of urban land prices.” *Journal of Urban Economics*, 41(3):321–336, 1997.

Couture, Victor. 2014. “Valuing the Consumption Benefits of Urban Density.” UC Berkeley Mimeo.

Davis, Morris A. and Michael G. Palumbo. 2008. “The Price of Residential Land in Large US Cities.” *Journal of Urban Economics*, 63(1):352–384, 2008

Duranton, Gilles and Diego Puga. 2004. “Micro-Foundations of Urban Agglomeration Economies,” in J. V. Henderson and J. F. Thisse (eds.), *Handbook of Regional and Urban Economics* 4. Amsterdam and New York: North Holland, 2063–2117.

George, Lisa and Joel Waldfogel. 2003. “Who Affects Whom in Daily Newspaper Markets?” *Journal of Political Economy*, 111(4): 765-784.

Ghez, Gilbert and Gary S. Becker. 1975. *The Allocation of Time and Goods over the Life Cycle.* New York: Columbia University Press.

Glasaer, Edward L., Jed Kolko, and Albert Saez. 2001. “Consumer City.” *Journal of Economic Geography* 1: 27-50.

Gollin, Douglad, Rémi Jedwab, and Dietrich Vollrath. 2016. “Urbanization with and without Industrialization.” *Journal of Economic Growth* 21:35-70.

Handbury, Jessie. 2013. "Are Poor Cities Cheap for Everyone? Non-Homotheticity and the Cost of Living Across U.S. Cities." Mimeo.

Lancaster, Kelvin J .1966. "A New Approach to Consumer Theory." *Journal of Political Economy* 74(2): 132-157.

Lucas, Robert E., Jr. and Esteban Rossi-Hansberg. 2002. "On the Internal Structure of Cities." *Econometrica* 70(4):1445–1476.

Mills, Edwin S. 1967. "An Aggregative Model of Resource Allocation in a Metropolitan Area." *American Economic Review* 57(2): 197-210.

Moretti, Enrico. 2013. "Real Wage Inequality." *American Economic Journal: Applied Economics* 5(1): 65-103.

Muth, Richard F. 1969. "*Cities and Housing: the Spatial Pattern of Urban Residential Land Use*." University of Chicago Press.

Peiser, Richard B. and Lawrence B. Smith. 1985. "Homeownership Returns, Tenure Choice and Inflation." *American Real Estate and Urban Economics Journal* 13: 343-60.

Roback, Jennifer. 1982. "Wages, Rents, and the Quality of Life." *Journal of Political Economy* 90: 1257-1278.

Rogerson, Richard. 2008. "Structural Transformation and the Deterioration of European Labor Market Outcomes." *Journal of Political Economy* 116(2): 235-259.

Rosenthal, Stuart, and William Strange. 2008. "Agglomeration and Hours Worked." *Review of Economics and Statistics* 90(1): 105–118.

Ruggles, S. J., T. Alexander, K. Genadek, R. Goeken, M. Schroeder, and M. Sobek. 2010. "Integrated Public Use Microdata Series: Version 5.0." University of Minnesota.

Turner, Matthew A. 2007. "A Simple Theory of Smart Growth and Sprawl." *Journal of Urban Economics* 61:21-44.

Appendix A. Resident Mobility and Spatial Equilibrium

The baseline model restricts resident mobility. Here I extend the model to permit mobility across different neighborhoods. The objective is to demonstrate that the predictions of the baseline model are robust to setups with alternative causes of neighborhood density. The particular force behind density in the sorting model is zoning, which has been shown empirically to affect intra-city density patterns (Brooks and Lutz 2014). The model's neighborhoods are identical in terms of land size, proximity to residents' work location, and productivity. In the absence of zoning restrictions or other differences, neighborhoods feature identical densities. If a subset of neighborhoods restricts the amount of land that can be used by service establishments (relative to the efficient level across all neighborhoods), then the restricted neighborhoods will be less dense.

The effect of density in the model with mobility operates through the same mechanisms as density in the model above. The region with higher density must use land more efficiently. Since market production uses land more efficiently, denser regions must feature higher market production than the lense dense region in order to equalize utilities across regions. The price difference that mediates this relative substitution toward market purchases is higher land prices in the dense region. Furthermore, residents of the dense region work more because they are home producing less and because they need higher income to afford the additional market expenditures.

