

AMENITIES AS TFP AND THE FACTOR OF FOUR*

Morris A. Davis François Ortalo-Magné

University of Wisconsin-Madison,

Department of Real Estate and Urban Land Economics

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Abstract

Data from the NIPA and from the Decennial Census of Housing show that the household expenditure share on housing is remarkably constant over time and across metropolitan areas, despite sizeable changes to real rental prices and variation in income. Consistent with this fact, we consider a basic frictionless model in which identical households have Cobb-Douglas preferences for consumption and housing. Households choose an MSA in which to live, and MSAs differ in the income residents receive and in amenities. Equilibrium in the model satisfies the following properties: (1) MSA-level per-capita income and rental prices increase at the same rate only when per-capita housing is held constant; (2) per-capita housing will not be constant when per-capita incomes increase at different rates across MSAs; (3) this income dispersion leads to disproportionate rent dispersion, that is, given our estimate of the expenditure share on housing of 0.25, and holding amenities constant, the difference in log rental prices of two MSAs must equal 4 times the difference in log per-capita income; (4) the difference in log rental prices in any two MSAs is independent of the local housing supply in either MSA. The model provides an exact methodology to quantify changes to the MSA-level total stock of housing and MSA-level amenities, much in the same way that neoclassical growth theory provides a framework to identify changes to TFP given estimates of capital and labor inputs. We find that in the past 24 years, the per-capita and total stock of housing has increased in almost every MSA we consider, and changes to per-capita income and amenities have been nearly perfectly negatively correlated across MSAs. The model raises issues with regard to existing studies of the relationship of house prices, income, and local amenities.

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1 Introduction

Data from the NIPA and from the Decennial Census of Housing show that the household expenditure share on housing is remarkably constant over time and across metropolitan areas, despite sizeable changes to real rental prices and variation in income. The constancy of this expenditure share suggests using a Cobb-Douglas utility function to represent household preferences over housing and other consumption goods. Quantitative macroeconomic studies of residential investment and house prices have by and large adopted Cobb-Douglas preferences for consumption and housing,¹ but, to our knowledge, the assumption of Cobb-Douglas preferences is not widely used in the field of urban economics. A number of recent papers assume that utility is linear in consumption and housing is something that must be purchased but does not in itself provide any utility.²

In this paper, we study the properties of a frictionless multi-MSA model where households derive utility from a Cobb-Douglas aggregate of housing and numeraire consumption. We allow for MSA-specific amenities that shift this Cobb-Douglas aggregate to accommodate the idea that households may strictly prefer the same bundle of housing and consumption in San Francisco, CA rather than in Madison, WI. The model maintains the tractability of the standard textbook urban framework, while clarifying the determinants of the dispersion of housing prices and providing a method for the measurement of local amenities.

The model delivers four results. First, we show that within each MSA, per-capita income increases at the same rate as rental prices only when per-capita housing is constant. This is a direct implication of the constancy of expenditure shares. Second, holding amenities fixed, per-capita housing will not be constant if there are any differences across MSAs in the growth rate of per-capita income. Third, income dispersion across MSAs leads to disproportionate rental price

¹See Greenwood, Rogerson, and Wright (1995), Fisher (1997), Iacoviello (2004), Davis and Heathcote (2005), and Li and Yao (2006) to name just a few examples.

²See Glaeser and Gyourko (2006) or Gyourko, Mayer, and Sinai (2006) for two recent examples. In a recent paper, van Nieuwerburg and Weill (2006) include housing in utility function, but preferences are quasi-linear. Other older papers such as Mayo (1981) and Cronin (1982) have also included housing in utility, but have specified Stone-Geary preferences.

dispersion. Given our estimate of the expenditure share on housing of 0.25, and holding MSA-level amenities constant, the difference in log rental prices of two MSAs will equal 4 times the difference in log per-capita income. Fourth, and perhaps most surprising, the difference in log rental prices in any two MSAs is independent of the local housing supply in either MSA.

This last result occurs because people move. Suppose that San Francisco were to allow many more homes to be built. If the number of residents in San Francisco were fixed, this might result in lower house prices. But, if prices in San Francisco were to fall, people from other parts of the country would move to San Francisco to enjoy the high income, nice weather, and pleasant scenery. The fact that people move from other areas pushes prices down in those areas and back up in San Francisco. In equilibrium, the relative price between San Francisco and these other areas does not change despite the increase in the number of housing units in San Francisco.

