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House Prices and Female Labor Force Participation*

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Abstract: The simple correlation between relative house prices and female labor force participation across US metro areas is positive. Both have risen over the last forty years. Causation could be in either direction. High house prices could induce women to work or labor force participation could drive up the price of housing. I construct a model of endogenous housing and labor market decisions which predicts that shocks to house prices will raise female labor force participation, while shocks to female labor supply will raise house prices. Using geographical instruments on cross-section data, I find that higher house prices do not raise women's labor force participation or earnings. In contrast, when I instrument for female labor force participation, I find substantial evidence that greater female labor market activity leads to higher house prices. The estimated cross-section effect is large enough to imply that the rise in female labor force participation over the past 40 years could explain a substantial portion of the rise in the relative price of housing over the same period.

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Two salient changes over the past four decades have been the rising labor force participation of married women and an increase in the relative price of housing. This paper examines the possible links between the two phenomena. A plausible argument can be made for causation in either direction. Robert Frank and Philip Cook (1995) have argued that the higher relative cost of housing induces households to supply more labor to the market by sending two earners into the labor market. But an equally plausible case could be made for the causation running in the opposite direction. The rise of two-earner families bids up the price of land thereby raising the relative price of housing. This direction of causation is consistent with the findings of Gyourko, Mayer and Sinai (2006) who identify increasing national income inequality as a force creating "superstar cities" with markedly higher relative housing costs as the housing demands of an expanding number of high-income households collide with housing supply constraints in certain cities. Although Gyourko, Mayer and Sinai do not explicitly mention the rise of two-income households as a cause of increasing income inequality, other studies have found that assortative mating and a greater tendency for well-educated wives to pursue careers exacerbates income inequality across households.

This paper tries to untangle the direction of causation using data on a cross-section of US metropolitan areas. The simple cross-section relation between real house prices and married women's labor force participation is positive – high-priced housing markets are associated with greater female labor force participation. This could arise because 1) high house prices induce women to work; 2) more working women bid up housing prices; or 3) a third variable is correlated with both house prices and labor force participation of women. My empirical results suggest that higher female labor force participation leads to higher house prices, but not the reverse. This finding could help explain the rise over time in relative house prices as at least partly the result of increasing labor force activity of women.

A simple model of labor supply and residential location within a metropolitan area motivates both directions of causation. Assuming a monocentric city in which all employment occurs at the center, households with two earners will have a greater incentive to save on commuting cost by locating close to the city center, bidding up the price of close-in land and raising the overall cost of housing. Other things equal, cities with more two-earner households will have higher land prices. Labor supply choices are made in the standard way, balancing the value of non-market time against the purchased goods foregone by not working, but the household also takes into account the cost of housing and commuting. With reasonable assumptions about preferences and positive assortative mating, the model shows that high wage households will choose to send two earners into the labor market and will reside in high priced housing close to the city center. Lower wage households will have only one earner and will live on the periphery in lower priced housing.

The model can generate cross-section differences in labor supply and house prices across metropolitan areas. Cities may differ in the capacity to build housing close to the city center; the model captures that with a parameter which represents the fraction of land that is buildable. The cost of building may also differ across cities due to legal restrictions or geographic conditions. These supply factors will affect the price of housing across metropolitan areas and, indirectly, labor supply since the decision to work depends on housing costs and commuting times[1].

Metro areas might also differ in factors that affect the demand for housing and the supply of labor. If preferences for purchased goods relative to non-market time differ across cities, that may be reflected both in labor supply behavior and in housing prices. Climate, for example, might affect preferences for purchased goods over leisure.[2] Religious affiliation could be an indicator of preferences for purchased goods. Moreover, cities may differ both in the productivity-related individual characteristics of their residents, such as education, and in factors like capital or infrastructure complementary to labor generating real wage differences across cities which will also affect labor supply and house prices.

The model generates some empirical implications that are confirmed by the data. House prices are higher and commuting times are longer in metropolitan areas with less close-in buildable land. Married women are less likely to work in cities with longer commuting times and less expensive housing as well as more favorable climates.

The hypothesis that house prices cause female labor supply can be probed by instrumenting for endogenous house prices to estimate the extent to which exogenous variations in house prices across metropolitan areas affect married women's labor force participation. The instruments are measures of the physical and climatic characteristics of metropolitan housing markets which affect both the cost of building and the desirability of the location. The results show no significant effect of house prices on labor

[1] The role of commuting time in explaining cross metro area differences in women's labor force participation is highlighted in the work of Black, Kolesnikova and Taylor (2008).
[2] Or, more accurately, individuals with greater taste for leisure activities might gravitate to cities with favorable climates.

supply. The reverse direction of causation is examined by instrumenting for female labor supply in an equation explaining house price variation across metro areas. Here the instruments are determinants or correlates of labor supply that are arguably exogenous to the housing market such as religious affiliation and female educational attainment. The instrumental variable estimates suggest that exogenous variation in female labor supply across metro areas affects house prices.

I. The Empirical Puzzle

The rise in the labor market activity of women, especially married women with children, is well-known and has been a central focus of research attention by labor economists. The fraction of married women in the labor market has more than doubled since 1960. Economic explanations for this increase have centered on the rising relative wages of women, availability of effective contraception, and the changing structure of labor demand. Non-economic explanations have relied on what economists term changes in tastes or what sociologists call "norms".

The second time-series observation is the rising relative price of housing in the United States. Although the housing market is cyclic and localized, quality-adjusted house prices nationally have risen on average faster than overall inflation over the past 35 years at least. Houses have become more expensive relative to other goods. Since 1975, an index of house prices, based on repeat purchases of the same house, has risen 114% relative to the GDP deflator and 76% relative to the CPI.[3]

[3] See US Housing Finance Agency, http://www.fhfa.gov/webfiles/2350/1q09hpi_reg.txt

Cross-section evidence also points to a possible relation between house prices and women working. Housing markets and labor markets in the US are usually identified by metropolitan areas. House prices vary widely by metro area, with the highest prices in California, New York and New England. Less well known is the fact that female LFP varies substantially across metro areas with the highest rates in the upper Midwest.[4] The cross metro area relationship between female LFP and housing prices is significantly positive. In Figure 1, each additional percentage point of female LFP in the 2000 Census data is associated with $2000 extra in average house prices across metropolitan areas. So, the crude cross-section data agree with the time-series evidence.

Empirical associations between house prices and female LFP would not be worth pursuing were there not a plausible theory linking the two. In this case, there are at least *two* theories. First, it is argued that higher housing prices are the *cause* of married Women's LFP. For example, a recent popular book entitled The Two Income Trap (Warren(2003)) argues that housing has become so expensive that married women must work (in the paid labor force) to maintain the standard of living that households achieved in the 1950's with only one earner. This is essentially an argument based on falling real wages of husbands, a trend which is not evident in the aggregate data, so it would be hard to produce the time series pattern from this theory. To be sure, if house price inflation has been so intense in certain markets that the real earnings of men in those markets have decreased, that might raise female LFP in those markets. The reverse

[4] Black, Kolsnikova, and Taylor (2008) highlight the variation in married women's labor force participation across metro areas and conclude that commuting costs drive some of the variation. They find no correlation between labor force participation with housing cost differences but their analysis uses only 50 large MSAs. The analysis here uses over 200 MSAs. When I restrict my estimates to Black et al's smaller sample of metro areas, I, too, find no correlation between housing cost and labor force participation.

would be true in other housing markets, so this theory might be consistent with the cross-section evidence but not with the time series trends.