Spatial Equilibrium Model. Consider a geography in which N identical residents live in residential locations indexed by $j \in \{1,2, \ldots J\}$. Locations each have land size L and are equidistant from residents' work location, where each resident earns the exogenous wage w. Production technologies and consumer utility are as specified in the baseline model.

Spatial equilibrium requires that utility is the same across neighborhoods. In particular,

$$\left(M_i^{\frac{\sigma-1}{\sigma}} + H_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} = \left(M_j^{\frac{\sigma-1}{\sigma}} + H_j^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{18}$$

for any pair of neighborhoods i, j. The time and budget constraints for a resident of neighborhood j are

$$t = t_j^W + H_j. \tag{19}$$

and

$$wt_j^W = r_j H_j + p_j M_j, \tag{20}$$

where the subscript identifies the resident's neighborhood. The land-market-clearing condition is a slight modification from the model above to account for the endogenous number of residents N_j in neighborhood j:

$$L = N_j\left(b_H H_j + b_M M_j\right). \tag{21}$$

The total number of residents across neighborhoods must equal the total number of potential residents: $\sum_j N_j = N$.

Equilibrium: The consumer's first-order condition is the same as above,

$$\left(\frac{H_j}{M_j}\right)^{\frac{1}{\sigma}} = \frac{a + b_M r_j}{w + b_H r_j}, \tag{22}$$

(after substituting for prices), which implies that H_j/M_j is falling in the land price when condition (13) is satisfied. Due to the symmetry across neighborhood locations, the equilibrium conditions are satisfied when density and all other variables are identical across locations. Denote by $\bar{M}$ the level of market production that prevails across neighborhoods in the symmetric equilibrium and the amount of land allocated to market establishments as $\bar{l}^M = b_M \bar{M}$.

Now consider a situation in which a subset of neighborhoods restricts the amount of land to be no greater than $l_R^M < \bar{l}^M$, which effectively restricts market production to be no greater than $M_R = l_R^M / b_M < \bar{M}$. Let subscripts R and U denote zoning-restricted and zoning-unrestricted neighborhoods.

Proposition A1: When land is sufficiently efficient in the market sector, the unrestricted neighborhoods are denser and feature higher land prices. Their residents have higher market-based expenditure and spend less time on home production.

Proof: By the nature of being unrestricted, we have that $M_R < M_U$. By spatial equilibrium, it must be the case that $H_R > H_U$, which implies that $\frac{H_R}{M_R} > \frac{H_U}{M_U}$. Under condition (13), M_j/H_j is falling in the land price, so it follows that $r_R < r_U$. To show that the unrestricted areas are denser, note that the spatial equilibrium condition can be linearized around the symmetric equilibrium to yield

$$dH_R - dH_U = -(dM_R - dM_U)\left(\frac{H}{M}\right)^{\frac{1}{\sigma}}, \tag{23}$$

where H and M are symmetric equilibrium values of home and market production. Land-market clearing, $L = N_R(b_H H_R + b_M M_R) = N_U(b_H H_U + b_M M_U)$, can be linearized to yield

$$b_H(dH_R - dH_U) + b_M[dM_R - dM_U] = (dN_U - dN_R)\frac{(b_H H + b_M M)}{N}. \qquad (24)$$

Since all migration inflows to and from restricted neighborhoods equals migration outflow to and from unrestricted neighborhoods, we have that $dN_U = -dN_R$. Substituting this migration equation into (24) and substituting (23) for $dH_R - dH_U$ in (24) yields

$$(dM_R - dM_U)\left[b_M - b_H\left(\frac{H}{M}\right)^{\frac{1}{\sigma}}\right] = 2dN_U\frac{(b_H H + b_M M)}{N},$$

which states that a relative fall in market production in the restricted neighborhood is associated with an increase in the number of residents in the unrestricted neighborhood if and only if

$$\frac{b_M}{b_H} < \left(\frac{H}{M}\right)^{\frac{1}{\sigma}}.$$

By substituting in the first-order condition (22) for H/M, it is straightforward to show that this condition is equivalent to condition (13). ■

Furthermore, residents of dense areas spend more time at work. Intuitively, since residents of dense neighborhoods have higher expenditure, they need higher incomes. Since wages are identical across residents, the only way to obtain higher incomes is to work more.