This argument does not imply that the level of rental prices in San Francisco and Madison do not depend on the local supply levels. Actually, the model reveals that changes in the supply of housing do affect the level of rental prices, and further, changes in the supply of housing of MSAs with high per-capita income have a greater impact on price levels everywhere than changes in the supply of housing of MSAs with lower per-capita income. It still remains that as long as households are free to move, the ratio of rental prices between San Francisco and Madison will be a function of only the ratio of per-capita incomes in these two MSAs and will not depend how the supply of housing in each MSA evolves, unless one of two MSAs is abandoned.

Based on the logic of the model, we conclude that supply constraints will always appear to bind in order to keep prices high in MSAs with good amenities and high income. They must bind at the margin or else the highest-income and highest-amenity MSA would absorb the entire population. If an MSA simultaneously offered high income, high amenities, and plentiful housing, people would migrate to that MSA, in effect driving down the amount of housing consumed by each person.

The theory also offers a straightforward way to uncover two objects of interest to urban economists, that are not by themselves easily measurable: Changes to the real housing stock per-person by MSA,³ and changes to amenities, also by MSA. Because expenditure shares are constant,

³See Malpezzi, Shilling, and Yang (2001) for a recent attempt to estimate housing stocks by MSA.

the growth rate of the real housing stock per person in each MSA is measurable as the growth rate of per-capita income less the growth rate of real rental prices. We find that real per-capita housing has increased in every MSA over the 1980-2004 period. Total growth in per-capita housing over this period, however, has varied widely across MSAs, ranging from about 1-1/2 percent in Los Angeles to nearly 46 percent in Dallas.

Similarly, we use the theory to exactly derive changes to MSA-amenities given data on the growth in real per-capita income and growth in real rental prices. Amenities in our model are analogous to TFP in macroeconomics. In our model, consumption and housing are combined with amenities to produce utility; in macroeconomic models, capital, labor, and TFP are combined to produce output. In multiple-sector macroeconomic models, with labor and capital mobility across sectors, and equal capital shares of production, the ratio of relative sector prices exactly reflects the ratio of sector TFP.⁴ In our case, the ratio of MSA-level amenities is an exact function of rental prices and per-capita incomes. Thus, amenities have no interpretation like the number of vineyards per square mile (San Francisco) or available cross-country skiing opportunities (Madison). Rather, amenities enable the model to match the data, the same way that TFP in neoclassical macroeconomics reconciles output with measurable inputs and an assumed production function.

We find that changes in amenities for any MSA are almost perfectly negatively correlated with changes in per-capita income growth in that MSA. This finding calls into question the use of regression-based techniques to uncover MSA-specific amenities. Defining amenities as the residuals of a regression of housing prices or rents on income imposes the false restriction that amenities are orthogonal to income. This idea also has precedence in the macroeconomics literature: Since TFP is correlated with the capital and labor inputs, TFP cannot be uncovered as the residual of a simple regression of output on capital and labor.⁵

We are not the first to apply a Cobb-Douglas utility specification to an urban model. Lucas and Rossi-Hansberg (2002) show how Cobb-Douglas utility aids in explaining a number of established empirical features of the internal structure of cities. Our model is closest to that studied

⁴Fisher (2006) exploits this relationship to derive TFP shocks to the investment goods sector.

⁵See Blundell and Bond (2000) for a discussion of GMM estimation of production functions.

in Eeckhout (2004). Rather than taking local incomes as given as we do, Eeckhout assumes that labor productivity within cities depends both positively on the number of workers (agglomeration economies) and negatively (congestion) externalities. The focus of his paper is to demonstrate how such a simple structure can account for the size distribution of places. His findings add further support for the use of Cobb-Douglas preferences in urban economics.

In the next two sections of the paper, we describe our model and derive its implications. In section 4, we calibrate the model and in section 5, we derive model-consistent MSA-level data for the growth rate of per-capita housing and relative growth to MSA amenities. In section 6, we explain how the theoretical arguments and empirical findings we put forward in this paper contradict the premise of several lines of research within the fields of finance and urban economics. Section 7 concludes.

