LOCAL ECONOMIC CONDITIONS AND THE NATURE OF NEW HOUSING SUPPLY

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Abstract

We explore the impact of local economic conditions on the type and size of newly constructed housing. A slightly modified standard open monocentric city model predicts that, as long as land use regulation is relatively lax, positive local income shocks cause construction of more multifamily housing and smaller units. Exploiting metro area-level American Housing Survey (AHS) data from 1984 to 2004, we confirm that (i) local economic shocks have the predicted effects, (ii) these effects are confined to metro areas with relatively lax land use regulation, and (iii) the adjustment process appears to be driven by migration (as is assumed in the open monocentric city model). Hence, severe land use controls may hamper metro area labor market adjustment not only through limits on the quantity of newly supplied units, but also by constraining their type to housing that is less suitable for migrants.

JEL classification: R11, R21, R31, R52.

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1. Introduction

The composition and quality of the existing housing stock does not only determine the "character" of a location but arguably also its household composition, and thereby, its future prospects. Affluent households in the United States tend to choose communities with spacious and high quality – rather expensive – single family homes. Such communities tend to have higher local tax income per capita and therefore better local schools and other local public services. In contrast, low income households prefer to sort into – inexpensive but – lower quality housing in decaying areas (Rosenthal, 2008)[1] or into areas where government programs have contributed to "affordable" housing (Baum-Snow and Marion, 2008). Minimum lot size restrictions imposed by affluent households in order to keep less well off households at bay, tend to reinforce such sorting by income based on the underlying "built environment".

The type of housing (single family versus multifamily units) – a key attribute of new housing supply – is strongly (and arguably causally[2]) related to the housing tenure status of properties (owner-occupied versus renter-occupied), which in turn is associated with various externalities. While single family homes are predominately owner-occupied, the vast majority of multifamily units are rented-occupied.[3] The literature strongly suggests that owner-occupiers (i) maintain their housing units better (e.g., Galster, 1983), (ii) invest more in local public goods such as public schools (e.g., Hilber and Mayer, 2008) or social capital (e.g., DiPasquale and Glaeser, 1999; Hoff and Sen, 2005; Hilber 2007a), and (iii) are more motivated to control local government (Fischel, 2001).[4] Hence, the composition of the housing stock may not only exert direct visual externalities but also externalities associated with homeownership and renting.

As a consequence of the durability of housing, if the nature of the existing housing stock is important for a location's fortunes, then so should be the nature of *new* housing supply. Housing units built in a certain period – quite possibly reflecting the demand conditions at

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[1] Glaeser and Gyourko (2005) show that the same mechanism is at play at the geographical level of MSAs. In declining cities where labor demand is weak, house prices are low but through decay, the housing stock adjusts only slowly to these conditions. This leads to a sorting process in which people with lower human capital levels stay in the cities in decline in order to benefit from relatively cheap housing.

[2] For expositions of the argument that the housing type causally affects the housing tenure status and for empirical evidence consistent with the proposition see Linneman (1985), Hilber (2005), and Hilber (2007b).

[3] According to the national American Housing Survey (AHS), only about one in seven MF units in the US are owner-occupied. Roughly the reverse is the case for SF units.

[4] This is not because homeowners are per se better citizens but because ownership and housing related transaction costs imply that homeowners have a stake in their neighborhood and local community (Hilber, 2007a).

that point in time – last for several decades (and sometimes centuries), continuing to exert positive and negative externalities associated with their characteristics.

Given the seeming importance of the nature of the newly built housing stock it is surprising how little is known about its *determinants*. In particular, very little is known about whether local economic conditions – at the time when new housing developments are being planned and built – affect the nature of new housing supply. The housing supply literature has either focused on new housing supply in units or on the "volume" of residential investment at the national level, thus aggregating all composition and quality aspects into one single variable and ignoring the spatial dimension (e.g., DiPasquale, 1999). Studies in the former category generally focus on the single family (*sf*) sector, thus ignoring the supply of multifamily (*mf*) housing. Heterogeneity within the *sf*-sector is ignored as well, even if the hedonic literature suggests that the value of *sf* housing units varies widely depending on their attributes. The literature on *mf* housing supply is particularly thin.

Aiming to narrow this gap in the literature, our paper investigates the relationship between local economic conditions – more precisely, the Metro Statistical Area (MSA)-level annual income per capita[5] – and the nature of new housing supply, focusing mainly on the type (*mf* versus *sf*) and size of newly built units. We gather this information for over 700,000 housing units from numerous MSA-level American Housing Surveys (AHS) between 1984 and 2004. The resulting panel dataset consists of 47 MSAs. A key assumption in our empirical strategy is that after a unit is built, the underlying housing characteristics only change little and slowly. For example, we assume that the amount of *sf* houses that is converted to apartments or extended to increase their floor size within five to ten years is small. Building on this assumption, indices of the type and size of new housing supply can be created for each MSA by taking means conditional on the year of construction. These indices are subsequently related to MSA-level income per capita and construction industry-wages in a panel data analysis that fully controls for time-invariant heterogeneity and trends at the national level.

Our study also ties into the literature on the consequences of land use regulation. A growing body of literature highlights the impact that land use regulations exert on housing supply. For example, in metro areas where regulation is more stringent, residential construction in units is less responsive to price changes (Green et al., 2005) and shifts in labor

[5] The empirical analysis below uses income per capita rather than wages to capture demand side shocks in the housing market. The former measure is arguably more relevant to determine housing demand. However, we have replicated our analysis using wages instead of income per capita and our findings are essentially unchanged.

demand translate into higher wages and house prices, rather than into more jobs and houses (Glaeser *et al.*, 2006; Saks, 2008). However, land use regulation may not only limit the amount of newly constructed housing, but may also prevent that the *appropriate type* is being built, a proposition that has not been explored so far and on which we follow up.

Overall, our findings suggest that positive (negative) local economic shocks – through in- and out-migration – cause the construction of more *mf* (*sf*) housing and smaller (*larger*) units, thereby dampening the impact of the shocks. However, these adjustment processes are confined to MSAs with comparably lax land use regulation. In places with tight control, measures such as zoning or minimum lot size restrictions prevent adjustments of the housing stock composition. Our findings imply that severe land use controls may hamper MSA-level labor marked adjustment not only through limits on the quantity of newly supplied units, but also by constraining their type to *sf* houses that are less suitable for migrants.

Our paper is structured as follows. In Section 2 we provide a theoretical framework for our empirical analysis. Section 3 describes the data and empirical strategy in more detail. In Section 4 we present results. Conclusions are offered in the final section.

2. Theoretical framework

At first sight, it seems natural to conjecture that economic upswings will have positive effects on the "quality" of new housing. Many housing characteristics appear to be normal or luxury goods and one might therefore expect that an increase in average income associated with a booming economy leads to higher quality housing. Indeed, there is little doubt that *at the national level*, the quality of housing has improved substantially over time and that this development is related to changes in household incomes. What we focus on in this paper, however, is the impact of changes in *local* economic conditions on the composition and quality of new housing supply, controlling for nationwide developments in these variables. As we will see below this changes the predictions fundamentally.

The key assumption that may alter the sign of the predicted effects of income growth on certain characteristics of newly supplied housing is that utility is equalized between metro areas. A recent paper by Glaeser and Gottlieb (2008) discusses this assumption at length and concludes that it "…*is effectively impossible to prove that welfare levels are equalized across space. A better way to describe the evidence is that there are many facts that are quite compatible with the spatial equilibrium assumption and few, if any that would cause us to reject that assumption.*" One of the more prominent stylized facts supporting the spatial equilibrium assumption is the substantial magnitude of migration flows between US cities. An immediate consequence for our empirical analysis is that, since it controls for all effects that are relevant at the national level, our findings should be interpreted within the theoretical framework of an *open city* in which utility is determined exogenously at the national level. It is well-known from the urban economics literature that in an open city, rising incomes push up land prices everywhere, which induces a reduction in the size of lots. Hence, housing built after a positive *local* income shock is in fact of a *lower quality*, at least in some measures.[6]

This result is usually obtained in an urban model in which housing services are produced with capital and land, which has become known as the "Muth model" (see Muth 1969; Fujita, 1989). However, as our empirical analysis will focus mainly on the type of housing that is built and on the amount of floor space per housing type, we adapt this standard framework in order to obtain precise predictions with respect to these variables. Specifically, we distinguish two housing types – *sf* and *mf* housing, and we assume that building height of each type is fixed.[7] Moreover, we assume that deprecation of the housing stock is an exogenous process, so that developable land becomes available at a constant and exogenous rate ω everywhere within the city.[8]

2.1. Demand for floor space

We adopt a framework in which (homogeneous) households have preferences for floor space as a differentiated commodity. Floor space is available in two versions: the first is provided by *mf* housing, the second by *sf* housing, and a household can consume floor space in only one of these two types of housing. One reason to treat floor space in *mf* and *sf* units as inherently different is that through noise and other nuisances, apartments are much more prone to negative externalities from neighbors, which renders them inferior to floor space in *sf*

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6 Even in a closed city, income shocks may push up land prices and lead to smaller lot sizes, see for instance Fujita (1989) for a discussion of the comparative statics of the monocentric model.

7 It is straightforward to extend the theoretical framework with multiple housing types that vary in building height, which would make it more similar to the traditional Muth model. However, as our empirical analysis distinguishes between *mf* and *sf* units only, there is no merit in pursuing this approach here. Alternatively, one could introduce an arbitrary threshold value of the capital land ratio in the standard model, and interpret it as the boundary between single and multifamily housing. The amount of housing services on each side of the threshold could then be related to floor space. Such a model would lead to similar predictions. See Rouwendal (1998) for the relationship between a housing services approach and a characteristics approach to housing demand.