The other theoretical story reverses the direction of causation. Here some external cause sends more women into the labor market, raising household money incomes and setting off a bidding war for goods like housing that may be in relatively inelastic supply when location is accounted for. In the extreme form of this argument, with an absolutely fixed supply of housing, the households with the most income will get the best house, and so on down the line. The house a household attains will depend on its income relative to the income of other households. This is the mechanism in the popular book, The Winner-Take-All Society by economists Robert Frank and Philip Cook ((Frank 1995)). So, if other households send wives into the labor market that makes single-earner households worse off because those two-earner households now get the best houses. In other words, two-earner households bid up the price of housing. We would expect that over time, more married women working would lead to higher relative house prices, and that in metro areas with many married women working house prices will be higher.

II. A Model of Housing and Labor Force Participation

In this section, I sketch a simple model in which housing choices and wives' labor force participation are both endogenous at the individual level and housing markets clear at the level of the metropolitan area. Readers interested only in the empirical results can skip to section III. The model is static, the number of households is fixed, and each worker's wage rate is fixed. In other words, the metropolitan area labor market clears, trivially, because labor demand is assumed to be perfectly elastic. One could indigenize wages at some cost of complicating the model, but the main conclusions of the analysis remain.

Consider a metropolitan area in isolation The area consists of a central place of employment, a point with no area, surrounded by undifferentiated land on which housing can be built.[5] Every worker who is employed must commute to the center from his house; commuting costs are a function of the distance to the center and the opportunity cost of time, the wage rate. Every household consists of two adults who have the same wage rate, but wages vary across households. I assume that every husband works, but wives can choose whether or not to work. The labor supply choice is a binary one. Households with two earners and those with high wages will have a greater incentive to live close to the center to reduce commuting costs, creating a price premium for land close to the center. Households simultaneously choose where to live and whether the wife works, taking into account the equilibrium land prices for different locations.

Within a metro area, households are differentiated only by wages; they have identical preferences over leisure and non-housing consumption. Housing in the model is a "necessity" whose cost takes away from income available to spend on goods the household enjoys. A housing unit is produced by one unit of land, the same for every unit, plus per period resources of the amount B, representing the building. B is the same for every household within the metro area and is exogenous, but we will be interested in how changes in B affect land rents and labor force participation.

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[5] This monocentric city model is standard in urban economics although my modifications are not. See Goldstein and Moses (1973)

Household Choices

Each household consists of two adults, each of whom can earn *w* if they work. The wage, *w*, differs across households. Denoting *H* as a (0, 1) indicator of whether the wife works and recalling that all husbands work, household income is $w\ (1+H)$. Household utility depends on its non-labor time and money income less housing and commuting costs. The cost of housing is the sum of the per period building cost, *B*, and the land rent, *R*. Land rent will depend on distance from the center, *r*. Recall that each housing unit requires one unit of land and that all land is assumed homogeneous except for location. The household takes the land rent function *R(r)* as given and chooses a location, *r*. The center is $r = 0$.

Commuting costs reflect the distance from the center, *r*, the wage rate of the household and the number of workers in the household. Specifically, suppose that commuting costs per period are $w(1+H)r$, where distance from the center, *r*, can be thought of as being measured by the fraction of the worker's potential worktime spent on commuting. The participation constraint, which is assumed to be satisfied, requires r to be less than 1, enough so that even the lowest wage husband will want to work, living at the boundary of the city.

Suppose each household's preferences over non-market time and purchased goods less commuting cost are described by the Cobb-Douglas function:

(1) $$\left[k+(1-H)\right]^{1-\alpha}\left[w(1+H)-B-R(r)-w(1+H)r\right]^{\alpha}$$

Non-market time for the household is $k+(1-H)$, where *k* can be thought of as the household's non-market time when both adults work, and $k+1$ is the amount of non-market time for the household when only one adult works. All that matters for household choices is the ratio of *k* to $k+1$ and that is perfectly flexible depending on the value of *k*; the bigger is *k*, the smaller the proportional reduction in non-market time caused by the second adult working.

The household chooses *H* and *r* to maximize (1). The first order conditions for optimal *r* balance the cost of commuting against the higher cost of land closer in:

(2) $$\begin{array}{ll} R'(r)=-2w & \text{if } H=1 \\ R'(r)=-w & \text{if } H=0 \end{array}$$

(2) says that two income households will choose a location such that the rent gradient equals twice the wage, while one-earner households choose a location where the slope of the land rent gradient equals the wage. Since optimal location depends on *H* and *w*, we can write the household's optimal location as a function, $r(H,w)$.

Now consider the labor supply decision. The household opts for two earners if and only if

(3) $$\left(\frac{k}{1+k}\right)^{1-\alpha}>\left(\frac{w[1-r(0,w)]-R(r(0,w))-B}{2w[1-r(1,w)]-R(r(1,w))-B}\right)^{\alpha}$$

The left hand side of condition (3) is the ratio of non-market time with two vs. one earners, weighted by the weight of non-market time in household tastes $(1-\alpha)$, while the right-hand side is the ratio of income available for non-housing consumption with one vs. two earners, again weighted by its weight in the preference function, α.

If households differ only in their value of *w*, the highest wage households will choose two earners and the lowest wage households will choose one earner. To see intuitively why this is so, consider the right hand side of condition (3). If housing and commuting costs doubled when a second earner went to work, then the right hand side of (3) would be independent of *w*. But housing and commuting costs must less than double when a second earner enters the labor market for two reasons. First, the building cost, *B*, is independent of the number of earners. Second, since location, *r*, is chosen solely to minimize the sum of land rent and commuting costs, the worst a household could do when it sends a second earner into the labor force is to keep the same location, *r*, thereby doubling commuting cost but not changing land rent. So housing and commuting costs must increase but by less than a doubling when a second earner goes to work, implying that the ratio on the right hand side of (3) is a decreasing function of the household's wage, *w*.

Condition (3) also implies that building costs, *B*, will increase the likelihood of two earners. The intuition is that here housing is an unavoidable cost which reduces economic resources available for other purchases. With these Cobb-Douglas preferences, households will respond to an increase in housing costs by trying to earn more.

Market equilibrium

I now consider a metropolitan area composed of *N* households. The number of households with wage *w* is given by the function $n(w)$, with support $[\underline{w}, \overline{w}]$. Land can either be used for housing or for some non-housing activity (agriculture ?) with opportunity cost, *a*. I assume that every household in the city can have positive income net of housing and commuting costs; this is a participation constraint for the existence of the city's population. The lowest wage households will locate at the edge of the city on the boundary with undeveloped land. Denote the edge of the city by $\overline{r}$. Since each household requires one unit of land for housing, $\overline{r}$ is determined by $N = \pi \overline{r}^2$, or $\overline{r} = \sqrt{N/\pi}$. Figure 2 depicts the circular city.

Land rent at the edge of the city must equal its non-housing value, *a*, so the total housing and commuting costs of a one-earner household living on the edge of the city will equal $\underline{w}\sqrt{N/\pi} + B + a$. The participation constraint is that the wage income net of housing and commuting costs of that household be positive, or

$$\underline{w}\left(1 - \sqrt{N/\pi}\right) - B - a > 0 \tag{4}$$

The participation constraint puts an upper limit on the population of the city

$$N < \pi\left(1 - \frac{B+a}{\underline{w}}\right)^2 \tag{5}$$

which will be assumed to hold. This in turn puts an upper limit on the geographic size of the city, $\bar{r}$:

(6) $$\bar{r} < 1 - \frac{B + a}{\underline{w}}$$

Depending on the value of the preference parameter, α , and the wage distribution, the city might be composed entirely of one-earner households, entirely of two-earner households, or a mixture of one and two earner households. The last case is the most interesting case, so I focus on that. Since the only difference between households is their wage and since a higher wage makes it more likely that a household will have two earners, if there are both one-earner and two-earner households in the city, there must be a w^*, $\underline{w} < w^* < \bar{w}$, such that all households with $w > w^*$ choose $H = 1$ and all households with $w < w^*$ choose $H = 0$. The labor force participation rate of wives will equal the fraction of households with $w > w^*$, or

(7) $$LFPR = \frac{1}{N} \cdot \int_{w^*}^{\bar{w}} n(w) dw$$

LFPR is a decreasing function of *w**.