2 Model

We consider an economy with N MSAs indexed by $i = 1, \dots, N$. The economy is populated by a measure μ of infinitely lived identical agents. Any agent who lives in MSA i in period t produces $w_{i,t}$ units of food, the numeraire consumption good. Per period income within each MSA is allowed to fluctuate over time. In period t there are $H_{i,t}$ units of divisible housing in MSA i owned by a measure zero of agents who behave competitively in the rental housing market.

Agents choose in which MSA to live, how much food to consume and how much housing to rent. In period t , given a set of housing rents for each MSA, $\{r_{i,t}\}_{i=1,N}$, agents choose the MSA i , food consumption c and housing h that solve the following problem:

$$\max_{i,c,h} a_{i,t} c^{1-\alpha} h^\alpha \tag{1}$$

$$\text{subject to } c + r_{i,t} h \leq w_i, \tag{2}$$

with $0 < \alpha < 1$. All agents who choose a same MSA i in period t choose the same numeraire and housing levels $c_{i,t} = (1 - \alpha) w_{i,t}$ and $h_{i,t} = \alpha w_{i,t}/r_{i,t}$.

An *allocation* is fully characterized by the set of food consumption and housing chosen by agents in each MSA at each time period, $\{c_{i,t}, h_{i,t}\}_{i=1,N}^t$ and the measures of agents living in each MSA,

$\{n_{i,t}\}_{i=1,N}^t$. An *equilibrium* in this economy is a set of rental prices $\{r_{i,t}\}_{i=1,N}^t$, and an allocation such that: (1) Agents maximize their utility taking the rental prices as given; (2) In every MSA that is occupied, the housing market clears; i.e., $n_{i,t} h_{i,t} = H_{i,t}$ if $n_{i,t} > 0$; (3) No household wants to move; i.e., all agents derive the same utility whatever MSA they choose.

Without loss of generality and for ease of exposition, we restrict our attention to sets of parameters such that all MSAs are occupied in equilibrium. Rearranging the market clearing conditions and summing over all MSAs yield:

$$\sum_{i=1}^N n_{i,t} = \sum_{i=1}^N H_{i,t}/h_{i,t} = \mu. \quad (3)$$

The condition that agents are indifferent between living in MSAs i and j means:

$$a_{i,t} [(1 - \alpha) w_{i,t}]^{1-\alpha} [h_{i,t}]^\alpha = a_{j,t} [(1 - \alpha) w_{j,t}]^{1-\alpha} [h_{j,t}]^\alpha \quad (4)$$

where we replace food consumption using the solution to the agents' utility maximization problem. Rearranging, we obtain:

$$\frac{h_{i,t}}{h_{j,t}} = \left(\frac{w_{i,t}}{w_{j,t}} \right)^{\frac{\alpha-1}{\alpha}} \left(\frac{a_{i,t}}{a_{j,t}} \right)^{\frac{-1}{\alpha}}. \quad (5)$$

Combining this equation with equation (3) yields the equilibrium housing in each MSA:

$$h_{i,t} = \frac{\left(\sum_{j=1}^N H_{j,t} a_{j,t}^{\frac{1}{\alpha}} w_{j,t}^{\frac{1-\alpha}{\alpha}} \right)}{\mu a_{i,t}^{\frac{1}{\alpha}} w_{i,t}^{\frac{1-\alpha}{\alpha}}}. \quad (6)$$

Plugging this equation into the solution to the agent's optimal housing choice then yields the equilibrium rental prices:

$$r_{i,t} = \frac{\mu \alpha a_{i,t}^{\frac{1}{\alpha}} w_{i,t}^{\frac{1}{\alpha}}}{\left(\sum_{j=1}^N H_{j,t} a_{j,t}^{\frac{1}{\alpha}} w_{j,t}^{\frac{1-\alpha}{\alpha}} \right)}. \quad (7)$$

The equilibrium measures of households for each MSA are then trivial to obtain:

$$n_{i,t} = \frac{\mu H_{i,t} a_{i,t}^{\frac{1}{\alpha}} w_{i,t}^{\frac{1-\alpha}{\alpha}}}{\left(\sum_{j=1}^N H_{j,t} a_{j,t}^{\frac{1}{\alpha}} w_{j,t}^{\frac{1-\alpha}{\alpha}} \right)}. \quad (8)$$