8 In reality, the timing of redevelopment within urban areas depends on both physical and economic decay (e.g., Rosenthal and Helsley, 1994). Redevelopment is partly determined by the age and quality of the existing housing or other buildings, which are historically determined and independent of the presence of a recent economic upswing. Since it is known that in the centers of many US cities existing housing is of old age, the opportunity costs of conversion are relatively low at these locations (Brueckner and Rosenthal, 2005). This suggests that a local economic upswing may generate substantial new redevelopment in central cities, which is likely to be of *mf* type. Furthermore, as the decision to redevelop existing construction depends on current economic conditions, we should expect that more redevelopment will take place in a booming housing market – i.e. after an income shock, than under "quiet" market conditions. Hence, taking account of these aspects of redevelopment reinforces our prediction that local income shocks raise the share of *mf* units in new construction.

units. Formally, households have a utility function $u = u(c, s, i)$, where c is a composite consumption good and s the amount of floor space, while i (= *sf, mf*) indicates the dwelling type. Utility is increasing and quasiconcave in c and s. Inferiority of floor space in *mf* units is reflected in the assumption that $u(c, s, sf) > u(c, s, mf)$ for all c and s. The inverse of the utility function with respect to c, $z = z(u, s, i)$, may be interpreted as the amount of composite consumption goods that have to be offered to a household that lives in a housing unit of type i with an amount s of floor space, in order to guarantee utility level u. Its partial derivative with respect to s equals minus the willingness to pay for floor space. This willingness to pay is always larger for floor space in single family housing: $-\partial z(u, s, sf)/\partial s > -\partial z(u, s, mf)/\partial s$ for all u and s.

For simplicity we assume that all housing is rented and that rent levels adjust fully to changes in market conditions.[9] Letting p_i denote the rent of a square unit of floor space in housing of type i and normalizing the price of composite consumption goods to unity, we write the household budget constraint as $y - tx = c + p_i s_i$, where y denotes income, x distance to the CBD and t the transportation cost per unit of distance. Equilibrium on the markets for floor space requires that p_i is equal to the bid rent for floor space, which is the maximum amount of money a household can afford to pay for a unit of floor space, while still being able to reach utility level u:

$$\Psi(u, x, y, i) = \max_s \frac{y - tx - z(u, s, i)}{s}. \tag{1}$$

For the floor size s that solves this optimization problem, it holds that:

$$-\frac{\partial z(u, s, i)}{\partial s} = \frac{y - tx - z(u, s, i)}{s}. \tag{2}$$

This equation states that the marginal willingness to pay for floor space should equal the amount of money per unit of floor space that is a available to a household that has to reach utility level u. Hence, the equilibrium rent level for each type of housing is equal to the corresponding marginal willingness to pay. Under the usual assumptions on preferences, the bid rents are decreasing convex functions of the distance to the city center. Furthermore, the bid rent function for floor space in *mf* units lies below that for floor space in *sf* units.[10]

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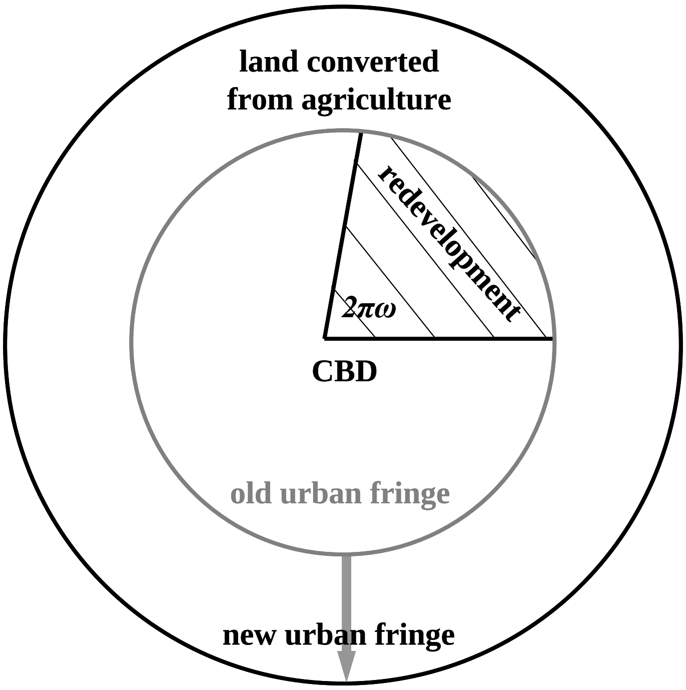
[9] Owner occupied housing could be dealt with by concentrating on user costs rather than rents, but in that case we must take into account the wealth effects of house price changes which can be ignored in the standard setting with absentee land owners.

[10] Suppose, on the contrary, that the bid rent for *mf* housing would be higher than or equal to that for *sf* housing. Since we have assumed that the willingness to pay for floor space in *mf* units is smaller than the willingness to pay for floor space in *sf* units, if evaluated at the same level of u and s, convexity of $z(u, s, mf)$ would imply that

2.2. Clearing of land markets

Within the urban fringe, developable land becomes available at a constant and exogenous rate ω everywhere within the city. Costs of demolition are ignored. At the urban fringe, agricultural land is converted to residential when residential land rents exceed opportunity costs. These assumptions are illustrated for the case of an expanding city in Figure 1, in which all developable land that becomes available within the urban fringe is treated as if it is located within the same segment.

Figure 1: Urban form



On open land, either *mf* or *sf* housing is developed. Buildings containing *mf* units are such that F square units of floor space can be created on one square unit of land, while we assume for convenience that in *sf* housing 1 square unit floor space is created per square unit of land.[11] Hence, even if consumers are never willing to pay more for floor space in *mf* units than for floor space in *sf* units, it may be attractive for a developer to supply the former type of housing. Developers build and rent out *sf* and *mf* units in perfectly competitive markets. They

$s_{mf} < s_{sf}$. For households who consume less floor space in the inferior *mf* units to obtain the same level of utility, it should be the case that $c_{mf} > c_{sf}$. However, this would imply that $\left(y - tx - c_{mf}\right)/s_{mf} < \left(y - tx - c_{sf}\right)/s_{sf}$, meaning that the first-order condition (2) associated with the consumer problem would not be satisfied. Hence, it must be the case that the bid rent for *mf* housing lies below that for *sf* housing.

[11] Our data indicate that the average number of floors in SF housing equals 2 and for MF housing it is 3, which would suggest a value of F = 1.5. However, SF housing may use more land for gardens instead of floor space relative to the MF sector, leading to a higher value of F.

maximize profits per square unit of land π_i, which are given by either $\pi_{mf} = Fp_{mf} - p_l - C_{mf}$ or $\pi_{sf} = p_{sf} - p_l - C_{sf}$, depending on the housing type they construct. In these equations, p_l denotes the land rent and C_{mf} and C_{sf} the (annualized) construction cost per square unit of developed land.[12] Perfect competition on land markets implies that all profit disappears into the price that developers bid for residential land. Hence, bid rent functions for land may be characterised as follows:

$$\Pi(u,x,y,mf) = F\Psi(u,x,y,mf) - C_{mf} \text{ and}$$
$$\Pi(u,x,y,sf) = \Psi(u,x,y,sf) - C_{sf}. \tag{3}$$

Note that in this expression, developers choose floor sizes optimally, which means that they choose the floor sizes that solve the consumer problem (1).

Land use is determined by the highest bid. Hence, construction takes place only in places where the maximum of $\Pi(u,x,y,mf)$ and $\Pi(u,x,y,sf)$ exceeds the agricultural land rent p_A, and *mf* units are built wherever it holds that $\Pi(u,x,y,mf) > \Pi(u,x,y,sf)$. This latter condition may be written as

$$p_{mf} > \frac{p_{sf} + (C_{mf} - C_{sf})}{F}, \tag{4}$$

so *mf* housing will be supplied at a particular site in the city when rents for floor space in such housing are not too low in comparison to that in *sf* housing. We would expect to see *mf* housing close to the city centre and single family housing in the suburban ring around the centre. This pattern emerges when inequality (4) is satisfied in the centre and the profits associated with the construction of *mf* housing decrease faster than the profits associated with the construction of *sf* housing, or

$$\frac{\partial \Pi(u,x,y,mf)}{\partial x} < \frac{\partial \Pi(u,x,y,sf)}{\partial x}. \tag{5}$$

The spatial ordering of different types of land use depends on the steepness of bid rent curves for land. Note that by substitution of the expressions for bid rents for floor space (1) into condition (5), and by using the familiar Muth condition that $\partial p_i / \partial x = -t / s_i$, we may rewrite it as saying that $F/s_{mf} > 1/s_{sf}$. Hence, the density of households on land in *mf* use should exceed the density of households on land in *sf* use.

[12] We assume that $C_{mf} > C_{sf}$. It should be noted that the model is only meaningful if the difference between the construction costs of both housing types $C_{mf} - C_{sf}$ is not too large.

2.3. The effect of a local income shock

In order to assess the effect of a local income shock, we compare a steady state scenario to the new equilibrium that would result from an unexpected increase Δy in the household income. In the steady state scenario, new construction takes place on the share ω of the land within the urban fringe, according to conditions (4) and (5), but as the bid rent functions for floor space and land do not alter, the urban fringe does not expand. However, when incomes rise unexpectedly, the bid rent curves for floor space and land shift outward by an amount $\Delta y / t$. Mathematically, this is easily seen by substitution in expression (1):

$$\begin{aligned} \Psi\left(u, x+\Delta y/t, y+\Delta y, i\right) &= \max_s \frac{y+\Delta y - t\left(x+\Delta y/t\right) - z\left(u,s,i\right)}{s}, \\ &= \Psi\left(u,x,y,i\right) \end{aligned} \tag{6}$$

and a similar derivation can be made for bid rents for land in expression (3). This implies that for all model variables – land use, land prices, prices for floor space and floor sizes, realizations shift outwards from the CBD by an amount $\Delta y / t$.

We illustrate the effect of this income shock on the functioning of markets for floor space and land in figures 2 and 3 respectively. Figure 2 shows bid rents for floor space in *mf* units with continuous lines, and bid rents for floor space in *sf* units with dashed lines. Furthermore, lines that correspond to the steady state scenario are grey and lines that refer to the situation after an income shock are black. This figure illustrates first of all that bid rents for floor space are higher in the *sf* than in the *mf* sector. The border between land use in these two sectors is indicated by x^{*0} and x^{*1} in the scenarios without and with income shock respectively, and the urban fringe is denoted by x^{b0} and x^{b1} respectively. The way in which these borders are determined becomes apparent in Figure 3, which depicts bid rents for land: land use is determined by the highest bid. Both figures clearly illustrate how the income shock pushes land use patterns outwards.