We can now derive the equilibrium land rent function R . The lowest wage households live at the urban boundary, where $r = \bar{r}$ and $R(\bar{r}) = a$. The highest wage households live at the center where $r=0$. Using the results in (2), we can derive the land rent at the center:

(8) $$R(0) = a + \int_{\underline{w}}^{w^*} (-w)dw + \int_{w^*}^{\overline{w}} (-2w)dw = a + \overline{w}^2 - \frac{1}{2}\left((w^*)^2 + \underline{w}^2\right)$$

Holding constant the opportunity cost of land, a, and the distribution of wages, *n(w)* , the lower is w^*, the higher will be labor force participation of wives and land rents at the center; housing costs and female labor force participation are thus simultaneously determined in the model. Figure 3 depicts equilibrium land rents and household wages as a function of r, distance from the center.

Comparative Statics across Metropolitan Areas

To this point, the model has focused on one metropolitan area. Now I consider a number of metropolitan areas, each with a fixed and equal population[6]. The model needs to explain differences in housing costs and labor supply across metro areas. On the housing supply side, metro areas may differ in the cost of building and in the amount of close-in land available for building. The parameter B captures the cost of building which may differ across metro areas; for example, Glaeser and Gyourko (2002) argue that legal restrictions are an important cause of differences in house prices across metro areas. The

[6] At this stage, the model makes the unrealistic assumption that all metro areas must accommodate the same population. Implicitly, the model does not allow migration between metro areas, although I argue below that allowing costly migration would not alter the direction of the comparative statics effects derived here

model can also reflect unbuildability by adding a parameter θ representing the fraction of land that can be used for building.[7] For simplicity, θ is taken to be constant across all distances from the center.

Introducing the new parameter, θ, alters the expression for the edge of the city to $\bar{r} = \sqrt{N/\theta\pi}$. Clearly, for a metro area with some unbuildable land ($\theta < 1$), the city must be built farther out to accommodate the same population, N.

The key endogenous variable in this model is *w**, the boundary wage between two earner households, who live close to the city center, and one earner households, who live farther away. Households with a wage of *w** are indifferent between sending one and two earners into the market, which implies that *w** is defined by:

(9)
$$\left(\frac{k}{1+k}\right)^{1-\alpha} = \left(\frac{w^*(1-r^*) - R^* - B}{2w^*(1-r^*) - R^* - B}\right)^{\alpha}$$

where *r** is the optimal location of a *w** household, and *R** is the land rent at *r* = *r**. The location of the borderline household is given by an expression which equates the demand for land closer than *r**, which is the population with wages greater than *w**, and the supply of land closer than *r**, which is just the buildable fraction θ times the area of a circle with radius *r**.

[7] Rose(1989) finds that both natural geographic restrictions on building and legally imposed restrictions affect urban land prices. Saiz (2008) shows that topographic variables affect housing supply elasticity.

(10) $$r^* = \sqrt{\frac{1}{\theta\pi}\int_{w^*}^{\bar{w}} n(w)dw}$$

Finally, the land rent at r^* can be found by solving the differential equation implied by the rent gradients (2) along with the boundary condition that rent at the edge of the city is a.

(11) $$R^* = a + \int_{\underline{w}}^{w^*} (-w)dw = a + \tfrac{1}{2}\left[(w^*)^2 - \underline{w}^2\right]$$

Comparative statics of the system (9), (10), and (11) with respect to parameters $\alpha, B,$ and θ are derived in the appendix. From these we can derive the following results. First, an increase in the preference parameter, α, roughly speaking, the strength of preference for purchased goods, raises the labor force participation of wives and pushes out the boundary between the two income and one income households. Second, an increase in the cost of building, B, also raises the labor force participation of wives and expands the area of the city that house two income households. Finally, a reduction in buildable land, a decrease in θ, also raises the labor force participation of wives and pushes out the boundary between two and one earner households.

Now consider the effect of these parameter changes on the price of land. Figure 4 illustrates the case of an increase in the preference for purchased goods. The effect is to move out the boundary between one and two earner households and to raise the price of all land occupied by two earner households. Since the price of land occupied by single earner households stays the same, the average price of land rises, with the increase concentrated close to the center. The same results follows from an increase in the cost of building, which similarly raises the number of two earner households and hence causes the price of land close to the center to be bid up.

The effect of changes in the third parameter, θ , the fraction of surface area that is buildable, is somewhat more complex. As θ falls, the city must expand to accommodate a constant population. At the same time, the number of two earner households rises, so the boundary between the two, r^*, moves out for two reasons: less housing can be built within any given distance to the city center and there are more two earner households who want to be close to the center. It is clear that the price of land at any distance from the center rises. However, this does not necessarily prove that the average price of land rises, since people are also being pushed out into the hinterlands where land prices are lower. It turns out that if one considers the land price as a function of the wage rate of the household that buys it, it can be shown that the land bought by every type of household (i,.e., value of w) rises, except for the lowest-wage household who buys the cheapest land at the boundary valued still at its alternative use, a.

So the model establishes that the effect of changes in building cost or the availability of land which raises the price of housing will also raise the labor force participation of wives. Likewise, if there are variations in the preference for purchased goods across metro areas, they will also generate a positive relation between house prices and female labor force participation.

Although I do not pursue it here, one can imagine a variation on this model in which the level of real wages differs across cities. A simple way to do this is to keep the shape of the distribution the same, but let the mean wage vary by city. One could let the wage distribution be represented by the function $n(w/\overline{w}_i)$ where $\overline{w}_i$ is the average wage level in city *i*. If cities differ in $\overline{w}_i$, that will generate variations in labor supply and housing supply across cities. With the specific form of preferences adopted here, cities with higher housing prices will also have greater LFP.

Effect of Migration between Cities

The model above assumes that there is no migration between cities. What would equilibrium look like if movement were possible? Recall that in the basic model there is no amenity difference between cities, nor is there any labor market difference. In that model, a household can earn the same wage no matter where it locates. The only potential differences between cities relevant to individuals are the cost of building, or the price of land as a function of distance from the center. These might be caused by differences across cities in land availability (θ), building costs (B) or the preferences of other households (α). With perfectly costless mobility, households would move between cities seeking the cheapest housing .until in equilibrium every city had the same housing prices as a function of distance from the center. Cities with less buildable land would be smaller in population (but identical in maximum distance from the center). Moreover, in equilibrium each city would have the same labor force participation rates.

Although a formal treatment of costly mobility is beyond the scope of this paper, one can surmise that with costly migration, the equilibrium would be somewhere between the no migration equilibrium and the costless migration equilibrium with a muted, but still positive relationship between house prices and labor force participation .

If amenity differences or labor market differences are introduced, the model resembles the models of Rosen (1974) and Roback (1982) in which equilibrium establishes compensating differentials in wages and land rents. In these models, the equilibrium relation between house prices and labor force participation is not easily characterized.