Proposition A2: Residents of unrestricted dense neighborhoods spend more time at work.

Proof: Totally differentiate the budget constraint for neighborhoods of type $j \in \{R, U\}$:

$$wdt_j^W = b_H r dH_j + (a + b_M r)dM_j + Ldr_j.$$

Let $dX = dX_R - dX_U$ for any variable X. Then subtracting the linearized budget constraint for restricted neighborhoods from the constraint for unrestricted neighborhoods yields

$$wdt^W = b_H r dH + (a + b_M r)dM + Ldr.$$

Substitute the linearized spatial equilibrium condition (23), which can be written as $dH = -dM\left(\frac{H}{M}\right)^{\frac{1}{\sigma}}$ for dH in the linearized budget constraint to yield

$$wdt^W = \left[a + b_M r - b_H r_j \left(\frac{H}{M}\right)^{\frac{1}{\sigma}}\right] dM + Ldr.$$

Finally substitute the first-order condition for $\left(\frac{H}{M}\right)^{\frac{1}{\sigma}}$ and rearrange to obtain $wdt^W = w\left[\frac{a+b_M r}{w+b_H r}\right] dM + Ldr$. Since $dM > 0$ and $dr > 0$, it follows that $dt^w > 0$ ■

Appendix B: Model with Discreet, Satiable Wants.

Here I present an alternative model setup in which residents have utility over discreet wants that can be satisfied through market purchases or home production (rather than utility over bundles of home and market-produced goods). One benefit of this alternative setup is that it is straightforward to introduce heterogeneity in service land or labor requirement. For example, preparing a snack requires little time and is therefore more likely to be home produced than cooking a large meal, which requires more time input by households. This setup clearly demonstrates that marginal services will switch from being home produced to purchased on the market as neighborhood density increases. I also extend the model to incorporate costs of building materials and other intermediates into the production of services.

As in the baseline setup, Land L is a fixed quantity in the neighborhood. Residents use their income to purchase land (for housing services/home production) and market-based services from establishments located in the neighborhood. For simplicity, rents from land are assumed to accrue to agents outside of the city. Service establishments use labor from workers outside the neighborhood to produce local services (in addition to land). The unit labor cost of market-based services is exogenous, although identical comparative statics hold when residents also supply labor to service establishments.

To incorporate intermediate inputs (such as housing or building material) into production I build on the insights in Lancaster (1966) that materials and other inputs are not direct objects of utility themselves, but rather are intermediary inputs into the production of services that ultimately provide utility. Consider an extension of the Leontief production functions of home and market-produced services to include imported intermediates. Then modified prices are

$$p_M = a + b_M r + d_M, \qquad p_H = w + b_H r + d_H,$$

where d_M and d_H are unit costs of the intermediates in market and home production, respectively.

Residents have utility over discrete, satiable wants indexed by $i \in \mathbb{R}^+$. Each want is associated with a service that can be home produced or purchased on the market:

$$U = \int_0^\infty [q^M(i) + q^H(i)]di. \tag{25}$$

$q^M(i)$: $\mathbb{R}^+ \to \{0,1\}$ indicates whether want i is satisfied on the market, and $q^H(i)$: $\mathbb{R}^+ \to \{0,1\}$ indicates whether the want is satisfied through home production. The discrete nature of consumption simplifies the analysis and maintains the focus of the model on whether a given service is purchased on the market or produced at home (rather than on relative quantities).

Consumer Problem. A representative agent maximizes (25) subject to

$$wt^M = \int_0^\infty d_H q^H(i)di + rl^H + \int_0^\infty p_i q^M(i)di, \tag{26}$$

$$t = t^W + t^H, \tag{27}$$

$$t^H = \int_0^\infty a_i q^H(i)di, \tag{28}$$

$$l^H = \int_0^\infty b_H q^H(i)di. \tag{29}$$

Equation (26) is the budget constraint. Equation (27) is the agent's time constraint, which states that agents allocate their time endowment to working on the market, traveling to obtain services within their neighborhood, and home production. Equation (28) is the home-production time constraint, and equation (29) is the home-production land constraint.