Figure 2: Bid rents for floor space

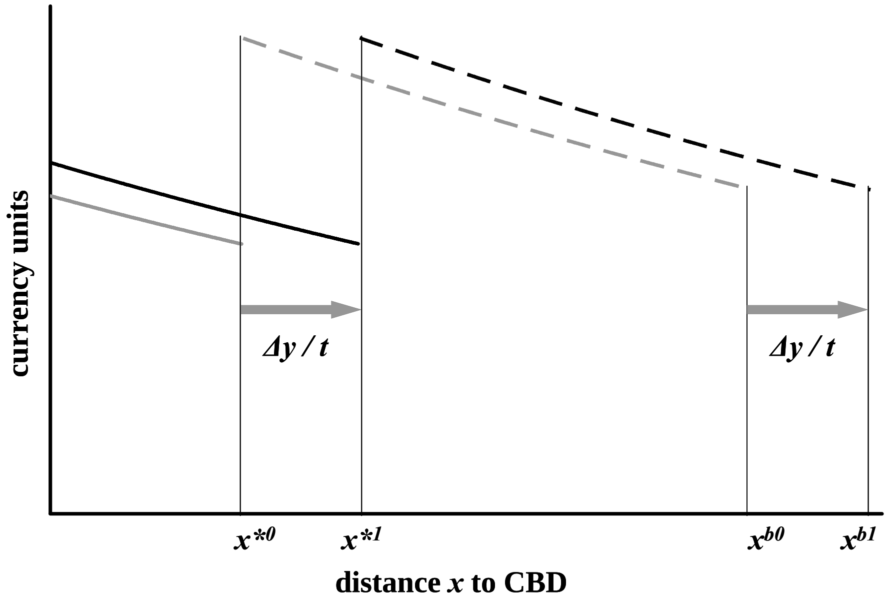
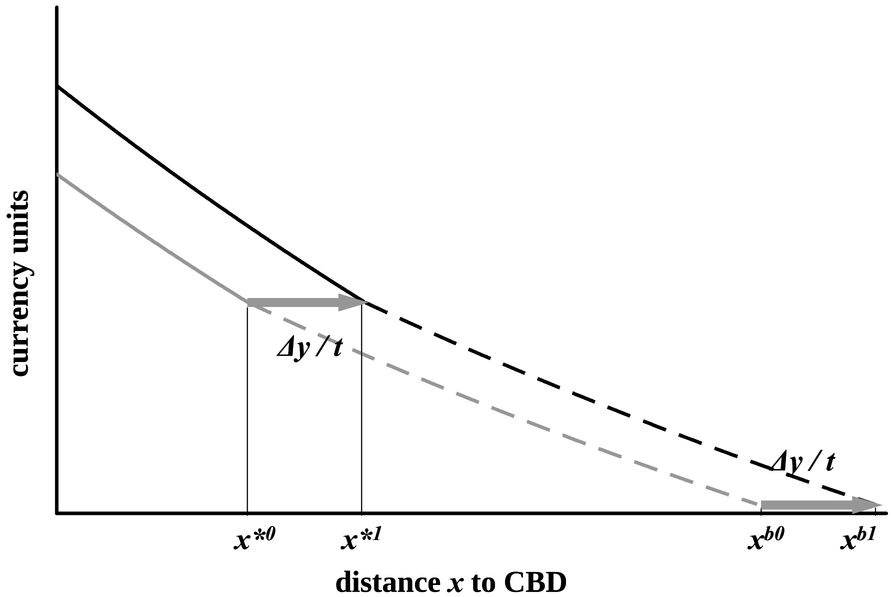


Figure 3: Bid rents for land



The impact of income shocks on the composition of new construction in terms of housing types depends on the share of new construction that takes place within the urban fringe. If ω is small and most construction takes place at the urban fringe, it is likely that new units are predominantly in the *sf* sector, irrespective of the extent to which household incomes have risen. At the other extreme, if housing is fully malleable and the city is rebuilt every period, a positive relationship exists between the income shock and the share of newly constructed units that is in the *mf* sector. This is easily seen for the case of a linear city: the segments with *mf* and *sf* housing shift outward by an amount $\Delta y\ /\ t$ and the number of units with these segments does not change, but in addition a new segment becomes available close to the CBD in which *mf* units are constructed at a high density. In Appendix A1, we show that this relationship holds as well for the circular city that we have assumed here. Furthermore, if it holds for $\omega = 1$, then under some regularity conditions it also holds for other values of ω provided that they are sufficiently large. Hence, we have the following prediction:

> **Prediction 1:** *If ω is sufficiently large, an increase in income raises the share of mf housing in new construction.*

Figure 1 suggests that ω should in fact be significantly smaller than unity. However, Prediction 1 would still hold true when the share of new construction that takes place within the urban fringe is large relative to new construction on converted agricultural land. This might be the case in cities that are large, so that the amount of redevelopable land within them is large, or in cities in which natural barriers prevent expansion in a full circle around the fringe. Whether such conditions are met in reality is of course an empirical question. In the empirical analysis below, we are able to deal with this issue in a sensitivity analysis, by considering observations on new construction in city centers only. Extension of the urban fringe, where in all likelihood *sf* units would be constructed, is not an issue in the city center, so both Prediction 1 and Prediction 2 that we will introduce below should hold in this part of the city *a fortiori* (see Table 3 for the empirical confirmation).

For the limiting case in which $\omega = 1$, it may also be shown that the average floor size of newly constructed units falls with income in both sectors. In a linear city, this would occur only in the *mf* sector, where the new segment close to the CBD would raise the average density of units, whereas the average unit size would be unaffected in the *sf* sector. In a circular city, the mean density of *sf* units rises because houses with the smallest amount of floor space get a larger relative weight in the average. This effect exists also for the part of the *mf* sector that is shifted outwards, and under a mild condition, it is even stronger than for the *sf* sector. Proofs and a formal statement of this condition are provided in Appendix A2. Moreover, for the *mf* units that are built close to the CBD, filling the space that is freed by the horizontal shift of the original bid rent curve, floor size will be below average. We thus obtain the following prediction:

> **Prediction 2:** *If ω is sufficiently large, an increase in income lowers the average amount of floor space in newly built units of both types. Under a mild additional assumption, this effect is stronger in the mf than in the sf sector.*

2.4 Heterogeneity of migrants and local residents

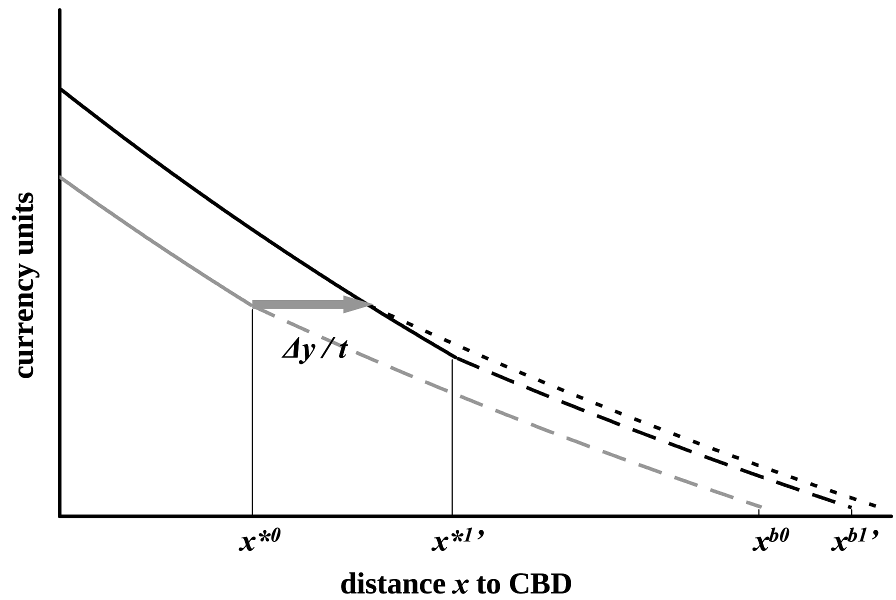
A concern related to the above analysis is that it assumes a homogenous population. It could be argued that one should distinguish between *mobile* households, mainly consisting of younger people at the beginning of their career who are looking for job opportunities in many cities, and *less* mobile people who are usually in later stages of their career and have become more or less settled in one metropolitan area. The former group is more interested in rental *mf* housing, whereas the latter group prefers *sf* housing that is owner-occupied.[13]

We investigate the robustness of our predictions for this type of heterogeneity by introducing two different household types in our model, that vary in precisely these dimensions. First, the mobile households look for job opportunities all over the country and their utility level is determined outside the city we consider, whereas their number adjusts so as to keep utility at that level. However, there is now also a group of immobile households, which is fixed in size and for whom the utility level is determined locally. For simplicity we assume that the mobile households only demand *mf* housing, whereas the immobile households live in *sf* housing. The income shock is equal for households in both groups.

Under these assumptions, the consequences of a positive income shock are illustrated in Figure 4, which shows bid rents for land as in Figure 3. First, for the group of mobile households, equalization of utility with the rest of the country means that after the income shock, more mobile households move into the city. Their bid rent curves for floor space and land are identical to the bid rent curves for floor space and land in *mf* housing that were illustrated in Figures 2 and 3. If the utility level of the immobile households would remain unchanged as well, their bid rent curves for floor space and land would be identical to the bid rent curves for floor space and land in *sf* housing that were illustrated in Figures 2 and 3. Figure 4 indicates this case with the black dotted line. However, we have seen that in this case, the number of *sf* households increases, which would contradict our assumption that households in this group do not move between cities. In order to accommodate their fixed number in the city after the income shock, a smaller increase of their bid rent curve suffices, as indicated by the black dashed line in Figure 4, and the utility of this group will rise.

[13] One piece of evidence in the AHS that supports this claim is that foreign migrants are significantly more likely to live in *mf* units and that they are significantly less likely to own a house.