III.Empirical Tests

Consider some empirical implications of the model. One implication is that across cities, more buildable land reduces commuting costs. In column 1 of Table 2, I explain average commuting times across metro areas in the US with variables representing the fraction of land not covered by water or by land outside the United States and land with more than a 20% slope within a 25 mile radius of the city center. [8] The first variable is an empirical counterpart of the parameter θ from the model above. The results in column 1 show that metro areas with less buildable land have longer commuting times, while steep slopes increase commute times.

[8] This statistic was calculated using mapping technology that neglects small bodies of water, so the variation is driven by large bodies of water like oceans and large lakes and by proximity to international borders, where the assumption is that the land in another country is not a perfect substitute for land within the borders of the U.S.

A second implication of the model is that house prices are higher in metro areas with less buildable land. Saiz (2008) studies the effect of topography on housing cost and he also finds that the fraction of land covered with water or steeply sloped raises the cost of housing. In columns 2 and 3 of Table 2, I regress two different measures of house prices on the fraction of buildable land and other geographic and climate variables. The climate variables pick up variation in the amenity values of metro areas. Although the basic model does not include amenity values, one can easily imagine expanding the model to include mobile non-workers (such as retirees) who value amenities but do not work. The geographic variables might pick up amenities, too. Much of the non-buildable land is water and proximity to water might be a valued amenity. Steeply sloped land allows for views which may also be an amenity. The prediction is that favorable climate, low fraction of buildable land and sloped land increases house prices. Columns 2 and 3 shows that this prediction is confirmed, although again the slope variable is not significant.

The dependent variables in the two columns represent two quality-adjusted house price indices constructed by Yong Chen and Stuart Rosenthal (2008) and by Edgar Olsen as described in Olsen, Davis and Carillo (2005). While each house price index uses a different methodology, they both attempt to control for housing quality differences across metro areas and are quite highly correlated. I standardize these indices so that a unit represents one standard deviation in house price variation across metro areas.

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Household Labor Supply Decisions and House Prices

Does house price variation across metro areas affect married women's labor supply? Using the 2000 Census Public Use Micro Sample (PUMS) sample of households, I select a one percent sample of married women, aged 21 to 65, with spouse present in the household, living in metro areas. . This yields a sample size of roughly 200,000 women, which is described in the right panel of Table 1. Tables 3A and 3B examine labor supply behavior with linear probability estimates and probit of labor force participation. Column (1) in both Tables 3A and 3B sets a baseline regression showing the importance of education, young children and other family income, including husband's earnings. Columns (2) and (4) add house prices and climate variables as well as mean commuting times within the metro area. The rationale for including climate in the labor supply equation is twofold. First, climate may affect the labor supply decision directly by changing the value of non-market time.[9] Second, climate exerts a selection effect; those with greater taste for non-market time will be more likely to live in areas with warm and sunny climates.

Adding the metro area variables shows that the aggregate story told by Figure 1 holds up even when we consider individual data and control for household and other metro area determinants of labor supply. Married women in metro areas with higher house prices are more likely to work. Black, Kolesnikova and Taylor (2008) emphasize the role of commute times in generating cross metro area differences in married women's labor supply. That finding is echoed here where the estimated coefficient implies that 3 minutes more in commute time reduces labor force participation by 2 percentage points.

[9] Connolly (2007) examines the effect of weather on labor supply decisions in the short run and finds that sunny weather reduces time spent at work.

Instrumenting for House Prices

Since house prices and mean travel times are endogenous to labor supply behavior in the metro area, we need to uncover whether the positive relation between house prices and labor supply reflects causality from house prices to labor supply. To do this, I repeat the labor supply estimates of columns (2) and (4) in both Tables 3A and 3B, except that I instrument for house prices and mean travel times with the geographical and climatic determinants of housing prices used in Table 2. The estimates show that when instrumented, neither variations in the Rosenthal-Chen house price index nor in the Olsen index appear to increase women's labor supply. Indeed, the estimated coefficients switch from positive to negative in all cases. For the IV probit estimates in Table 3B we can reject the hypothesis of a positive effect of house prices on female labor supply, while for the linear probability estimates in Table 3A, the standard errors are large enough that we cannot rule out a positive response of labor supply to higher house prices.

Tables 4A and 4B offer another view of the effect of house prices on female labor market behavior. Here the dependent variable is earnings rather than labor force participation, including women with no earnings; Table 4A presents linear estimates while Table 4B shows Tobit estimates. Earnings capture two additional behaviors that might be affected by house prices. Most obviously, earnings incorporate the effect of variation in hours, but in addition may capture individual investments in earning capacity not picked up by years of education. The hypothesis would be that higher house prices induce women to earn more both by working more and by earning more per hour.

The non-instrumented estimates in columns (2) and (4) of both Tables 4A and 4B show that metro house price indices are positively related to female earnings. However, columns (2) and (4) which instrument for house prices show consistently negative effects of house prices on female earnings. The standard errors are large for the linear estimates in Table 4A, implying that we cannot rule out a positive response of female earnings to house prices. However, the IV Tobit results in Table 4B clearly reject the hypothesis of a positive effect of house prices on female labor supply.

Taken altogether, the eight IV results in tables 3 and 4 lend little support to the hypothesis that house prices increase female labor force participation or earnings. Are the instruments for house prices weak? In columns (2) and (3) of Table 2, the F-statistics for the exogenous determinants of house prices range from 20 to 35, which is far above the standard set by Stock and Yogo (2005).

Instrumenting for Labor Supply

Do exogenous determinants of labor supply affect a metro area's house prices ? Here the search for valid instruments is more difficult. Metro area differences in the determinants of labor supply at the individual level are valid instruments only if one supposes that they do not affect house prices directly, except for their influence on female labor force participation or earnings. For example, other family income and number of children under five affect spousal labor supply but also likely exert a direct effect on housing demand. For instruments, I chose three variables representing the religious makeup of the metro area (fraction of regular churchgoers, fraction Catholic and fraction evangelical) as well as three variables representing the educational makeup of the adult female population in the metro area. Controlling for male earnings, it is difficult to see how female education would affect house prices except through female labor supply or earnings.[10] In any case, the results are not appreciably different when only the religion variables are used as instruments. It should be noted, however, that in three of the four estimates in Table 5 the null hypothesis of valid instruments is rejected.

Table 5 shows the IV estimates explaining house prices across metro areas with instruments for female labor force participation and earnings. The results are similar to unreported OLS versions of the same equations. Labor force participation has a significant positive effect on both prices indices. The size of the effect is not inconsiderable; a 10 percentage point increase in the female labor force participation rate in a city appears to be associated with from 1/3 to 2/3 of a standard deviation rise in house prices depending on the price index used. [11] The results for earnings in columns (2) and (4)are similar; a $3000 rise in female earnings raises house prices by 1/3 to ½ of a standard deviation. This estimated effect can be shown to be a reasonable order of magnitude. One standard deviation in house prices in 2000 was $28,000. So the earnings estimates imply that a $3000 increase in women's earnings raises house prices by $10,000 to $14,000. At a 5% discount rate and a 25% marginal tax rate, an increase in annual earnings has a present discounted value of roughly $45,000. So this estimate implies that households spend from a quarter to a third of their extra earnings on housing.