Model Solution. The consumer's first order conditions yield the necessary conditions for consumption of service i through market purchase and home production, respectively:

$$1 \geq \lambda p_i, \tag{30}$$

$$1 \geq \lambda[wa_i + rb_H + d_H], \tag{31}$$

where λ is the multiplier on the budget constraint. Service i is purchased on the market if and only if equation (30) holds and if the cost of home production, $wa_i + rb_H + d_H$, exceeds the total cost of purchasing on the market, p_i,which can be equivalently written as

$$p_i \leq wa_i + rb_H + d_H.^{5} \tag{32}$$

The market price of each service is based on cost minimization by competitive firms:

$$p_i = wa_M + rb_M + d_M. \tag{33}$$

Substituting (33) into (30) and (31) implies the following:

Proposition B1: Service i is purchased on the market if and only if equation (30) holds and if the cost of market purchase is less than the cost of home production,

$$wa_i + rb_H + d_H > wa_M + rb_M + d_M. \tag{34}$$

It is home produced if and only if equation (31) holds and

$$wa_i + rb_H + d_H < wa_M + rb_M + d_M. \tag{35}$$

To explicitly solve for the services that are produced at home, assume that time costs of home production are uniformly distributed over $\mathbb{R}^+$ so that the home labor requirement of a service is equal to its index: $a_i = i \ \forall \ i \in \mathbb{R}^+$. Substituting into equations (34) and (35) implies that the necessary condition for market production is

$$i \geq \frac{a_M}{w} - \frac{r}{w}(b_H - b_M) - (d_H - d_M), \tag{36}$$

and the necessary condition for home production is

$$i < \frac{a_M}{w} - \frac{r}{w}(b_H - b_M) - (d_H - d_M). \tag{37}$$

Condition (37) is also a sufficient condition for home production because any service that satisfies equation (37) also satisfies (30) and (31). ■

Let H denote the mass of services that are produced at home and M denote the mass of services that are purchased on the market. Then

[5] Equation (32) captures the familiar notion of the opportunity cost of time emphasized in Becker (1965). For example, a minimum-wage worker will launder his own clothes because the value of time required to do so is less than the market price of laundry services. If the worker's wage increases so that the value of his time exceeds the market price of laundry services, he will instead purchase the service on the market.

$$H = \int_0^{a_M - \frac{r}{w}(b_H - b_M) - (d_H - d_M)} di = a_M - \frac{r}{w}(b_H - b_M) - (d_H - d_M), \qquad (38)$$

and

$$M = \int_{a_M - \frac{r}{w}(b_H - b_M) - (d_H - d_M)}^{\bar{\imath}} di = \bar{\imath} - H, \qquad (39)$$

where $\bar{\imath}$ is the highest index of the services $i \in [0, \bar{\imath}]$ that are consumed in equilibrium.

Given H and M and the Leontief nature of the production technology, we can determine the allocation of land across market and home production:

$$l^M = b_M M, \qquad l^H = b_H H. \qquad (40)$$

The allocation of time to home production is

$$t^H = \frac{1}{2} H^2. \qquad (41)$$

In (41), time devoted to home production is derived from $t^H = \int_0^H i di$, where H is equal to the upper limit on the index of home-produced services.

The equilibrium can be characterized by four equations that solve for t^W:

$$w t^W = (b_H r + d_H) H + (a + b_M r + d_M) M, \qquad (42)$$

$$t = t^W + \frac{1}{2} H^2, \qquad (43)$$

$$H = \frac{a_M}{w} - \frac{r}{w}(b_H - b_M) - (d_H - d_M), \qquad (44)$$

$$L = b_H H + b_M M. \qquad (45)$$

Total differentiation of these equations yields identical comparative statics as in the baseline model. Decreases in L (increases in density) are associated with increases in $M/H, t^w$, and r.

Figure 2: Effect of an increase in land size in baseline model.