3 Model Predictions

The model yields the following predictions. First, expenditure shares on housing are identical across MSAs. They are also constant over time as local incomes change. This is a direct consequence of the Cobb-Douglas utility assumption. The household optimization problem yields:

$$\frac{r_{i,t} h_{i,t}}{w_{i,t}} = \alpha. \quad (9)$$

Second, the above equilibrium relationship implies that MSA-level per-capita income and rental prices increase at the same rate if and only if per-capita housing is constant over time. Note that equation (6) can be rewritten as:

$$h_{i,t} = \frac{\left(\sum_{j=1}^N H_{j,t} a_{j,t}^{\frac{1}{\alpha}} (w_{j,t}/w_{i,t})^{\frac{1-\alpha}{\alpha}} \right)}{\mu a_{i,t}^{\frac{1}{\alpha}}}. \quad (10)$$

Clearly $h_{i,t}$ will change over time if there are any changes in income dispersion as measured by the ratios of per-capita income across MSAs.

Third, the ratio of rental prices between any two MSAs depends on the ratio of their incomes and amenities only. At any point in time it is:

$$\frac{r_{i,t}}{r_{j,t}} = \left(\frac{a_i w_{i,t}}{a_j w_{j,t}} \right)^{\frac{1}{\alpha}}. \quad (11)$$

Fourth, and related, the supply of housing in MSA i or j does not affect relative rental prices. This is because agents are free to move across MSAs. A particular MSA's own housing supply affects directly the number of agents who live in this MSA. It does not affect local rents and per-capita housing in any way differently than supply in the other MSAs. Mathematically H_i enters in r_i and h_i only through the term $\left(\sum_{j=1}^N H_{j,t} a_{j,t}^{\frac{1}{\alpha}} w_{j,t}^{\frac{\alpha}{1-\alpha}} \right)$, just as the supply of any other MSA. A direct implication of this formula is that changes in the total supply of housing in high-income MSAs have a more pronounced impact on the rental price level than changes in the total supply of housing in low-income MSAs.

4 Calibration

In this section, we document that rental expenditure shares appear to be constant across time and across places at about 25 percent.

We start by constructing an estimate of the expenditure share on housing using macroeconomic data from the National Income and Product Accounts (NIPA). We construct this estimate as

$$\frac{\text{Expenditures on Housing Services (line 14) + Household Operation (line 15)}}{\text{Total Personal Consumption Expenditures (line 1)}}. \quad (12)$$

These data are taken from NIPA table 2.3.5, “Personal Consumption Expenditures by Major Type of Product.”

NIPA expenditures on housing services include both measured rental payments by tenants and an imputation of the rental value of owned homes. NIPA expenditures on household operation include expenditures on electricity, gas, water, and telephone.⁶ We include expenditures on household operation as part of rental expenditures, because a case can be made that a housing structure is not very useful if it has no heat, lights, or running water. With regards to the denominator, we include all personal consumption expenditures (line 1) including expenditures on durable goods.⁷

The rental expenditure shares from this calculation over the 1980-2004 period is shown in figure 1. The average expenditure share on rents over this period is 0.21, and the maximum and minimum over this period are 0.22 and 0.20.⁸ The NIPA estimate is potentially suspect in the sense that the estimated expenditure share depends on the procedure NIPA uses to impute the rental value of owned homes. In 2004, for example, space rent for owner-occupied dwellings, \$910.1 billion,

⁶There are some other miscellaneous components of spending on housing services and household operation. In 2005, these other components accounted for about 8-1/2 percent of the sum.

⁷The NIPA mis-classifies expenditures on durable goods (like cars) as consumption rather than investment. A more accurate accounting would be to treat durable goods in the NIPAs analogously to housing, which would be to impute the service flow from the stock of durable goods as consumption, and treat expenditures on durable goods as private investment. We do not make this adjustment.