Could this effect account for some of the rise in relative house prices over the past three decades? Married women's labor force participation rose by roughly 20 percentage points from 1970 to 2000, which would lead to a rise in house prices ranging from 2/3 of a standard deviation to 1.3 standard deviations. The standard deviation of house prices

[10] Robert Michael (1973) argues that holding earnings constant, education acts like an increase in income by raising home productivity. That would imply greater housing demand.
[11] Standard deviations here refer to the variation in city means across cities, not variation at the individual level.

across metro areas is about 28% of its mean value, so an increase of 2/3 to 4/3 of a standard deviation would imply an increase in house prices of 18% to 36%. The actual increase from 1975 to 2008 was 50% relative to the CPI and 86% relative to the GDP deflator. So the rise in women's LFP might account for 20 to 70 percent of the total increase in house prices.

If the cross-section results in Table 5 imply a causal relation between female labor market activity and house prices, can that be detected in changes over time within metro areas ? To pursue this, I regress the percent change in house prices over a decade on the female labor force participation rate at the beginning of the decade, using metro area data and a fixed effects estimator. The two decades of data are the 1980's and the 1990's. The result is:

$$\%\Delta Houseprice_{i,t} = 2.04 FemaleLFP_{i,t-1} - .408 Decade90s - .471$$

The standard error on lagged female LFP is 2.83 so we cannot reject the hypothesis of no relationship, but the point estimate is positive and does correspond roughly in size to the cross section estimates in Table 5. Here a percentage point of labor force participation leads to two percentage points of house price inflation, which would imply that the 20 percent increase in LFP from 1970 to 2000 would result in a 40 percent rise in house prices.

Conclusion

We began with the observations that female labor force participation and house prices are positively related across US metro areas and that both have risen in the past three decades. The paper seeks to discover whether any causal direction can be teased out of the data. A model of labor supply and housing demand in a metro area can generate house prices sensitive to labor supply determinants such as women's education and preferences for purchased goods. It can also generate labor supply affected by determinants of house prices such as building costs and the availability of buildable land in the metro area.

The empirical results fail to find a positive effect of house prices on female labor supply. In contrast, higher house prices appear to be caused by female labor supply and earnings. This may provide a partial explanation for the rise in relative house prices over the past three decades.

Appendix: Derivation of Comparative Statics

Comparative statics of the system (9), (10), and (11) with respect to parameters $\alpha, B,$ and θ are derived as follows.

First, to simplify notation, let $\Psi \equiv \frac{k}{1+k}$, $NI_1 \equiv [w^*(1-r^*) - R^* - B]$, and $NI_2 \equiv [2w^*(1-r^*) - R^* - B]$.

(12) $$\mathbf{X}\bullet\begin{bmatrix} d\alpha \\ dB \\ d\theta \end{bmatrix} + \mathbf{Y}\bullet\begin{bmatrix} dw^* \\ dr^* \\ dR^* \end{bmatrix} = 0$$

where

$$\mathbf{X} = \begin{bmatrix} -\ln\Psi - \ln NI_1 + \ln NI_2 & \alpha A & 0 \\ 0 & 0 & \pi\theta r^{*2} \\ 0 & 0 & 0 \end{bmatrix}$$

and

$$\mathbf{Y} = \begin{bmatrix} -\alpha(1-r^*)C & \alpha w^* C & \alpha A \\ n(w^*) & 2r^*\theta\pi & 0 \\ -w^* & 0 & 1 \end{bmatrix}$$

$$A \equiv \left[\frac{1}{NI_1} - \frac{1}{NI_2}\right];\ C \equiv \left[\frac{1}{NI_1} - \frac{2}{NI_2}\right]$$

Since NI_1 is the net income of a one earner household with wage *w** located at *r**, and NI_2 is the net income of a two earner household with the same wage at the same location, we know that

$$NI_2 > NI_1$$

and hence $A > C > 0$.

Solving (12) yields the following comparative statics results.

(13) $$\frac{dw^*}{d\alpha} = \frac{-2r^*\theta\pi(-\ln\Psi - \ln NI_1 + \ln NI_2)}{|\mathbf{Y}|} < 0$$

(14) $$\frac{dw^*}{dB} = \frac{-2\pi\theta r^*\alpha A}{|\mathbf{Y}|} < 0$$

(15) $$\frac{dw^*}{d\theta} = \frac{\alpha w^* r^{*2} C\pi\theta}{|\mathbf{Y}|} > 0$$

(16) $$\frac{dr^*}{d\alpha} = \frac{n(w^*)(-\ln\Psi - \ln NI_1 + \ln NI_2)}{|\mathbf{Y}|} > 0$$

(17) $$\frac{dr^*}{dB} = \frac{n(w^*)\alpha A}{|\mathbf{Y}|} > 0$$

(18) $$\frac{dr^*}{d\theta} = \frac{(-\alpha\pi\theta r^{*2})(Aw^* - (1-r^*)C}{|\mathbf{Y}|} < 0$$

Note: One can sign the determinant of Y as negative using methods described in Samuelson's Foundations pp. 279-280. If we convert the static model into a dynamic model in which *r** and *R** adjust instantaneously (according to (10) and (11) while *w** adjusts at rate proportional rate $\lambda \equiv \frac{dw^*}{dt} \Big/ w^*$ according to

$$(1-\alpha)\ln\Psi - \alpha\ln NI_1 + \alpha\ln NI_2 = \lambda w^*$$

That is, the time derivative of *w** is equal to the size of the log of the left hand side of equation (9). Since *w** should fall (implying more two earner households) when the left-hand side of (9) is large, λ should be negative. Dynamic stability then implies that the determinant of a matrix exactly like $\mathbf{Y}$ except with $-\alpha(1-r^*)C + \lambda$ as the upper left element be equal to zero. This matrix is the matrix of derivatives of the three equations of motion with respect to the three endogenous variables. So, taking the determinant of this matrix we have $|\mathbf{Y}| + \lambda 2\pi\theta r^* = 0$, which implies that $|\mathbf{Y}| > 0$.

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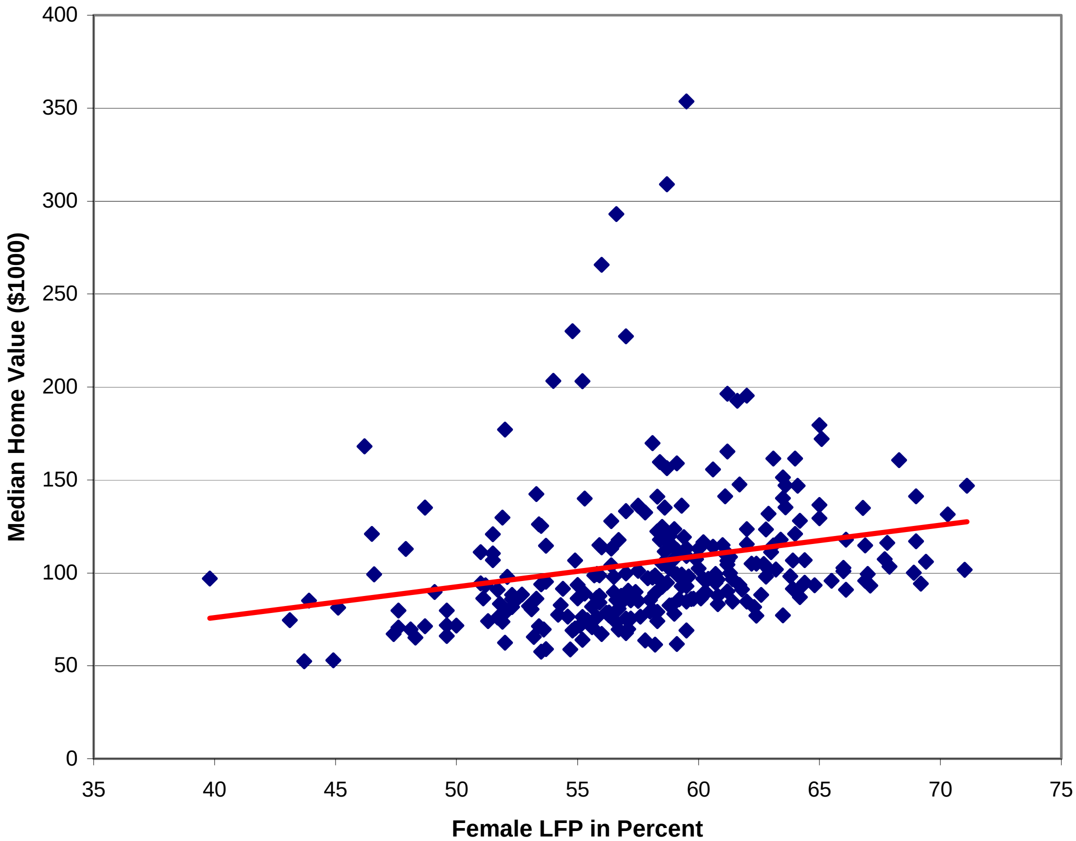