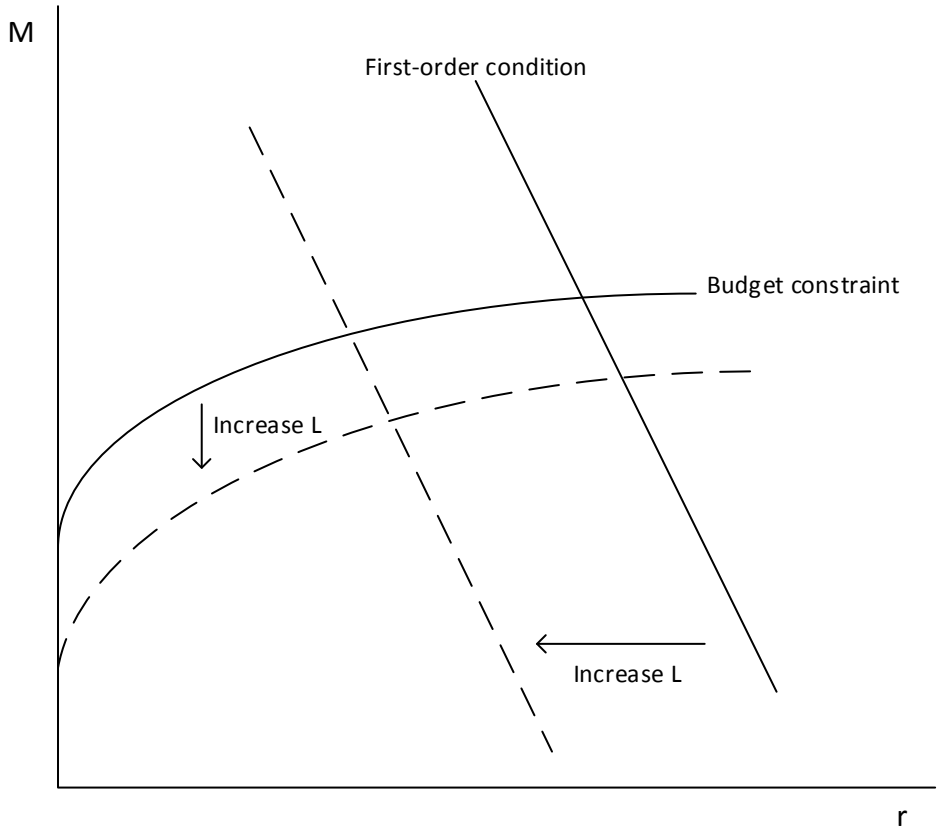

M
First-order condition
Budget constraint
Increase L
Increase L
r

Figure 3: NYC Metro Area PUMAs by Service-Establishment Density

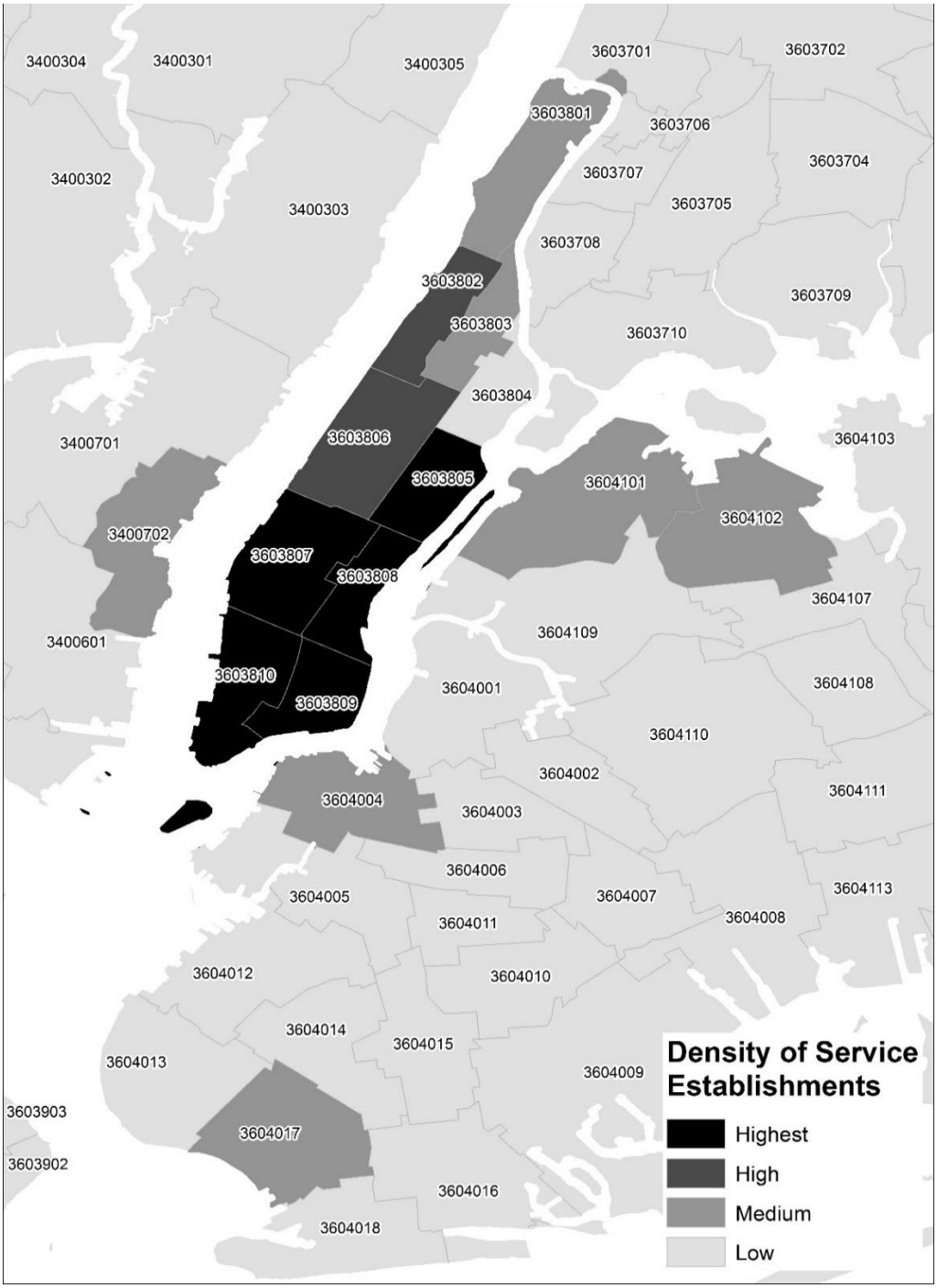


Table 1: Percent of respondents living in central city, by MSA size

MSA Size	Not Identified or Nonmetropolitan	Metropolitan, balance of MSA	Metropolitan, Central City	Total
Not Identified or Nonmetropolitan	83.81	15.7	0.49	100
100,000 - 999,999	0	75.46	24.54	100
1 million - 5 million	0	66.97	33.03	100
5 million +	0	56.15	43.85	100
Total	17.18	57.21	25.61	100

Note: The data are based on the 2003-2015 waves of the American Time Use Survey.

Table 2-Dependence of Home Production on MSA Size and Central City Status

Dependent Variable: Minutes spent per day on home production							Year<2006	Year>2010
regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MSA population								
(Not identified or nonmetro omitted)								
100,000 - 999,999	-7.89***	-6.59***	-6.36***					
	(1.63)	(1.64)	(0.29)					
1 million - 5 million	-13.43***	-11.15***	-10.12***					
	(1.53)	(1.55)	(0.46)					
5 million +	-17.45***	-15.64***	-19.04***					
	(1.78)	(1.80)	(1.59)					