⁸For reference, the average value of the rental expenditure share over the entire post-war period for which we have quarterly data (1947:1 - 2006:3) is 0.20.

accounted for 54 percent of the sum of expenditures on housing services and household operation, \$1,686.1 billion.⁹

To get a sense of the expenditure share on housing by renters, for which hard data are available, we turn to micro data from the Decennial Census of Housing (DCH) files. These data are available at the Integrated Public Use Microdata Series (IPUMS) web site, <http://usa.ipums.org/usa/>.

Table 1 lists the median of the ratio of annual gross rent to total household income for 23 MSAs, sorted by population in 2004,¹⁰ for renter households with nonzero household incomes, for the years 1980, 1990, and 2000. These MSAs account for 37 percent of the US population in each year over the entire 1980-2004 period. Although the total proportion of the population living in this set of MSAs has remained about fixed, population has shifted among MSAs: For example, the population in Atlanta has more than doubled from 1980-2004, whereas Pittsburgh has lost almost 10 percent of its population. Gross rental payments are inclusive of expenditures on utilities and the estimates in this table are likely comparable to the NIPA-based estimate. Also reported in table 1 is the inflation-adjusted log change to the MSA-specific price index for tenant rent, as reported by the Bureau of Labor Statistics (BLS). We adjust for inflation in each MSA using the Consumer Price Index excluding Shelter for that MSA, as also published by the BLS. The table lists the the full set of MSAs for which the BLS price index for tenant rents is available over the 1980-2004 period.¹¹ The first column of the table lists the name of the MSA as reported in the IPUMS data files.

In all three years, the median expenditure share is remarkably stable across MSAs: The av-

⁹Importantly, we think (but are not entirely sure at this point) that the NIPA is not imputing the rental value of owned-homes in such a way as to ensure the constancy of α : Since 1984, it appears that the BEA computes owner-occupied rent as the price index for owner-equivalent rent from the CPI, times a quality adjustment to account for improvements to the stock, times an estimate of the aggregate number of owned housing units. See page 61 of the Personal Consumption Expenditures (1990) handbook for details.

¹⁰The population data come from table CA04 of the BEA regional accounts; these BEA data are discussed later in the paper.

¹¹We omit the rental price index for Phoenix, Tampa Bay, and Washington DC because the first date of the rental price index for these series occurs after 1980. We also omit Anchorage because this MSA is not separately identified in the 2000 DCH.

erage of the median is either 0.24 or 0.25 with a standard deviation of about 0.017. The median expenditure share is stable over time in each MSA, despite sometimes large changes to real rental prices that are listed in the right-most column. The absolute value of the average change in the median ratio, by MSA, is less than 0.01 with a standard deviation of 0.01.

Table 2 highlights that these share are constant across MSAs, even in the presence of meaningful variation in the household income of renters. For example, renting households in the San Francisco MSA with an expenditure share on housing within one percentage point of the San-Francisco median spent about \$1,013 per month on rent in 2000, whereas renting households in St. Louis with an expenditure share on housing within one percentage point of that MSA’s median expenditure share spent just \$547 on rent. Further, not shown, the distribution of the expenditure shares in the population of renters is stable as well: The 25th and 75th percentiles are approximately 0.16 and 0.36, respectively, for each of the MSAs shown and for all three DCH years.

From this analysis, we conclude that any model designed to explain MSA-level changes to house prices or population movements should have as an implication that expenditure shares on housing are constant across MSAs and over time. If not, the model will miss what appears to be a robust stylized fact about the way in which households adjust housing consumption in response to variation in income and prices.

5 Identifying Changes to MSA-Level Housing and Amenities

5.1 MSA-Level Per-Capita and Aggregate Housing

We start by taking logs and rearranging equation (9),

$$\log r_{i,t} + \log h_{i,t} = \log \alpha + \log w_{i,t}. \quad (13)$$

To continue, we note that a rental price index $\hat{r}_{i,t}$ is available and not the level of rental prices: $\log \hat{r}_{i,t} = \kappa_i + \log r_{i,t}$, where κ_i is a scale factor that maps the rental price index to the true but unobserved rental price level. Since κ_i is unobserved, the level of the per-capita stock of housing is

not observable.¹² A first-difference of equation (13) yields growth in real per-capita housing over time:

$$\Delta \log w_{i,t} - \Delta \log \hat{r}_{i,t} = \Delta \log h_{i,t}. \quad (14)$$