Figure 1: Median Home Value and Female Labor Force Participation
Across US Metro Areas: 2000 Census

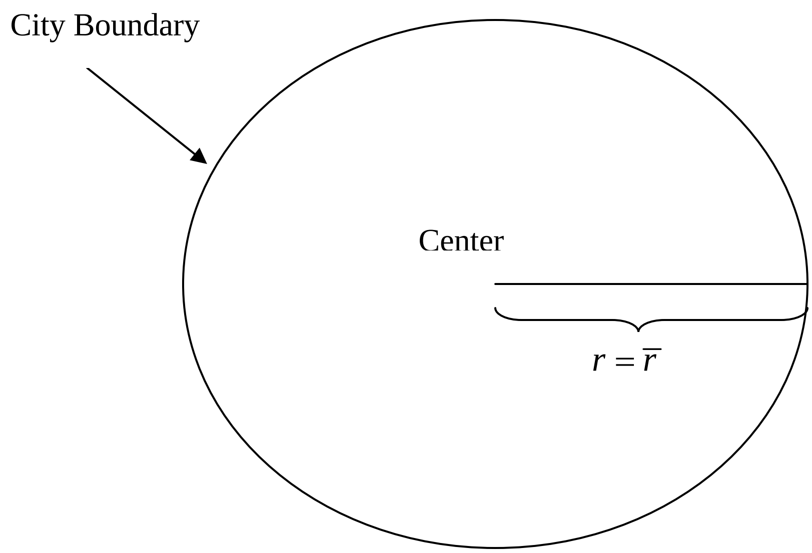

Figure 2: The Circular City

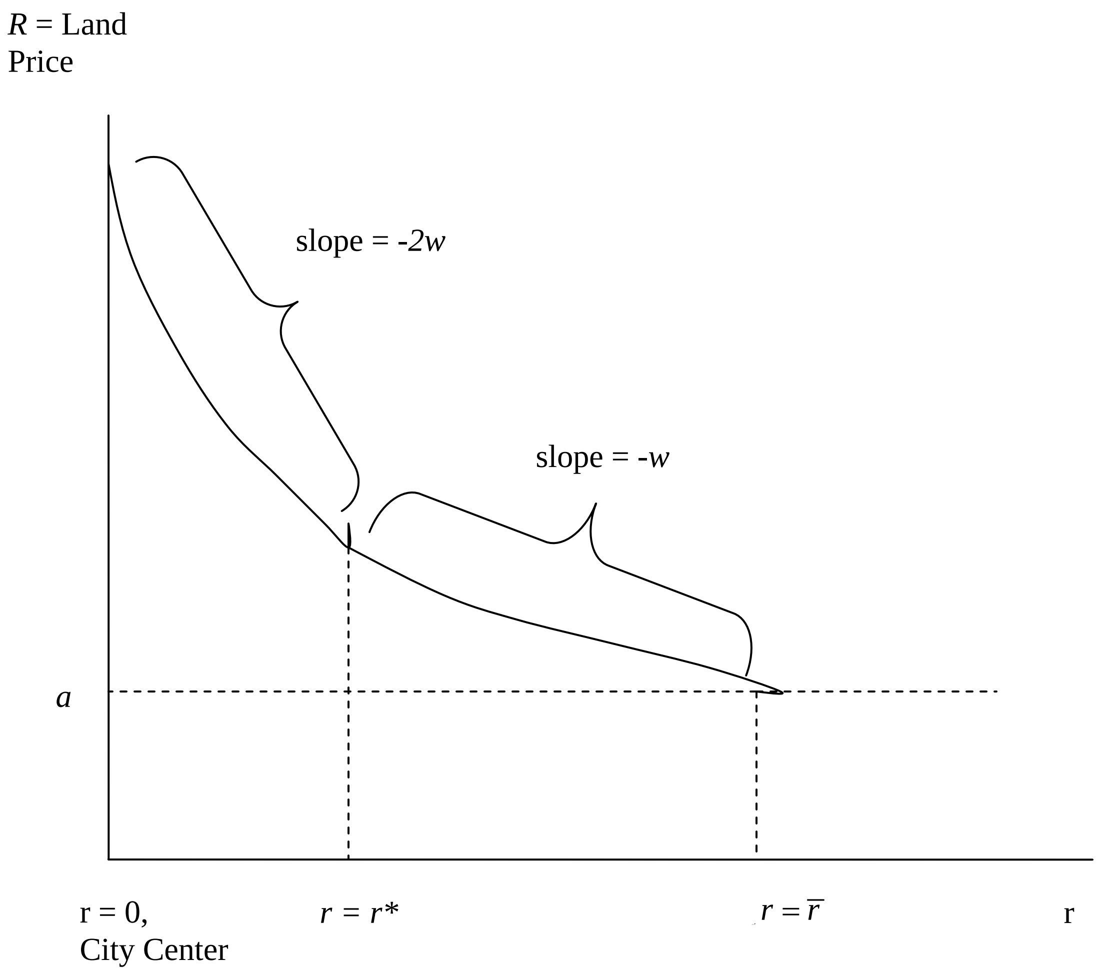

Figure 3: Equilibrium Rent Gradient

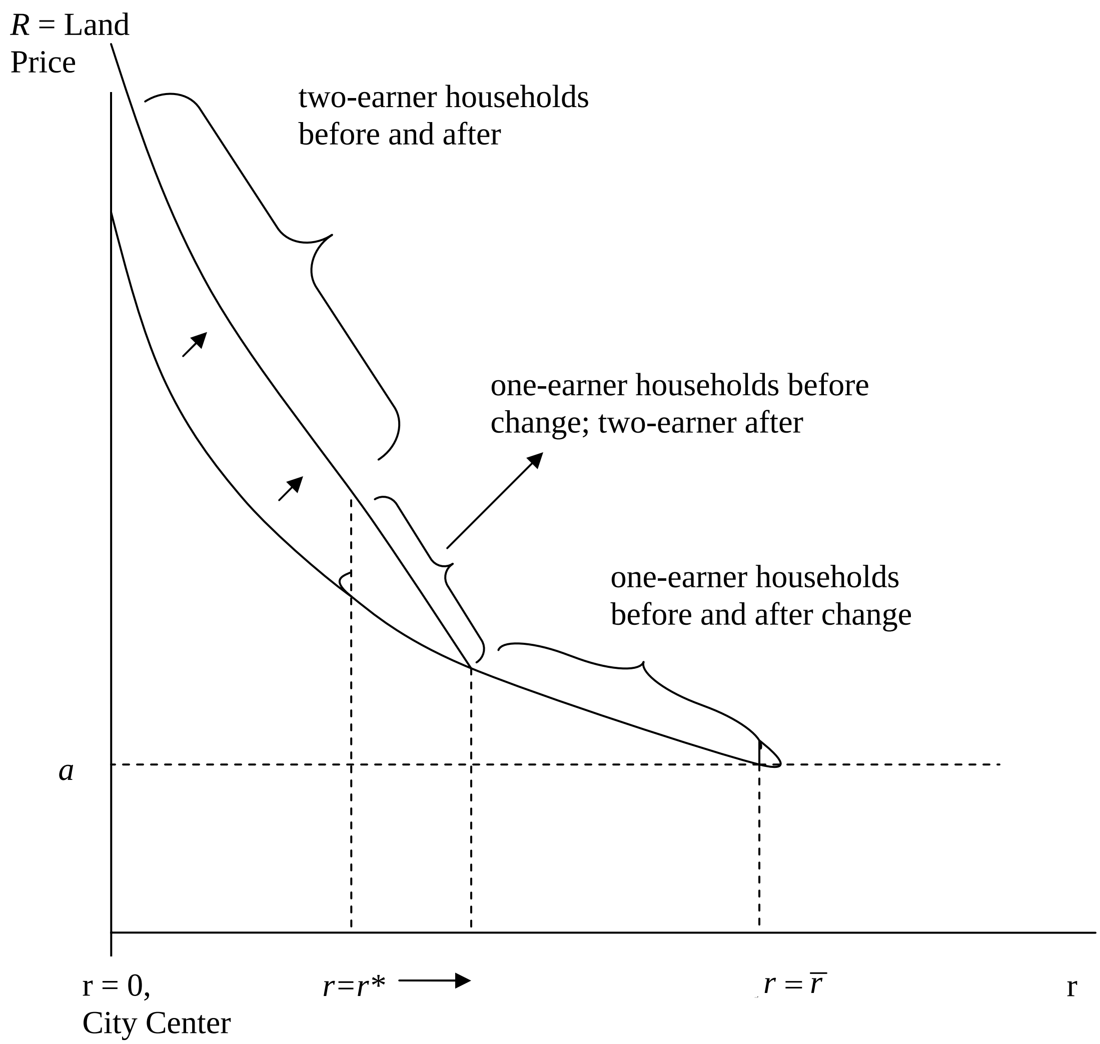

Figure 4: Effect of Increase in Preference for Purchased Goods on Rent Gradient

Table 1: Descriptive Statistics

Metro Area Variables	Mean (Std. Dev)	Individual Level Variables for Married Women (N= 203974)	Mean (Std. Dev.)
Rosenthal-Chen house price index standardized (N= 297)	0 (1)	High School	.257 (.44)
Olsen house price index standardized (N= 329)	0 (1)	Some College	.301 (.46)
Fraction of Buildable Land (N= 283)	.925 (.158)	College	.306 (.46)
Mean July high temperature (F^o) (N= 283)	86.9 (5.8)	Labor Force Participation	.679 (.46)
Mean January low Temperature (F^o) (N= 283)	26.9 (12.2)	Number of Children under five	.30 (.60)
Annual Precipitation (inches) (N = 283)	38.3 (13.8)	Other Family Income (thousands of dollars)	63.76 (66.57)
Sunshine (percent of days) (N= 283)	57.5 (8.7)	Wage Income (wives) (thousands of dollars)	20.97 (29.19)
Fraction of land with slope greater than 20% (N=93)	.087 (.111)	Metro area unemployment rate, April 2000	3.62 (1.64)
Mean Travel to Work Time (minutes) (N = 295)	22.5 (3.7)		
Female labor force participation (%) (N = 277)	58.0 (5.4)		
Median full-time male earnings (1000$) (N= 275)	36.4 (4.7)		
Median full-time female earnings (1000$) (N=275)	25.7 (3.4)		

Notes: Rosenthal index from Y.Chen and S. Rosenthal (2008). Index is $(Q_H + Q_B)/2$. Olsen index from unpublished estimates by Edgar Olsen as described in Olsen et al (2005). . Fraction of buildable land and 20% slope variables are author's calculations using Census maps. Climate variables from NOAA. Other variables from US Census 2000 and Census 2000 PUMS

Table 2: Effects of Geography and Climate on Cross-Metro Area Differences in Mean Commute Times and House Prices

	(1)	(2)	(3)
	Mean Commute Time	Rosenthal-Chen House Price Index	Olsen House Price Index