Central City / Suburban status								
(Not identified or nonmetro omitted)								
Suburbs (balance of MSA)				-10.02***	-7.95***	-8.15***	-8.07***	-7.12***
				(1.57)	(1.59)	(0.24)	(0.75)	(0.51)
Central City				-24.54***	-22.76***	-16.94***	-14.49***	-18.60***
				(1.70)	(1.72)	(0.49)	(1.45)	(0.82)
Education								
(No high school diploma omitted)								
High School graduate		-11.05***	-0.75		-12.16***	-1.07	-1.15	-2.21
		(2.30)	(1.20)		(2.30)	(1.19)	(2.55)	(2.69)
Some College		-14.62***	-3.17*		-15.48***	-3.34*	-1.80	-4.84*
		(2.24)	(1.78)		(2.24)	(1.85)	(3.16)	(2.72)
Bachelors Degree		-22.80***	-7.70***		-23.60***	-7.77***	-5.44**	-9.82***
		(2.15)	(1.20)		(2.15)	(1.22)	(2.59)	(2.49)
Controls	NO	NO	YES	NO	NO	YES	YES	YES
N	111251	111251	111251	111251	111251	111251	31802	37180
R2	0.00	0.00	0.11	0.00	0.01	0.11	0.12	0.11

Note: Data from the 2003-2015 waves of the ATUS. Controls include age, sex, race, marital status, employment status, aned MSA fixed effects. All regressions are population weighted. The sample is limited to respondents between the ages of 25 and 60. Standard Errors in parentheses. *** indicates significance at the .1% level.