In table 3, we report $\Delta \log w_{i,t}$ (column 1), $\Delta \log \hat{r}_{i,t}$ (column 2), and the resulting $\Delta \log h_{i,t}$ (column 3) and $\Delta \log H_{i,t}$ (column 4),¹³ over the entire 1980-2004 period. The full set of this data, for each year over the 1980-2004 period, are available at http://morris.marginalq.com/davis_om.html. The rental price-index data are from the BLS, as mentioned. For per-capita income, we take MSA-level data on “Earnings by place of work” as published by the BEA and divide by MSA population, also made available by the BEA.¹⁴ The per-capita income growth and rental growth we report in this table has been adjusted for consumer price inflation using the MSA-specific CPI exclusive of shelter, as published by the BLS. The first column of the table lists the name of the MSA as listed by the BEA.

Table 3 illustrates that the per-capita stock of housing and the MSA-aggregate stock of housing has increased in each of the 23 MSAs we consider except for Los Angeles. Shown in the second-to-last row of the table, the average increase in per-capita housing of the MSAs in the sample (unweighted) was roughly 25 percent, and the average increase in the total housing stock was about 52 percent. There is significant variation in the log change to per-capita housing – the sample (unweighted) standard deviation is 11.7 percent – and to emphasize the magnitude of the disparity, we report the bottom and top quintile of $\Delta \log h_{i,t}$ in the small table below:

¹²As an aside, this is the case for the level of any real variable: For example, in the NIPA the level of real GDP is a quantity index that has been normalized to equal nominal GDP in an arbitrary base year. Even though the level of GDP is arbitrary, the growth rate of real GDP is not arbitrary. This is true in our application as well.

¹³Recall $\log h_{i,t} = \log H_{i,t} - \log n_{i,t}$.

¹⁴Earnings by place of work and population data are both available in table CA04, “Personal income and employment summary,” in the BEA’s regional economic accounts. This earnings measure is defined as wage and salary disbursements plus supplements (employer contributions to pension and private and government insurance funds) plus proprietor income. These are all pre-tax measures.

MSA (from BEA)	1980 - 2004, $\Delta \log h_{i,t}$
Cincinnati-Middletown, OH-KY-IN	0.406
Seattle-Tacoma-Bellevue, WA	0.393
Detroit-Warren-Livonia, MI	0.391
Dallas-Fort Worth-Arlington, TX	0.389
St. Louis, MO-IL	0.377
Honolulu, HI	0.168
San Diego-Carlsbad-San Marcos, CA	0.131
Chicago-Naperville-Joliet, IL-IN-WI	0.090
San Francisco-Oakland-Fremont, CA	0.012
Los Angeles-Long Beach-Santa Ana, CA	-0.015

We expected to find that housing per capita had not increased much or perhaps even declined in Honolulu, San Diego, San Francisco, or Los Angeles, but were surprised to find that Cincinnati, Seattle, Detroit, Dallas, and St. Louis have experienced rapid growth in their real per-capita housing. Taking the data we have on hand at face value, there is no other way to reconcile the fact that expenditure shares are constant, rental prices are flat, and incomes have increased in these MSAs.

Table 4 shows the correlation matrix of the data listed in table 3. Per-capita income growth is not correlated with growth in either per-capita housing or the MSA-aggregate stock of housing. This lack of correlation points to potentially important changes to MSA-level amenities. Suppose that per-capita housing in 1980 in each MSA was the equilibrium outcome of the dispersion of MSA incomes and amenities in 1980. If per-capita income and per-capita housing increase at the same time in (say) Cincinnati, consumption must have increased as well (since the expenditure share of housing is constant). The model rationalizes the fact that households are still indifferent in 2000 between Cincinnati and the other MSAs by the fact that amenities in Cincinnati must not have increased as fast as in other MSAs. Referring again to the TFP analogy, the productivity of consumption and housing in the production of utils in Cincinnati must have dropped relative to that of other MSAs.