Figure 4: Bid rents for land with heterogeneous households

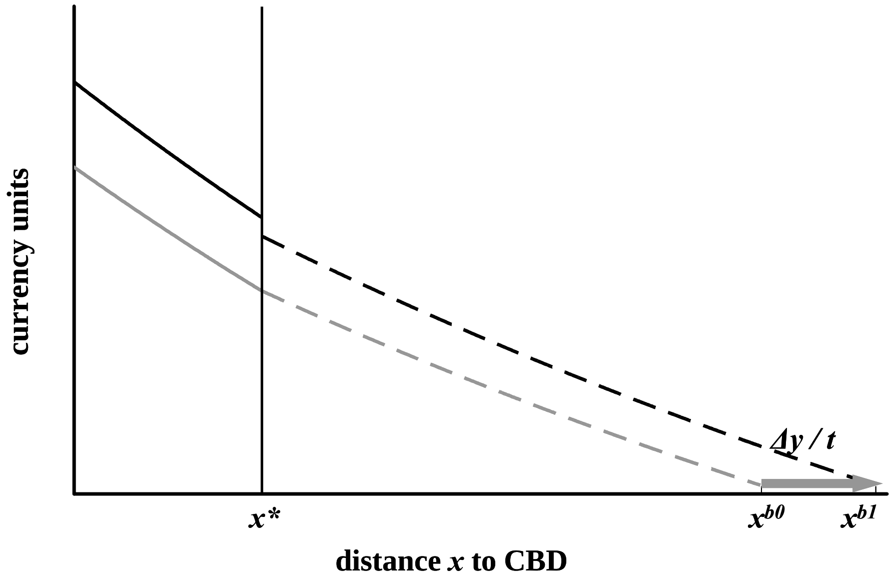


What does this imply for Predictions 1 and 2? First, we observe that the fringe between the *mf* and *sf* sectors shifts outward by even more than in the case with homogeneous households. Hence, our first prediction that the share of *mf* housing in new construction rises with a positive income shock is *reinforced*. However, while the model with heterogeneous households is still compatible with the second prediction, it can not be shown to hold under general conditions. The reason is that as the fringe between the *mf* and *sf* sectors shifts outward by more, there will be a contingent of *mf* units with a relatively large amount of floor space after the income shock, which counteracts the negative effects on average floor space in *mf* housing.

2.5. Land use regulation

While we have so far assumed that there were no restrictions on the amount and type of newly constructed housing, it is well known that in some American cities, land use is strongly regulated. One important form of zoning imposes minima on lot sizes (motivated by a desire of affluent residents to exclude low income households from entering their communities in order to prevent fiscal externalities), For similar reasons, communities impose restrictions on *mf* housing construction, which tends to attract lower income households as well. We investigate the effect of this latter type of land use regulation by assuming that the fringe between the *mf* and *sf* sectors is fixed at its steady state level, so that it cannot shift outward after a positive income shock. The consequences of this assumption are illustrated in Figure 5, which shows again the bid rent curves for land.

Figure 5: Restrictions on rezoning to the mf sector



The figure shows that in the *mf* segment, land rents are pushed up. This will induce a reduction in average floor sizes, so that the number of newly constructed *mf* units will rise after a positive income shock. Land rents are pushed up in the *sf* segment as well. In fact, both curves are the same as in Figure 3, except that the resulting land price curve is not determined by the maximum of the two anymore. This is seen at x^*, the fringe between the *mf* and *sf* sectors, where land rents now drop by a discrete amount. After the income shock, the number of newly constructed *sf* units rises as well, and it rises by more than in the case without land use regulation. Hence, it is not clear anymore whether Prediction 1 still holds. Prediction 2 would still seem to apply in this case, floor sizes are decreased, in particular in the *mf* sector. However, in cities in which restrictions on conversion of land to the *mf* sector are in place, we also expect the presence of minimum lot size zoning, which would render this prediction ambiguous as well. Hence, in cities with relatively severe land use regulation, little can be said about the impact of local income shocks on the composition of new construction.

3. Data, empirical strategy, and specifications

3.1. The data

The metropolitan area datasets from the AHS considered in our analysis were collected between 1984 and 2004.[14] The US Census conducted these AHS metro surveys annually between 1984 and 1993 and at irregular dates after that. In each year, a different set of MSAs

[14] The data were obtained through HUD User at http://www.huduser.org/datasets/ahs.html.

was surveyed. In total, we have information for 47 MSAs and the average number of times that an MSA is surveyed equals 3.6. See Appendix Table A1 for a list of all MSAs and the years they were surveyed in the AHS. For our period of observation, definitions of the variables of interest were overall consistent, though a few minor adjustments had to be made.[15]

We measure local economic conditions by income per capita, taken from the Regional Economic Information System of the BEA.[16] From this dataset we also construct a proxy for construction wages by dividing total earnings in the construction industry by employment. An alternative measure of local economic conditions, used in our analysis to carry out a robustness check of our findings, is the wage per employee. We derive this data from the County Business Patterns (CBP) dataset. The CBP also provides employment data, which we use to generate two additional variables: the employment growth in the MSA and a measure indicating a labor demand shock (our instrument to identify employment growth). In computing this labor demand shock variable, we use the same underlying data and methodology described in Saks (2008).

Finally, in order to distinguish MSAs with more stringent land use regulation from those with less stringent controls, we use two indices of regulatory tightness. The first index, developed by Saks (2008) is the simple average of six independent surveys conducted during the 1980s. The six sources are: The Wharton Urban Decentralization Project, the Regional Council of Governments, the International City Management Association, the Fiscal Austerity and Urban Innovation project, the National Register of Historic Places (NRHP), and the American Institute of Planners. The method of index construction is described in detail in Saks (2008). The second index, the so called Wharton index, is derived based on a survey from the early 2000s (see Gyourko *et al*., 2008 and Saiz, 2008 for a description of the survey). Both indices aggregate information on many different types of land use regulation at the level of municipalities s. Since most of our data points are between the 1980s and the early 2000s, we create a new index by averaging the Saks and Wharton indices.[17] It is important to note however that our main results remain virtually unchanged if we use the ‘Saks index’ or the ‘Wharton index’ instead of the combined index.

[15] Definitions of the structure type, the number of dens and family rooms as well as the number of other rooms had to be slightly adjusted in order to make them consistent between different years. In 1984, variable definitions changed significantly compared to earlier years, so this prevented us from going back further in time.
[16] See http://www.bea.gov/regional/docs/reis2006dvd.cfm.
[17] For two MSAs that were missing in the Saks index we used the Wharton index and for one MSA that could not be matched with the Wharton index we use the Saks index. Thus, we could match each MSA in our data to an index value.

3.2. Empirical strategy

The predicted impact of local economic conditions on the nature of new housing supply is tested by regressing indicators of the type and size of newly built housing units on income and construction costs. These indicators are derived from the MSA-level AHS surveys (described above), by averaging housing characteristics over the year of construction. For instance, consider the computation of the share of housing built in Boston in 1994 that is of the *mf* type. First, we construct a dummy variable that is equal to one if a housing unit is *mf* and zero otherwise. There is an AHS metro sample for Boston in 1998, which provides us with information about the characteristics of a sample of housing units in this MSA, as well as the year in which these units were built. Hence, the index value is obtained by averaging the dummy variable over all housing units in this sample that were built in 1994. Formally, we compute:

$$I^k_{t\times MSA\times\tau} = E\left(I^k_i \,\middle|\, t, MSA, \tau\right), \tag{7}$$

where I^k_i is the value that indicator I^k takes for housing unit i, which is built in year τ and observed in a AHS survey of *MSA* in year t. Besides the *share of mf units*, we consider the *unit square footage* of new units in both the *mf* and *sf* sector. Following expression (7), indices for this variable are created by averaging unit square footage over MSA, year of observation and year of construction. Next to these indices on which we have formulated explicit predictions in the theory section, we also study the *share of housing units within the city center* for the *sf* and *mf* sector. As the boundary between *mf* and *sf* housing was predicted to shift outwards after a positive income shock, we would expect this indicator to rise for the *mf* sector and to fall for the *sf* sector.

3.3. Econometric model

The main results of this paper are derived from the following econometric model:

$$I^k_{t\times MSA\times\tau} = C_{t\times MSA} + D_\tau + \alpha \log\left(Y_{MSA\times(\tau-1)}\right) + \beta \log\left(W_{MSA\times(\tau-1)}\right) + \varepsilon_{t\times MSA\times\tau}, \tag{8}$$

where $Y_{MSA\times(\tau-1)}$ is the (lagged) per capita income and $W_{MSA\times(\tau-1)}$ is the (lagged) wage level in the construction industry, which proxies construction costs.[18] In this model, $C_{t\times MSA}$ is a fixed effect that is specific to each *MSA* and to the year t in which it was surveyed in the AHS. Most

[18] Income and construction wages refer to the year of construction lagged by one, in order to take account for lags in the construction process.

metropolitan areas are surveyed several times between 1980 and 2004, and for each time they appear in the AHS, we enter a separate fixed effect. These fixed effects control fully for all heterogeneity that is time invariant. Notably, this should hold approximately for the composition of the urban housing stock. Furthermore, developments in the nature of new housing supply at the national level are held constant through the fixed effect D_τ. All remaining heterogeneity is absorbed by the error term $\varepsilon_{t\times MSA\times\tau}$. In the estimation of (8), we account for variation in the number of observations in the AHS on which each $t \times MSA \times \tau$ cell is estimated (and hence the precision of this estimate) by using Weighted Least Squares.[19]

Besides the baseline version of (7), we also consider two variants of this model. In the first place, our predictions 1 and 2 were conditional on the share of new construction that took place within existing boundaries, and they would not hold in cities in which most new construction took place on converted agricultural land. In the construction of the indicators in (8), we can select on observations in city centers only, which means that only new housing supply within the urban fringe is considered. Our theoretical predictions are expected to hold *a fortiori* when indicators are constructed in this way. Secondly, we have shown that predictions about the impact of local economic conditions on the nature of new housing supply are less clear cut in cities in which land use is severely regulated. By using an index of regulatory stringency, we split the sample of MSAs into subsets in which land use controls are more or less severe. By estimating (8) separately for these two subsets of the data, we may infer how land use regulation affects the responsiveness of the composition of new housing supply.