Table 3-Home Production Categories and Urban Geography

					Sample limited to weekdays			
Dependent Variable:	Food prep and housework	Interior and exterior maintenance	Maintenance of appliances and vehicles	Household management	Food prep and housework	Interior and exterior maintenance	Maintenance of appliances and vehicles	Household management
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Central City / Suburban status								
(Not identified or nonmetro omitted)								
Suburbs (balance of MSA)	-0.51	-4.61***	-1.17***	0.96***	-1.43	-6.14***	-0.54	1.12**
	(1.05)	(0.86)	(0.39)	(0.36)	(1.32)	(1.05)	(0.46)	(0.45)
Central City	-2.42*,	-10.03***	-2.15***	1.28***	-3.68*,	-10.44***	-1.38***	1.07**
	(1.20)	(0.90)	(0.38)	(0.40)	(1.50)	(1.09)	(0.43)	(0.49)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
N	111251	111251	111251	111251	55187	55187	55187	55187
R2	0.18	0.03	0.01	0.02	0.23	0.03	0.01	0.02

Note: Data from the 2003-2015 waves of the ATUS. Controls include education age, sex, race, marital status, and employment status. The sample is limited to respondents between the ages of 25 and 60. All regressions are population weighted. Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4-Time Use Categories and Urban Geography

Dependent Variable:	Work and Education	Work and Education	Leisure and Socializing	Leisure and Socializing	Purchasing and Eating	Purchasing and Eating	Personal Care	Personal Care	Other	Other
	(1)	(2)	(3)	(4)	(4)	(5)	(6)	(7)	(8)	(9)
Central City / Suburban status										
(Not identified or nonmetro omitted)										
Suburbs (balance of MSA)	16.22***	2.56	-16.56**	-4.18*	8.30***	5.23***	-4.56***	-1.69	1.79***	1.14*
	(3.26)	(2.67)	(2.33)	(2.16)	(1.10)	(1.10)	(1.54)	(1.51)	(0.59)	(0.59)
Central City	10.81***	0.18	-7.85***	-0.32	9.49***	8.77***	7.34***	2.01	4.14***	2.91***
	(3.67)	(3.13)	(2.64)	(2.52)	(1.26)	(1.27)	(1.76)	(1.76)	(0.71)	(0.72)
Controls	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
N	111251	111251	111251	111251	111251	111251	111251	111251	111251	111251
R2	0.00	0.26	0.00	0.13	0.00	0.02	0.00	0.06	0.00	0.02

Note: Data from the 2003-2015 waves of the ATUS. Controls include education, age, sex, race, marital status, and employment status. The sample is limited to respondents between the ages of 25 and 60. All regressions are population weighted. Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5-Expenditure on Local Services

Dependent Variable:	Expenditure share on local services				Total expenditure on local services			
			Exclude NYC				Exclude NYC	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Large City (population of PSU> 4 million)	0.020***	0.018***	0.013***		276.1***	249.0***	230.2***	
	(0.002)	(0.002)	(0.002)		(10.0)	(9.9)	(10.0)	
Suburbs of NYC				0.017***				336.2***
				(0.004)				(21.6)
New York City				0.066***				381.6***
				(0.005)				(27.8)
Constant	0.087***	0.130***	0.126***	0.132***	482.0***	267.7***	254.8***	310.8***
	(0.001)	(0.004)	(0.004)	(0.004)	(5.7)	(24.3)	(24.4)	(24.4)
Controls	NO	YES	YES	YES	NO	YES	YES	YES
N	20510	20510	19878	20510	20510	20510	19878	20510
R2	0.01	0.04	0.04	0.05	0.04	0.10	0.10	0.09