Fraction of Buildable Land	-4.61*** (1.20)	-.924*** (.34)	-1.29*** (.25)
Fraction of sloped land	2.21 (2.46)	.063 (.59)	.487 (.63)
Mean July high temperature		-.104*** (.01)	-084*** (.008)
Mean January Low Temperature		.011** (.005)	.002 (.004)
Annual Precipitation		-.009** (.004)	-.005 (.004)
Sunshine		.040*** (.007)	.030*** (.008)
F-Statistic	F(3,256)= 36.8	F(7,246)=56.2	F(7,275)=41.1
Number of Observations	258	254	283

Notes: dummy for missing slope data is also included. Standard errors in parentheses. *** = 1% significance, ** = 5% significance, * = 10% significance.

Table 3A: Labor Force Participation of Married Women: Linear Probability Models

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5)IV
High School	17.6*** (.7)	16.9*** (.70)	17.2*** (.70)	16.9*** (.70)	16.6*** (.72)
Some College	26.4*** (.66)	25.9*** (.62)	25.8*** (.63)	25.9*** (.63)	25.6*** (.68)
College	32.8*** (.69)	32.3*** (.69)	32.3*** (.85)	32.3*** (.71)	32.7*** (.67)
Kids under 5	-13.9*** (.32)	-13.9*** (.34)	-13.8*** (.43)	-13.9*** (.34)	-13.8*** (.3)
Other Family Income	-.10*** (.005)	-.09*** (.006)	-.09*** (.005)	-.09*** (.006)	-09*** (.005)
Metro Area Unemployment Rate	-.98*** (.23)	-.56*** (.19)	-1.1** (.5)	-.62*** (.20)	-1.02* (.57)
Rosenthal-Chen House Price Index		1.45* (.73)	-4.62 (3.9)		
Olsen House Price Index				.93** (.41)	-4.88 (5.3)
Mean Travel Time		-.52*** (.13)	-.25 (.54)	-.46*** (.11)	-.28 (.55)
January Low Temp		-.11*** (.03)	-.18** (.08)	-.09*** (.03)	-.30 (.19)
July High Temp		.02 (.08)	-.67* (.39)	-.01 (.05)	-.82 (.66)
Annual precipitation		.08*** (.03)	.09 (.07)	.05** (.02)	.23 (.15)
Sunshine		-.02 (.06)	-.38 (.26)	-.03 (.06)	.60 (.54)
test of overidentifying instruments: p value of Hansen's J			.74		.67
Number of Observations	202829	192277	192295	192277	192295

Notes: 2000 Census data. IV estimates are GMM. Standard errors in parentheses, clustered on metro areas. Coefficients and Standard errors multiplied by 100 for clarity. Other included covariates are age, age squared, and race. House prices and mean travel times are instrumented with topographical variables.