Essential in our identification strategy is the assumption that housing characteristics do not change between the year of construction and the year that the unit is observed in the AHS. However, conversions from *sf* houses to *mf* apartments are feasible in principle, and the floor size of houses may also be extended in renovations. In base line specifications, we consider a time window of 10 years, relying on the assumption that the number of newly built units that is converted or renovated within a decade after construction is limited. However, we check the sensitivity of our results for this assumption by limiting the time window to 5 years.

[19] As weights, we use the number of observations on which each cell is based, averaged over all observations in the same cluster that are based on at least one AHS observation, because time-varying weights are not allowed in a fixed effects estimator.

3.4 Descriptive statistics

By computing indices of the nature of new housing supply according to expression (7), we obtain a panel dataset in which the year of construction τ constitutes the time dimension and in which the cluster identifiers are AHS wave-MSA combinations $t \times MSA$. In order to be included in the sample on which model (8) is estimated, each $t \times MSA \times \tau$ cell has to satisfy a number of conditions. First, as discussed previously, the gap between t and τ has to satisfy the time-window we impose. Secondly, τ should be reported as a single year and not as a period of several years, which is usually the case for older houses. Finally, in order to obtain estimates of the indices I^k, these cells have to be nonempty. Table 1 provides descriptive statistics of the panel dataset that results from imposing these conditions. Besides reporting means and overall standard deviations, it decomposes the standard deviation into within and between clusters dimensions. This is relevant for our purposes because all estimates that are reported in the subsequent section are identified on variation within clusters only. Table 1 also reports overall minima and maxima, the number of clusters, and the number of observed cells.

– *Insert Table 1 around here* –

As indicated in Panel A of Table 1, for most variables 167 $t \times MSA$ combinations are observed.[20] The means in this panel are sensible and generally straightforward to interpret. About 30% of newly constructed units are part of a *mf* structure. The majority of new housing – particularly *sf* housing – is built in suburbs. Units in the *sf* sector are on average significantly larger than in the *mf* sector. Furthermore, the average size of an AHS-metro area is almost 3 million people, that is, our regression sample consists mainly of large MSAs. The variation of variables is usually larger between than within clusters, particularly for income, population and construction wages. Only for the unit square footage of *mf* housing the variation within is larger than between clusters.

Panels B and C of Table 1 describe subsets of the data in Panel A, in which land use regulation is respectively more or less restrictive than in the median cell. Although overall, the descriptive statistics are rather homogeneous over these two categories, a number of differences stand out. Perhaps most strikingly, MSAs in which land use regulation is more stringent are more than 60% larger in terms of population than MSAs in which regulation is less stringent. This may partly explain another significant difference, that in more regulated MSAs, a larger percentage of both *sf* and *mf* housing construction takes place in suburbs.

[20] For some variables, the number of clusters is smaller because in 1998, the variable that indicated the location within an MSA was missing in the AHS.

Finally, Panel D of Table 1 reports descriptive statistics for the indicators in which only observations in city centers were used.[21] As the number of observations on which the cluster identifier × τ cells are based is smaller, the number of cells for which there are no AHS observations is larger and we have less clusters and data points. Comparing descriptive statistics to Panel A, it appears that a larger share of new construction occurs in the *mf* sector and units are smaller in both the *sf* and *mf* sectors, which is consistent with what the monocentric model would predict.

4. Empirical results *(preliminary draft)*

4.1. Results for base specifications

Table 2 reports results for the base line estimation of model (1).

– *Insert Table 2 around here* –

Consistent with Prediction 1 in Section 2, the findings in this table point to a particularly strong relationship between (lagged) local income and the share of *mf* housing in new construction. More specifically, in MSAs where income is 10% above national average, the share of *mf* housing is 6.4 percentage points higher, a substantial effect. Since the estimates in Table 2 are conditional on time-invariant heterogeneity, it makes sense to interpret this finding in terms of variation over time, meaning that in MSAs in which income per capita grows at a higher rate than at the national level, the share of construction in the *mf* sector rises faster or declines less compared to the national trend.

Consistent with Prediction 2, we find a negative effect of local income on floor size that is stronger in the *mf* sector than in the *sf* sector. Apartments built in MSAs where income exceeds the national level by 10% are smaller by about 17%. We also find a significant effect of income on the rate of "suburbanization" in the *sf* sector. In MSAs in which income increases by 10% relative to the national trend, the share of *sf* units built in city centers falls by about 5 percentage points. Although local wages in the construction industry are not statistically significantly associated with the other indicators, they appear to raise the share of new construction built in city centers.[22]

[21] Income, population and construction wages are unaffected, so we do not report descriptives for these variables here.

[22] The positive impact of construction wages may be explained by the land price differential between central and suburban locations, which could imply that in terms of expenditure, labor is a more important input in suburban constructions and land is a more important input in city centers, so that a rise in construction wages reduces suburban construction more.

Although all effects in Table 2 are measured relative to the US national level, aggregate trends in some of the dependent variables as well as in income and construction wages have been substantial. The suppressed time dummies that are reported in Appendix Table A2 shed some light on these trends. Notably, conditional on other explanatory variables and the fixed effects, there is a significant downward trend in the share of *mf* housing in aggregate construction and a significant upward trend in the unit surface of newly built houses, particularly in the *mf* sector.

Appendix Tables A3 and A4 verify that the results in Table 2 are robust with respect to the choice of lags of the explanatory variables and with respect to the time-window. In Table A3, we report estimation results for models in which the explanatory variables are either contemporaneous or lagged with 2 years. The findings suggest that the main effects are robust, although unsurprisingly, they slightly decrease in strength over time. The results do not change significantly when we limit the time window for the two relevant variables (the unit size variables) to five years, in fact, the effects get slightly stronger. See Table A4 for details.

4.2. City centers versus suburbs

The AHS allows us to estimate indices of the composition of new housing supply separately for city centers. This enables us to investigate the effect of economics shocks in a setting, where the extension of the urban fringe (where in all likelihood *sf* units are constructed) does not influence the estimates.

– Insert Table 3 around here –

As we would expect on the basis of the simple model presented in Section 2, the impact of income on the share of *mf* construction is much more pronounced in central cities (compared to the suburbs or the entire metro areas, see Table 2). A 10% increase in income is associated with a rise in the share of newly constructed *mf* units in central cities by about 15 percentage points (compared to 6.4 percentage points for the entire metro area).

4.3. The impact of land use regulation

Table 4 reports relationships between the composition and quality of new housing supply and local economic conditions for metro areas, in which land use regulation is more stringent and for metro areas, in which they are less stringent.

– Insert Table 4 around here –

The effects of income on indicators of the composition of new housing supply in metro areas where regulation is less restrictive are slightly more pronounced, though in the same order of magnitude, than the ones reported in Table 2. In particular, we find that a 10% rise in income relative to the national trend is associated with an increase in the share of *mf* housing by almost 9 percentage points. Now, we also find a significant negative impact of wages in the construction industry on this variable. The size of units in the *mf* sector appears to be more sensitive to income, as are the impacts of income and wages in the construction industry on suburbanization of *sf* and *mf* housing. For cities in which regulation is stronger than average, however, all of these effects are absent.

Our results thus strongly indicate that land use regulation mutes the responsiveness of the composition and quality of new housing supply to local economic conditions, at least in the short run. This could simply be a consequence of zoning ordinances that specify the type of housing that may be built at certain places, or impose limits to development densities (as is typically done in 'exclusionary zoning'). Adjustment of such regulations is likely to take time, so they will probably impose delays on supply responses to market conditions, or prohibit them altogether. In this sense, our results bear similarity to the finding that land use regulation limits the price elasticity of housing supply, as reported by Quigley and Raphael (2005) and Green et al. (2005).

4.4. Are the results driven by migration? *(very preliminary draft)*

Our empirical findings above are consistent with predictions derived from an open monocentric model, in which demand for land is fully elastic as a consequence of costless migration. In other words, migration is crucial to understanding why *positive* income shocks lead to new construction of *lower quality* housing units in terms of type and size, even if these are normal goods. In order to test for the appropriateness of this interpretation of the estimation results, we relate the same indicators of the nature of new housing supply to migration, rather than income. As is common in the literature (e.g., Blanchard and Katz, 1992 or Saks, 2008), we use employment growth as a proxy for net incoming migration.

Employment growth (or the net incoming migration) is obviously endogenous. Migration depends not only on demand shocks, but also on the extent to which housing supply accommodates such shocks, as has been recently shown by Glaeser et al. (2006) and Saks (2008). While these studies establish the impact of the housing supply side in terms of the number of newly built units, the same will arguably hold for housing characteristics, as migrants have a comparably strong demand for *mf* units and small units.

In order to identify the causal effect of employment growth on our measures that characterize the nature of new housing supply, we use an instrument first described by Bartik (1991) and applied in empirical work, for example, by Saks (2008). Specifically, we instrument for employment growth with a "labor demand shock variable" that equals the weighted average of national industry employment growth rates, where weights are equal to the lagged share of an industry's employment relative to total MSA employment. Intuitively, if an MSA has a large proportion of its jobs in an industry that is doing well at the national level, this MSA is predicted to have a high employment growth rate. The underlying idea is that both national industry specific demand shocks and the lagged industry composition of MSA employment are exogenous to local employment growth.

The results of our final specification test are reported in Table 5. The results are based on the sample of MSAs with lax land use regulation only. We limit the sample size to these MSAs because strict land use controls that prevent new housing supply and the conversion of buildings or units can be expected to also prevent in-migration (i.e., house prices will adjust rather than the quantity or quality of the housing stock).[23] Overall, the results provide tentative support for the proposition that the housing supply adjustments are driven by migration. MSAs with more immigration observed an increase in the share of new *mf* units being constructed, consistent with Prediction 1. The results reported in columns (2) and (3) furthermore suggest that stronger in-migration leads to smaller unit sizes and the negative effect is much stronger for *mf* units.

5. Conclusions

Economic conditions appear to have a strong impact on the composition (type and size) of newly constructed housing units, as well as on their location within urban areas. Our most marked finding is the sensitivity is the sensitivity of the share of *mf* housing to local income, which is particularly strong in city centers.