5.2 MSA-Level Amenities

In the previous section, we identified changes to per-capita housing in any particular MSA using only the data on rental prices and per-capita income from that MSA – no cross-MSA restrictions were required. To identify changes to amenities in any particular MSA, we compare data from that MSA with data from other MSAs. Specifically, the equilibrium conditions of the model imply that the rental price per unit of housing, per-capita income, and amenities for any two MSAs are linked as follows:

$$\log r_{i,t} - \log r_{j,t} = (1/\alpha) (\log w_{i,t} - \log w_{j,t}) + (1/\alpha) (\log a_{i,t} - \log a_{j,t}). \quad (15)$$

Noted earlier, we observe $\log \hat{r}_{i,t}$ and not $\log r_{i,t}$, implying

$$\log \hat{r}_{i,t} - \log \hat{r}_{j,t} = (1/\alpha) (\log w_{i,t} - \log w_{j,t}) + (1/\alpha) (\log a_{i,t} - \log a_{j,t}) + (\kappa_i - \kappa_j). \quad (16)$$

As was the case with the per-capita stock of housing, the level of amenities is not observable because κ_i is not observed. Of course, the absolute level of any MSA's amenities is not a helpful concept: If we double amenities everywhere, utility everywhere increases but equilibrium allocations do not change.

What determines allocations is the level of an MSA's amenities relative to some baseline level. The level of amenities relative to a baseline cannot be determined because we do not observe the level of rental prices. For exactly this reason, the MSA-level of amenities relative to some baseline is not separately identifiable from the MSA-level total stock of housing. Instead, what we identify, and what is important, is how an MSA's amenities have changed relative to the average change in MSA amenities. Since equation (16) holds for MSA i for any MSA j , it must hold for MSA i when compared to the average of all MSAs $j = 1, \dots, N$:

$$\log \hat{r}_{i,t} - \log \hat{r}_t = (1/\alpha) (\log w_{i,t} - \log w_t) + (1/\alpha) (\log a_{i,t} - \log a_t) + (\kappa_i - \kappa). \quad (17)$$

In this case $\log \hat{r}_t$ stands in for the average across MSAs of $\log \hat{r}_{j,t}$, $(1/N) \sum_{j=1}^N \log \hat{r}_{j,t}$, and $\log w_t$ and κ are defined analogously. After first-differencing equation (17) and re-arranging terms we uncover:

$$\Delta \log a_{i,t} - \Delta \log a_t = \alpha (\Delta \log \hat{r}_{i,t} - \Delta \log \hat{r}_t) - (\Delta \log w_{i,t} - \Delta \log w_t). \quad (18)$$

In table 5, we report our estimates of relative growth in per-capita income, $\Delta \log w_{i,t} - \Delta \log w_t$ (column 1), relative growth in rental prices, $\Delta \log \hat{r}_{i,t} - \Delta \log \hat{r}_t$ (column 2), and relative growth in amenities, $\Delta \log a_{i,t} - \Delta \log a_t$ (column 3) over the 1980-2004 period. In this table and subsequent analysis, we set $\alpha = 0.25$.¹⁵ Two examples from table 5 help illustrate exactly how relative growth in rental prices and relative growth in income identify relative growth in amenities. Start with San Francisco: Over the 1980-2004 period, relative growth in per-capita income outpaced the sample average by 8.4 percentage points. Without any growth to relative amenities, and with $\alpha = 0.25$, we would expect relative rental price growth in San Francisco of $.25^{-1} * 8.4 = 33.6$ percentage points. In fact, rental prices in San Francisco outpaced the average by 32.6 percentage points, and we thus conclude that relative amenities in San Francisco have basically not changed over the 1980-2004 period. In stark comparison is the experience of Los Angeles. Growth in per-capita income in Los Angeles lagged the average by 14.2 percentage points, but rental price growth outpaced the average by 12.8 percentage points. From this we conclude that relative amenities in Los Angeles must have increased quickly: Our estimate is 17.4 percentage points over the 24 year sample.

Table 6 displays the correlation matrix for the data in table 5. The relative growth in amenities is almost perfectly negatively correlated with the relative growth in per-capita income. Thus, if amenities had remained constant, we would have experienced more cross-sectional dispersion in rental prices than had actually occurred. A scatter-plot of the relative growth in per-capita income and relative growth in amenities is shown in figure 2. The point in the upper-left corner represents the experience of Los Angeles; the point in the bottom-right is for Boston. A regression of the relative growth in amenities on the relative growth of per-capita income yields a coefficient of -0.78 .