Table 3B: Labor Force Participation of Married Women: Probit Models

	(1)Probit	(2) Probit	(3) IV Probit	(4)Probit	(5)IV Probit
High School	.465*** (..019)	.446*** (.019)	.437*** (.009)	.445*** (.019)	.436*** (.010)
Some College	.725*** (.017)	.713*** (.016)	.705*** (.008)	.713*** (..017)	.702*** (.012)
College	.937*** (.017)	.923*** (.017)	.931*** (.010)	.923*** (.017)	.932*** (.012)
Kids under 5	-.403*** (.01)	-.406*** (.012)	-.405*** (.005)	-.406*** (.012)	-.403*** (.006)
Other Family Income (x 10^{-6})	-2.74*** (.16)	-2.72*** (.17)	-2.60*** (.48)	-2.72*** (.17)	-2.57*** (.50)
Metro Area Unemployment Rate	-.029*** (.007)	-.016*** (.005)	-.032*** (.5)	-.018*** (.006)	-.032*** (.003)
Rosenthal-Chen House Price Index		.043* (.02)	-.142*** (.022)		
Olsen House Price Index				.028** (.012)	-.160*** (.026)
Mean Travel Time		-.016*** (.004)	-.008** (.004)	-.014*** (.003)	-.009* (.004)
January Low Temp		-.004*** (.001)	-.006*** (.0004)	-.003*** (.001)	-.010*** (.0008)
July High Temp		.0004 (.002)	-.021*** (.002)	-.0005 (.002)	-.026*** (.003)
Annual precipitation		.002*** (.0008)	.003*** (.0004)	.0015** (.0007)	.007*** (.0006)
Sunshine		-.0006 (.001)	.012*** (.0013)	-.0009 (.0018)	.020*** (.003)
Number of Observations	202829	192277	192295	192277	192295

Notes: 2000 Census data. IV estimates use Newey's two step procedure. Standard errors in parentheses. Standard errors are clustered on metro areas for columns (1), (2) and (4). Bootstrapped standard errors for columns (3) and (5). Other included covariates are age, age squared, and race. House prices and mean travel times are instrumented with topographical variables.

Table 4A: Labor Earnings of Married Women: Linear Models

	(1) OLS	(2) OLS	(3) IV	(4) OLS	(5)IV
High School	5.92*** (.24)	6.15*** (.41)	6.1*** (.34)	6.14*** (.25)	5.96*** (.34)
Some College	11.30*** (.33)	11.6*** (.35)	11.6*** (.36)	11.58*** (.35)	11.51*** (.43)
College	24.10*** (.82)	24.0*** (.81)	24.5*** (.75)	24.04*** (.81)	24.50*** (.81)
Kids under 5	-4.0*** (.16)	-4.07*** (.17)	-4.0*** (.16)	-4.08*** (.17)	-3.96*** (.32)
Other Family Income	-.0046 (.00457	-.0074 (.0047)	-.0056 (.0038)	-.0075 (.0047)	-.0051 (.0038)
Metro area unemployment rate	-.251 (.25)	-.256*** (.09)	-.60* (.31)	-.28*** (.09)	-.64 (.46)
Rosenthal-Chen House Price Index		1.64*** (.41)	-2.26 (2.34)		
Olsen House Price Index				1.43*** (.28)	-3.09 (2.65)
Mean Travel Time		.13 (.09)	.37 (.29)	-.14* (.79)	.37 (.34)
January Low Temp		-.06*** (.02)	-.09** (.04)	-.02 (.02)	-.17 (.15)
July High Temp		.01 (.04)	-.41 (.25)	.01 (.04)	-.57 (.40)
Annual precipitation		.04** (.02)	-.02 (.42)	-.009 (.02)	.12 (.11)
Sunshine		.003 (.004)	.26 (.15)	-.01 (.04)	.44 (.41)
test of overidentifying instruments: p value of Hansen's J			.62		.62
Number of Observations	202829	192277	192295	192277	192295

Notes: 2000 Census Data. IV estimates are GMM estimates. Standard errors in parentheses. clustered on metro areas. Other included covariates are age, age squared, and race. House prices and mean travel times are instrumented with topographical variables.

Table 4B: Labor Earnings of Married Women: Tobit Models

	(1) Tobit	(2)Tobit	(3) IV Tobit	(4) Tobit	(5)IV Tobit
High School	12.85*** (.62)	12.9*** (.56)	12.9*** (.25)	12.9*** (.62)	12.82*** (.26)
Some College	20.9*** (.89)	21.0*** (.91)	21.2*** (.30)	21.06*** (.91)	21.15*** (.27)
College	35.9*** (1.49)	35.7*** (1.50)	36.4*** (.38)	35.67*** (1.5)	36.41*** (.30)
Kids under 5	-8.05*** (.28)	-8.14*** (.31)	-8.13*** (.17)	-8.14*** (.30)	-8.09*** (.14)
Other Family Income (x 10^{-3})	-.028*** (.006)	-.031*** (.006)	-.029*** (.002)	-.031*** (.0058)	-.028*** (.003)
Metro area unemployment rate	-.603*** (.272)	-.492*** (.129)	-1.01*** (.08)	-.54*** (.14)	-1.01*** (.11)
Rosenthal-Chen House Price Index		2.20*** (.56)	-3.70*** (.69)		
Olsen House Price Index				1.77*** (.355)	-3.89*** (.86)
Mean Travel Time		.014 (.113)	.344*** (.12)	-.042 (.96)	.29*** (.13)
January Low Temp		-.102*** (.02)	-.15*** (.01)	-.063*** (.022)	-.26*** (.03)
July High Temp		.032 (.06)	-.605*** (.07)	.023 (.04)	-.72*** (.10)
Annual precipitation		.071*** (.021)	.057*** (.015)	-.022 (.02)	.17*** (.02)
Sunshine		.024 (.046)	.39*** (.04)	-.02 (.02)	.58*** (.08)
Number of Observations	202829	192277	192295	192277	192295

Notes: 2000 Census Data. IV estimates use Newey's two step method. Standard errors in parentheses. Standard errors are clustered on metro areas for columns (1), (2) and (4). Bootstrap standard errors for columns (3) and (5). Other included covariates are age, age squared, and race. House prices and mean travel times are instrumented with topographical variables. Coefficients are in thousands of dollars.

Table 5: IV Estimates of Cross-Metro Area Differences in House Prices

	(1)	(2)	(3)	(4)
	Rosenthal-Chen Index		Olsen Index	
Female Labor Force Participation Rate	.072*** (.008)		.035*** (.010)	
Median Female Earnings		.178*** (.017)		.114*** (.022)
Median Male Earnings	.053*** (.008)	.008 (.009)	.054*** (.01)	.02 (.012)
Fraction of Buildable Land	-1.49*** (.27)	-1.11*** (.23)	-1.88*** (.28)	-1.65*** (.26)
Slopes Above 20%	1.19** (.47)	1.11*** (.40)	1.11** (.53)	1.24** (.50)
Mean July high temperature	-.060*** (.008)	-.057*** (.007)	-.040*** (.01)	-.034*** (.009)
Mean January Low Temperature	.033*** (.005)	.021*** (.003)	.016*** (.006)	.013*** (.003)
Annual Precipitation	-.015*** (.003)	-.011*** (.002)	-.015*** (.003)	-.013*** (.003)
Sunshine	.028*** (.006)	.029*** (.005)	.006 (.007)	.003 (.007)
Hansen's J p-value	.00	.17	.00	.00
Number of Observations	228	228	253	253

Note: Estimates are GMM estimates with robust standard errors. Instruments for female labor supply and earnings are education and religion variables. *** = 1% significance, ** = 5% significance, * = 10% significance.