With rising incomes, more *mf* units are being constructed and *sf* construction appears to be pushed to the suburbs. Furthermore, in times when incomes rise, smaller dwellings are built (which particularly cater to immigrant populations).

The standard urban economic model is a useful starting point for explaining these findings. In an open city where utility is exogenous because of migration, rising incomes should lead to higher land prices and therefore a higher capital intensity of land use. We have

[23] We also estimated the specifications for the full sample that includes MSAs with strict land use controls. As expected, the results are much less clear-cut.

proposed a stylized model in which this effect is brought about through substitution from *sf* to *mf* construction and through a reduction of the square footage of dwellings, consistent with our main empirical findings. In the short run, such substitution processes may even be more pronounced, since the supply of readily developable land is inelastic, particularly in city centers. However, the substitution towards constructing smaller *mf* housing units is likely to result also from shifts in the composition of housing demand following an income shock. Cities in which incomes rise faster than the national trend will attract migrants, who exert a demand for (temporary) rental accommodation until they have decided whether and where to settle in the city. Multifamily structures are the more efficient way to provide this type of housing.

Slicing our data with respect to the stringency of land use regulation, we find that the market responses that one would expect on the basis of these theoretical considerations are completely muted in MSAs in which this type of regulation is more severe. Presumably through zoning measures that limit development densities in order to exclude certain population groups from entering local communities, newly built houses and apartments are not significantly smaller when incomes rise and substitution towards *mf* construction is prohibited. To the extent that this type of housing caters to migrants, land use regulation may thus limit the labor supply response to demand shocks and hamper urban job growth, in line with the arguments put forward in Glaeser et al. (2006) and Saks (2008).

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Appendix

A1 Proof of Prediction 1

We show that for the case of ω = 1, in which housing is fully malleable, an increase in income raises the share of *mf* housing in new construction. To this aim, we compare the steady state scenario 0 to the situation 1 after a positive income shock.

In the steady state scenario, the number N_{sf}^0 of newly built *sf* units is:

$$N_{sf}^0 = \int_{x^*}^{x^b} 2\pi x g_{sf}^0(x)dx\,, \tag{A1}$$

where $g_{mf}(.)\left[\equiv 1/s_{mf}\right]$ denotes the density of single family houses. The income shock shifts the boundaries x^* and x^b by c units, where it has been derived in the main text that $c = \Delta y/t$. The number of *sf* units after the shock is therefore:

$$\begin{aligned} N_{sf}^1 &= \int_{x^*+c}^{x^b+c} 2\pi x g_{sf}^1(x)dx \\ &= \int_{x^*}^{x^b} 2\pi(x+c)g_{sf}^1(x+c)dx \\ &= \int_{x^*}^{x^b} 2\pi(x+c)g_{sf}^0(x)dx \\ &= \int_{x^*}^{x^b} 2\pi x g_{sf}^0(x)dx + \int_{x^*}^{x^b} 2\pi c g_{sf}^0(x)dx \\ &= N_{sf}^0 + \int_{x^*}^{x^b} 2\pi c g_{sf}^0(x)dx \end{aligned} \tag{A2}$$

The second line follows from a simple change of variables. The third line uses the fact that the income shock shifts the bid rent curve, and therefore also the lot size curve, horizontally. The fourth line is a simple elaboration of the third one and the last line uses (A1). Now, the relative change in the number of single family houses may be written as:

$$\frac{N_{sf}^1 - N_{sf}^0}{N_{sf}^0} = \frac{\int_{x^*}^{x^b} 2\pi c g_{sf}^0(x)dx}{\int_{x^*}^{x^b} 2\pi x g_{sf}^0(x)dx}\,. \tag{A3}$$

Next, it follows from the *mean value theorem for integration* that there exists a $\hat{x}^{sf}$ between x^* and x^b for which it holds that:

$$\int_{x^*}^{x^b} 2\pi x g_{sf}^0\left(x\right)dx = \hat{x}^{sf}\int_{x^*}^{x^b} 2\pi g_{sf}^0\left(x\right)dx\,. \tag{A4}$$

The value $\hat{x}^{sf}$ may be interpreted as the weighted mean of x over the interval $\left[x^*, x^b\right]$, where the weighting function is given by $2\pi g_{sf}^0\left(x\right)$. Clearly, if this weighting function were flat, that is the population density would not depend on the distance to the CBD, we would have $\hat{x}^{sf} = \left(x^b - x^*\right)/2$. However, it follows from convexity of the bid rent curve that the population density function $g_{sf}^0\left(x\right)$ is downward sloping, so that in fact $\hat{x}^{sf} < \left(x^b - x^*\right)/2$. Furthermore, it is intuitive that $\hat{x}^{sf}$ moves closer to x^* when the density gradient is steeper, because in this case, smaller values of x get a higher weight in the mean. We will need to make use of this property in Appendix A2. Substitution of (A4) into (A3) yields:

$$\frac{N_{sf}^1 - N_{sf}^0}{N_{sf}^0} = \frac{c}{\hat{x}^{sf}}\,. \tag{A5}$$

A similar exercise may be carried out for the number of newly built *mf* units. In the steady state scenario we have:

$$N_{mf}^0 = F\int_0^{x^*} 2\pi x g_{mf}^0\left(x\right)dx\,, \tag{A6}$$

and after the income shock:

$$\begin{aligned}
N_{mf}^1 &= F\int_0^{x^*+c} 2\pi x g_{mf}^1\left(x\right)dx \\
&= F\int_0^{x^*} 2\pi\left(x+c\right)g_{mf}^1\left(x+c\right)dx + F\int_0^{c} 2\pi x g_{mf}^1\left(x\right)dx \\
&= F\int_0^{x^*} 2\pi\left(x+c\right)g_{mf}^0\left(x\right)dx + F\int_0^{c} 2\pi x g_{mf}^1\left(x\right)dx \\
&= F\int_0^{x^*} 2\pi x g_{mf}^0\left(x\right)dx + F\int_0^{x^*} 2\pi c g_{mf}^0\left(x\right)dx + F\int_0^{c} 2\pi x g_{mf}^1\left(x\right)dx \\
&= N_{mf}^0 + F\int_0^{x^*} 2\pi c g_{sf}^0\left(x\right)dx + F\int_0^{c} 2\pi x g_{mf}^1\left(x\right)dx.
\end{aligned} \tag{A7}$$

In the second line we have distinguished explicitly between the houses in the shifted part of the bid rent curve for multifamily housing (the first term) and the area close to the CBD that becomes available for construction of multifamily housing after the shift of the original bid-rent curves. The other steps in this derivation are similar to those in (A2).

Again, by application of the mean value theorem for integration, we obtain an $\hat{x}^{mf}$ in the interval between 0 and $x*$ for which it holds that:

$$\int_0^{x^*} 2\pi x g_{mf}^0(x)\,dx = \hat{x}^{mf} \int_0^{x^*} 2\pi g_{mf}^0(x)\,dx, \qquad \text{(A8)}$$

and for similar reasons, it must hold that $\hat{x}^{mf} < x^*/2$ and that $\hat{x}^{sf}$ moves closer to 0 when the density gradient is steeper. Hence, we may derive:

$$\frac{N_{mf}^1 - N_{mf}^0}{N_{mf}^0} = \frac{c}{\hat{x}^{mf}} + \frac{\int_0^c 2\pi x g_{mf}^1(x)\,dx}{N_{mf}^0}. \qquad \text{(A9)}$$

Since $\hat{x}^{mf} < \hat{x}^{sf}$, we have that $c/\hat{x}^{mf} > c/\hat{x}^{sf}$. Furthermore, the second term in (A9) is positive. Therefore, it must be the case that:

$$\frac{N_{mf}^1 - N_{mf}^0}{N_{mf}^0} > \frac{N_{sf}^1 - N_{sf}^0}{N_{sf}^0}. \qquad \text{(A10)}$$

The number of newly built *mf* units rises faster after a positive income shock than the number of *sf* units, so that its share in new construction must rise.

A2 Proof of Prediction 2

We now consider the impact of a positive income shock on the average amount of floor space in newly built units, for the case of $\omega = 1$. Let A_i denote the total surface of the area in the city in which housing of type i is constructed. The average amount of floor space in new construction is then given by A_i/N_i, and the relative increase in this amount is given by $\left(A_i^1 - A_i^0\right)/A_i^0 - \left(N_i^1 - N_i^0\right)/N_i^0$. The second term of this expression has been derived in Appendix A1. With respect to the first term, it is easy to verify that:

$$A_{mf}^0 = \pi(x^*)^2, \text{ and}$$

$$A_{mf}^1 = \pi\left((x^*)^2 + 2cx^* + c^2\right). \qquad \text{(A11)}$$

Hence:

$$\frac{A_{mf}^1 - A_{mf}^0}{A_{mf}^0} = \frac{c}{x^*/2} + \left(\frac{c}{x^*}\right)^2. \qquad \text{(A12)}$$

We can derive similarly:

$$\frac{A_{sf}^1 - A_{sf}^0}{A_{sf}^0} = \frac{c}{\left(x^b + x^*\right)/2}. \qquad \text{(A13)}$$

Note that comparison of (A12) and (A13) shows that the percentage change in the area used for *mf* housing construction exceeds the percentage change in the area used for *sf* housing construction, so that the share of land used for *mf* construction rises with income.

Subtracting (A5) from (A13), we obtain the percentage change in average floor size in the *sf* sector:

$$\frac{c}{\left(x^b + x^*\right)/2} - \frac{c}{\hat{x}^{sf}}. \tag{A14}$$

As discussed in Appendix A1, we have that $\hat{x}^{sf} < \left(x^b - x^*\right)/2$ as the population density gradient is downward sloping. Hence, the average floor size in newly constructed *sf* units falls with income. For multifamily housing we find:

$$\left[\frac{c}{x^*/2} - \frac{c}{\hat{x}^{mf}}\right] + \left[\left(\frac{c}{x^*}\right)^2 - \frac{1}{N_0^{mf}}\int_0^c 2\pi x g_{mf}^1\left(x\right)dx\right]. \tag{A15}$$

As the population density gradient is downward sloping, we have that $\hat{x}^{mf} < x^*/2$, so that the first term in square brackets is negative. The second term in square brackets is also negative, because of the following inequality:

$$\frac{N_0^{mf}}{\pi\left(x^*\right)^2} < \frac{1}{\pi c^2}\int_0^c 2\pi x g_{mf}^1\left(x\right)dx. \tag{A16}$$

Since the density gradient of *mf* units is downward sloping, it must be the case that the density of *mf* units is higher in the area close to the CBD that becomes available after the shift of the original bid-rent curves than in the area used for construction of *mf* housing in the steady state scenario. Hence, both terms in square brackets in (A15) are negative, and we have that the average floor size in newly constructed *mf* units falls with income.