Note: Data are from the 2010 Consumer Expenditure Survey. Population Sampling Units with more than 4 million people are classified as large cities. 37% of respondents live in large cities. Local services include laundry, restaurants, taxis, and public transportation. Columns 5 through 8 show quarterly expenditure. Controls include age, race, sex, marital status, and employment status. The sample is limited to respondents between the ages of 25 and 60. All regressions are population weighted. Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6: Components of Expenditure

	Expenditure Share				
	All local services (1)	Laundry (2)	Restaurants (3)	Bus/Train (4)	Taxi (5)
Large City (not NYC)	0.013***	0.003***	0.005***	0.005***	0.001***
	(0.002)	(0.000)	(0.002)	(0.000)	(0.000)
NYC	0.069***	0.009***	0.015***	0.042***	0.003***
	(0.005)	(0.001)	(0.004)	(0.001)	(0.000)
Controls	YES	YES	YES	YES	YES
N	20510	20510	20510	20510	20510
r2	0.05	0.05	0.04	0.08	0.01

Note: Data are from the 2010 Consumer Expenditure Survey. Population Sampling Units with more than 4 million people are classified as large cities. Controls include age, race, sex, marital status, and employment status. Standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7: Density Classifications

	PUMA	Service Establishments per Square Mile	N
Highest	3810	685	728
	3808	648	1007
	3809	601	441
	3807	555	843
	3805	451	1400
High	3806	194	1110
	3802	174	177
Medium	702	117	330
	4004	105	300
	4101	99	303
	3803	99	154
	3801	98	225
	4102	96	105
	4017	88	156
Low	Others	22 (average)	16498

Table 8-Dependence of Hours Worked on Service Establishment Density

Dependent Variable: Average Hours Worked per Week	(1)	(2)	Sample restricted to single respondents with no kids (3)	Sample excludes finance, law professionals (4)
Medium Density	-0.298	-0.0747	-0.800*	-0.141
	(0.530)	(0.324)	(0.402)	(0.298)
High Density	3.024*	2.873**	2.257**	2.607**
	(1.204)	(0.904)	(0.779)	(0.832)
Highest Density	4.519***	3.765***	2.759***	3.577***
	(0.716)	(0.620)	(0.624)	(0.633)
Demographic controls	NO	YES	YES	YES
Control for proximity to work	NO	YES	YES	YES
Productivity controls	NO	YES	YES	YES
N	239110	217187	24298	205898
r2	0.01	0.14	0.13	0.13

Note: Data are from the 5 percent sample of the 2000 Census Integrated Public Use Microdata Series. Service establishment density is based on data from Zip Code Business Patterns provided by the U.S. Census. Controls include age, sex, marital status, proximity to work, wage, occupation, education, and work PUMA. All regressions are population weighted. Robust standard errors clustered at the PUMA level are in parentheses. ***, **, and * indicate significance at the 0.1%,1%, and 5% levels, respectively.

Table 9-Dependence of Rent Residuals on Service Establishment Density

Dependent Variable: rent residual	(1)	(2)	(3)	(4)	(5)	(6)
Medium Density	-0.002	-0.014	-0.005	0.002		
	(0.042)	(0.043)	(0.036)	(0.034)		
High Density	0.114*	0.097*	0.082*	0.078*		
	(0.163)	(0.161)	(0.143)	(0.130)		
Highest Density	0.225***	0.195***	0.174***	0.164***		
	(0.103)	(0.109)	(0.097)	(0.088)		
log(establishment density)					0.111*	0.128*
					(0.018)	(0.016)
log(transportation time to work)		-0.033***	-0.040***	-0.051***	-0.058***	-0.065***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Work PUMA fixed effects	NO	YES	YES	YES	YES	YES
Demographic controls	NO	NO	YES	YES	YES	YES
Wage and occupation controls	NO	NO	NO	YES	NO	YES
N	236893	225503	225503	215328	225503	215328
r2	0.06	0.09	0.15	0.16	0.12	0.15

Note: Data are from the 5 percent sample of the 2000 Census Integrated Public Use Microdata Series. Service establishment density is based on data from Zip Code Business Patterns provided by the U.S. Census. Demographic controls include age, marital status, and education. All regressions are population weighted. Robust standard errors clustered at the PUMA level are in parentheses. ***, **, and * indicate significance at the 0.1%,1%, and 5% levels, respectively.