A sufficient condition for the claim in Prediction 2 that the effect is stronger for the *mf* sector than for the *sf* sector, that is (A15) is smaller than (A14), is that

$$\left[\frac{1}{x^*/2} - \frac{1}{\hat{x}^{mf}}\right] < \left[\frac{1}{\left(x^* + x^b\right)/2} - \frac{1}{\hat{x}^{sf}}\right]. \tag{A17}$$

This condition is equivalent to:

$$\left[\frac{x^*/2 - \hat{x}^{mf}}{x^*}\right] > \left(\frac{\hat{x}^{mf}}{\hat{x}^{sf}}\right)\left(\frac{x^b - x^*}{x^b + x^*}\right)\left[\frac{\left(x^* + x^b\right)/2 - \hat{x}^{sf}}{x^b - x^*}\right]. \tag{A18}$$

For both sectors, the terms between square brackets measure the distance between $\hat{x}^i$ and the middle of the interval over which the mean of x is taken, scaled to the length of this interval.

We would expect the density gradient of *mf* units to be steeper than the density gradient of *sf* units[24], which would push the weighted mean value of x closer to the left boundary of its interval in the *mf* sector than in the *sf* sector, as explained in Appendix A1. This effect may be counterbalanced by the fact that densities are higher everywhere in the *mf* sector, which pushes $\hat{x}^{mf}$ towards x^*. However, even if this effect is stronger, and $\left(x^*/2-\hat{x}^{mf}\right)\big/x^* < \left(\left(x^*+x^b\right)/2-\hat{x}^{sf}\right)\big/\left(x^b-x^*\right)$, inequality (18) is still likely to hold because both factors $\hat{x}^{mf}\big/\hat{x}^{sf}$ and $\left(x^b-x^*\right)\big/\left(x^b+x^*\right)$ should be significantly smaller than unity in most cities. Moreover, even if condition (A18) is not met, but the two terms are not too far apart, average floor sizes may still decline by more in the *mf* sector than in the *sf* sector, because of the second term in square brackets in (A15): *mf* units that are built in the area close to the CBD that becomes available after the shift of the original bid-rent curves are relatively small.

[24] For most cities, the urban density gradients roughly conforms an exponential function (Anas et al., 1998), so that the slope of the density function becomes less steep as the distance to the CBD increases. Traffic congestion in areas closer to the CBD may be one of the explanations for this phenomenon (Anas et al., 2000). Since the *sf* sector is further away from the CBD than the *mf* sector, it should be expected that density gradients in this sector are less steep.

TABLES

TABLE 1

Metro-Area Level Summary Statistics

Variable	Mean	Std. Dev.	Between	Within	Min	Max	Clusters	Obs.
A. Full sample - no metro-dimension								
Share multifamily (*mf*) units	0.298	0.169	0.127	0.118	0	0.939	167	1829
Share of single family (*sf*) units within center city	0.153	0.196	0.178	0.090	0	1	152	1694
Share of *mf* units within center city	0.315	0.288	0.215	0.194	0	1	152	1659
Unit square footage, *sf*	2216	391	288	275	894	4453	167	1548
Unit square footage, *mf*	1632	888	592	691	340	5000	167	1513
Income per capita (p.a.)	17855	6448	6377	3623	7616	42030	167	1829
MSA population	2872300	2956012	2937453	203213	635318	17000000	167	1829
Wage per employee in construction sector (p.a.)	28597	7695	7465	4296	14546	56520	167	1829
B. Metro areas with more stringent land use regulation								
Share *mf* units	0.311	0.173	0.134	0.114	0	0.939	84	911
Share of *sf* units within center city	0.126	0.186	0.174	0.086	0	1	74	821
Share of *mf* units within center city	0.267	0.262	0.188	0.183	0	1	74	810
Unit square footage, *sf*	2227	411	278	311	894	4453	84	779
Unit square footage, *mf*	1688	916	633	701	340	5000	84	764
Income per capita (p.a.)	18521	6685	6506	3773	8262	42030	84	911
MSA population	3569994	3822744	3795910	224559	635318	17000000	84	911
Wage per employee in construction sector (p.a.)	29975	8241	7845	4712	14559	56520	84	911
C. Metro areas with less stringent land use regulation								
Share *mf* units	0.285	0.165	0.120	0.121	0	0.826	83	918
Share of *sf* units within center city	0.177	0.201	0.179	0.093	0	0.889	78	873
Share of *mf* units within center city	0.361	0.305	0.229	0.203	0	1	78	849
Unit square footage, *sf*	2204	369	299	232	1320	3794.733	83	769
Unit square footage, *mf*	1574	855	540	681	400	4999.998	83	749
Income per capita (p.a.)	17195	6136	6232	3470	7616	40324	83	918
MSA population	2179926	1397685	1395266	179664	837147	8304560	83	918
Wage per employee in construction sector (p.a.)	27229	6847	6890	3840	14546	53207.98	83	918
D. Center cities of metro areas								
Share *mf* units	0.348	0.179	0.155	0.098	0.000	0.824	110	328
Unit square footage, *sf*	2072	393	321	270	894	4452.535	103	268
Unit square footage, *mf*	1485	672	661	393	600	4999.998	102	264

TABLE 2
Base Specifications (Weighted Fixed Effects Models)

Dependent variables: Characteristics of newly built housing stock

	(1)	(2)	(3)	(4)	(5)
	Share *mf* units	Log (unit sq. foot, *sf*)	Log (unit sq. foot, *mf*)	Share of *sf* in centre	Share of *mf* in centre
Log(Personal income per capita), 1-year lagged	0.640**	-0.467*	-1.742**	-0.506*	-0.275
	(0.136)	(0.226)	(0.492)	(0.227)	(0.262)
Log(Construction sector annual wage per employee), 1-year lagged	-0.117	-0.071	0.166	0.209+	0.339*
	(0.110)	(0.120)	(0.303)	(0.107)	(0.153)
Metro area × AHS-year fixed effects	Yes	Yes	Yes	Yes	Yes
Year built-fixed effects†	Yes	Yes	Yes	Yes	Yes
Constant	-4.247**	12.501**	21.503**	2.727+	-0.394
	(0.924)	(1.830)	(3.930)	(1.443)	(1.902)
Observations	1829	1548	1513	1694	1659
Adjusted R-squared	0.60	0.62	0.45	0.81	0.60

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%. † Coefficients and robust standard errors of year built-fixed effects are reported in Appendix Table A3.

TABLE 3
Center City Submarkets within Metro Areas

Dependent variables: Characteristics of newly built housing stock

	(1)	(2)	(3)
	Share *mf* units	Log (unit sq. foot, *sf*)	Log (unit sq. foot, *mf*)
Log(Personal income per capita), 1-year lagged	1.510**	-0.700*	-1.530**
	(0.221)	(0.352)	(0.557)
Log(Construction sector annual wage per employee), 1-year lagged	0.098	-0.095	-0.219
	(0.285)	(0.253)	(0.479)
Constant	-14.012**	14.781**	23.156**
	(2.136)	(3.048)	(5.856)
Observations	1440	958	1045
Adjusted R-squared	0.48	0.22	0.29

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%.

TABLE 4
More Regulated versus Less Regulated Metro Areas

Dependent variables: Characteristics of newly built housing stock

	(1)	(2)	(3)	(4)	(5)
	Share *mf* units	Log (unit sq. foot, *sf*)	Log (unit sq. foot, *mf*)	Share of *sf* in centre	Share of *mf* in centre
Panel A: Metro Areas with *More Restrictive* Land Use Regulations Only					
Log(Personal income per capita), 1-year lagged	-0.034	-0.100	-0.139	-0.007	0.104
	(0.290)	(0.454)	(0.849)	(0.173)	(0.499)
Log(Construction sector annual wage per employee), 1-year lagged	0.193	-0.206	-0.276	0.075	-0.094
	(0.145)	(0.191)	(0.439)	(0.097)	(0.237)
Metro area × AHS-year FEs	Yes	Yes	Yes	Yes	Yes
Year built-fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	-1.163	10.540**	11.438+	-0.518	0.309
	(2.055)	(3.210)	(6.026)	(1.067)	(3.143)
Observations	911	779	764	821	810
Adjusted R-squared	0.62	0.55	0.43	0.85	0.55
Panel B: Metro Areas with *Less Restrictive* Land Use Regulations Only					
Log(Personal income per capita), 1-year lagged	0.878**	-0.569**	-2.440**	-0.818*	-0.380
	(0.149)	(0.173)	(0.419)	(0.336)	(0.318)
Log(Construction sector annual wage per employee), 1-year lagged	-0.339*	0.014	0.394	0.377*	0.750**
	(0.133)	(0.153)	(0.403)	(0.163)	(0.189)
Metro area × AHS-year FEs	Yes	Yes	Yes	Yes	Yes
Year built-fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	-4.223**	12.562**	25.433**	3.929+	-3.370
	(1.226)	(1.688)	(4.555)	(2.208)	(2.734)
Observations	918	769	749	873	849
Adjusted R-squared	0.62	0.69	0.44	0.78	0.60

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%. Sample split is based on the mean of an index of regulatory tightness during the 80s (Saks, 2008) and during the early 00s (Gyourko *et al.*, 2008; Saiz, 2008).

TABLE 5
Are the Results Driven by Migration? (TSLS-Estimates)

Dependent variables: Characteristics of newly built housing stock

	Metro Areas with *Less Restrictive* Land Use Regulation				
	(1)	(2)	(3)	(4)	(5)
	Share *mf* units	Log (unit sq. foot, *sf*)	Log (unit sq. foot, *mf*)	Share of *sf* in centre	Share of *mf* in centre
Employment growth, 1-year lagged	**1.448****	**-0.343**	**-2.271**	**-1.452***	**-0.581**
	(0.532)	**(0.581)**	**(1.506)**	**(0.581)**	**(0.963)**
Log(Construction cost sector annual wage per employee), 1-year lagged	0.047	-0.241+	-0.769+	0.105	0.774**
	(0.123)	(0.132)	(0.435)	(0.140)	(0.180)
Constant	-0.253	10.200**	15.017**	-1.124	-7.892**
	(1.301)	(1.392)	(4.573)	(1.463)	(1.873)
Observations	751	667	649	706	684
First-stage F: employment growth	20.6	11.8	21.6	30.2	32.4

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%. **Bold** variable is endogenous. Excluded instrument is labor demand shock variable.

APPENDIX TABLES

TABLE A1
AHS-Survey Years and Included MSAs

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1995	1996	1998	2002	2004	Total
Anaheim-Santa Ana (Or			1				1					1		1		4
Atlanta, GA				1				1				1			1	4
Baltimore, MD				1				1					1			3
Birmingham, AL	1				1				1				1			4
Boston, MA		1				1				1			1			4
Buffalo, NY	1				1							1		1		4
Charlotte, NC											1			1		2
Chicago, IL				1				1								2
Cincinnati, OH-KY-IN			1				1						1			3
Cleveland, OH	1				1				1			1			1	5
Columbus, OH				1				1			1			1		4
Dallas, TX		1				1						1		1		4
Denver, CO			1				1				1				1	4
Detroit, MI		1				1				1						3
Fort Worth-Arlington,		1				1						1		1		4
Hartford, CT				1				1				1			1	4
Houston, TX				1				1					1			3
Indianapolis, IN	1				1				1			1			1	5
Kansas City, MO-KS			1				1				1			1		4
Los Angeles-Long Beac		1				1										2
Memphis, TN-AR-MS	1				1				1			1			1	5
Miami-Hialeah, FL			1				1				1			1		4
Milwaukee, WI	1				1							1		1		4
Minneapolis-Saint Pau		1				1				1			1			4
New Orleans, LA			1				1				1				1	4
New York City, NY				1				1								2
Newark, NJ				1				1								2
Norfolk-Newport News	1				1				1				1			4
Oakland, CA													1			1
Oklahoma City, OK	1				1				1			1			1	5
Philadelphia, PA-NJ		1				1										2
Phoenix, AZ		1				1						1		1		4
Pittsburgh, PA			1				1				1				1	4
Portland, OR			1				1				1			1		4
Providence, RI	1				1				1				1			4
Riverside-San Bernard			1									1		1		3
Rochester, NY			1				1						1			3
Sacramento, CA												1			1	2
Saint Louis, MO-IL				1				1				1			1	4
Salt Lake City-Ogden,	1				1				1				1			4
San Antonio, TX			1				1				1				1	4
San Diego, CA				1				1				1		1		4
San Francisco, CA		1				1				1			1			4
San Jose, CA	1				1					1			1			4
Seattle, WA				1								1			1	3
Tampa-Saint Petersbur		1				1				1			1			4
Washington, DC-MD-VA		1								1			1			3
Total	11	11	11	11	11	10	10	10	8	7	9	17	15	13	13	167

TABLE A2
Base Specifications, Year-Built Dummy Variables

	(1)	(2)	(3)	(4)	(5)
	Share *mf*	Log (sq.f., *sf*)	Log (sq.f., *mf*)	Share *sf* in centre	Share *mf* in centre
Built 1980	-0.105**	0.069*	0.043	0.030	-0.035
	(0.018)	(0.030)	(0.062)	(0.025)	(0.032)
Built 1981	-0.182**	0.182**	0.367**	0.060	-0.041
	(0.027)	(0.052)	(0.105)	(0.044)	(0.051)
Built 1982	-0.242**	0.173*	0.400**	0.138*	-0.020
	(0.038)	(0.072)	(0.149)	(0.065)	(0.070)
Built 1983	-0.314**	0.163+	0.539**	0.126	-0.052
	(0.045)	(0.083)	(0.173)	(0.077)	(0.082)
Built 1984	-0.294**	0.216*	0.589**	0.165+	-0.080
	(0.047)	(0.094)	(0.197)	(0.085)	(0.093)
Built 1985	-0.319**	0.297**	0.723**	0.204+	-0.090
	(0.057)	(0.113)	(0.237)	(0.104)	(0.111)
Built 1986	-0.384**	0.372**	0.842**	0.212+	-0.075
	(0.066)	(0.124)	(0.258)	(0.114)	(0.127)
Built 1987	-0.455**	0.415**	0.880**	0.232+	-0.049
	(0.069)	(0.131)	(0.285)	(0.124)	(0.137)
Built 1988	-0.484**	0.490**	1.017**	0.234+	-0.023
	(0.076)	(0.142)	(0.294)	(0.131)	(0.147)
Built 1989	-0.550**	0.519**	1.131**	0.252+	-0.000
	(0.081)	(0.154)	(0.321)	(0.139)	(0.158)
Built 1990	-0.583**	0.530**	1.280**	0.286+	0.019
	(0.088)	(0.170)	(0.363)	(0.150)	(0.167)
Built 1991	-0.652**	0.601**	1.336**	0.301+	-0.037
	(0.091)	(0.182)	(0.384)	(0.157)	(0.171)
Built 1992	-0.723**	0.584**	1.386**	0.282+	-0.025
	(0.093)	(0.192)	(0.401)	(0.164)	(0.177)
Built 1993	-0.774**	0.602**	1.362**	0.292+	-0.024
	(0.098)	(0.200)	(0.417)	(0.168)	(0.185)
Built 1994	-0.764**	0.624**	1.555**	0.303+	-0.051
	(0.097)	(0.206)	(0.427)	(0.171)	(0.198)
Built 1995	-0.757**	0.676**	1.551**	0.308+	-0.050
	(0.103)	(0.212)	(0.443)	(0.179)	(0.204)
Built 1996	-0.811**	0.683**	1.649**	0.314+	-0.147
	(0.107)	(0.226)	(0.466)	(0.185)	(0.199)
Built 1997	-0.801**	0.716**	1.721**	0.349+	-0.098
	(0.113)	(0.233)	(0.489)	(0.195)	(0.218)
Built 1998	-0.820**	0.733**	1.806**	0.363+	-0.132
	(0.119)	(0.244)	(0.515)	(0.204)	(0.230)
Built 1999	-0.860**	0.794**	1.937**	0.386+	-0.092
	(0.122)	(0.254)	(0.534)	(0.214)	(0.244)
Built 2000	-0.875**	0.860**	1.955**	0.413+	-0.073
	(0.127)	(0.263)	(0.551)	(0.218)	(0.260)
Built 2001	-0.942**	0.883**	2.049**	0.430+	-0.051
	(0.134)	(0.279)	(0.581)	(0.230)	(0.269)
Built 2002	-0.950**	0.916**	2.035**	0.414+	-0.052
	(0.136)	(0.280)	(0.584)	(0.234)	(0.278)
Built 2003	-0.962**	0.928**	2.204**	0.380	-0.012
	(0.138)	(0.283)	(0.590)	(0.234)	(0.277)
Built 2004	-0.954**	0.981**	2.013**	0.388	-0.003
	(0.144)	(0.287)	(0.598)	(0.238)	(0.286)

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%.

TABLE A3
Base Specifications but with Contemporaneous / 2-Year Lagged Explanatory Variables

Dependent variables: Characteristics of newly built housing stock

	(1) Share *mf* units	(2) Log (unit sq. foot, *sf*)	(3) Log (unit sq. foot, *mf*)	(4) Share of *sf* in centre	(5) Share of *mf* in centre
Panel A: Contemporaneous Explanatory Variables					
Log(Personal income per capita), contemporaneous	0.659**	-0.507*	-1.867**	-0.566*	-0.498+
	(0.154)	(0.256)	(0.550)	(0.250)	(0.287)
Log(Construction cost sector annual wage per employee), contemporaneous	-0.137	-0.001	0.018	0.192+	0.341*
	(0.104)	(0.122)	(0.328)	(0.108)	(0.171)
Metro area × AHS-year FEs	Yes	Yes	Yes	Yes	Yes
Year built-fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	-4.285**	12.239**	24.295**	3.487*	1.635
	(1.068)	(1.996)	(4.022)	(1.651)	(2.039)
Observations	1829	1548	1513	1694	1659
Adjusted R-squared	0.60	0.62	0.45	0.81	0.60
Panel B: 2-Year Lagged Explanatory Variables					
Log(Personal income per capita), 2-year lagged	0.536**	-0.402*	-1.313**	-0.353+	-0.084
	(0.148)	(0.202)	(0.474)	(0.191)	(0.260)
Log(Construction cost sector annual wage per employee), 2-year lagged	-0.103	-0.086	0.329	0.148	0.289+
	(0.130)	(0.118)	(0.278)	(0.101)	(0.155)
Metro area × AHS-year FEs	Yes	Yes	Yes	Yes	Yes
Year built-fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	-3.395**	12.011**	15.890**	1.912	-1.620
	(0.997)	(1.581)	(3.987)	(1.198)	(1.921)
Observations	1829	1548	1513	1694	1659
Adjusted R-squared	0.60	0.62	0.44	0.81	0.60

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%.

TABLE A4
Base Specifications but with 5-Year instead of 10-Year Window

Dependent variables: Characteristics of newly built housing stock

	(2) Log (unit sq. foot, *sf*)	(3) Log (unit sq. foot, *mf*)
Log(Personal income per capita), 1-year lagged	-0.526*	-2.026**
	(0.212)	(0.640)
Log(Construction sector annual wage per employee), 1-year lagged	-0.019	-0.083
	(0.143)	(0.398)
Metro area × AHS-year FEs	Yes	Yes
Year built-fixed effects	Yes	Yes
Constant	12.549**	26.578**
	(1.769)	(5.926)
Observations	973	949
Adjusted R-squared	0.67	0.46

Notes: Robust standard errors in parentheses. + Significant at 10%; * significant at 5%; ** significant at 1%.