As noted, the MSAs shown in tables 1-5 account for 37 percent of the U.S. population over the 1980-2004 period. If we assume that the mark-up of per-unit prices over per-unit rents varies across MSAs, but changes over time at exactly the same rate in each MSA – possibly due to common changes in discount rates applied to (implicit) rental income accruing to owner-occupied housing – then we can expand our analysis by replacing rental price indexes with house price indexes.

¹⁵Qualitatively speaking, the results we report are not sensitive if we use $\alpha = 0.2$ or $\alpha = 0.3$.

OFHEO publishes repeat-sales house price indexes for many more MSAs than the BLS publishes its rental price index.¹⁶ The BEA income data and OFHEO house-price indexes are both organized by the same location codes and in principal are directly compatible.¹⁷ After merging the BEA and the OFHEO data, we have time-series observations on relative changes in per-capita income and constant-quality house prices for 122 MSAs from 1980-2004, accounting for 66 percent of the US population in 2004.

Note that the assumptions required to substitute house price indexes for rental price indexes are less restrictive in this application than when we estimated $\Delta \ln h_{i,t}$. In both cases, the ratio of rents to prices (“cap rates”) can vary across MSAs. To uncover the relative growth in amenities, we only require that the changes to log cap rates that have occurred over time be identical across MSAs. In the case of identifying $\Delta \ln h_{i,t}$, cap rates need to be fixed over time in each MSA, a condition that appears to be violated by the data (Campbell et. al. 2006).

The relationship of the relative growth in per-capita income and the relative growth in amenities using data from house-price indexes rather than rental-price indexes is shown in figure 3. The correlation of the two series in this scatter-plot is -0.90 , and a regression of the relative growth in amenities on the relative growth of per-capita income yields a coefficient of -0.80 – almost identical to the results achieved when we use rental price data. For the 23 MSAs in which we have both BLS rental price indexes and OFHEO house price indexes, the correlation of the relative growth in amenities measured first using with the BLS and then the OFHEO data is 0.75 . We conclude that estimates of how MSA amenities have changed over time is not sensitive to the use of rental-price or house-price indexes.

¹⁶The OFHEO repeat sales house-price indexes are available at <http://www.ofheo.gov>.

¹⁷One twist is that the BEA data are reported at an annual frequency whereas the OFHEO data are quarterly: We create an annual OFHEO index by averaging the quarterly observations. Another detail is that for 11 major MSAs a house-price index is not directly available, but rather house-price indexes for constituent Metropolitan Divisions are reported. In these cases, we create a population-weighted average of the non-missing Metropolitan Division house-price indexes to form an MSA-level house price index for each year.

6 Perspectives on the Literature

One line of macro-finance research seeks to understand if various macroeconomic and financial puzzles can be resolved if preferences for consumption and housing are more or less substitutable than Cobb-Douglas. The utility function in these papers¹⁸ is typically of the form

$$\left[(1 - \alpha) c_{i,t}^\gamma + \alpha h_{i,t}^\gamma \right]^{1/\gamma}. \quad (19)$$

These preferences reduce to Cobb-Douglas in the case of $\gamma = 0$. With these preferences, it is easily shown that the expenditure share on housing varies with the rental price of housing unless $\gamma = 0$, that is:

$$\Delta \log \left(\frac{r_{i,t} h_{i,t}}{c_{i,t}} \right) = \left(\frac{\gamma}{\gamma - 1} \right) \Delta \log p_{i,t}. \quad (20)$$

Turning back to table 1, the fact that in each MSA the median expenditure share of renters appears to be independent of changes to the real relative price of rent is strongly indicative that $\gamma = 0$, and a regression exactly based on equation (20) returns a coefficient of 0.018 with a t-statistic of 0.23.

A second and distinct line of research is focused on explaining the dispersion of house prices across major U.S. MSAs. In these papers it is typically assumed that households receive no utility from housing and have linear utility from food consumption.¹⁹ A model with linear utility from consumption and no utility from housing is likely not compatible with data suggesting that expenditure shares are constant across locations and time. If we had written our model with linear utility from consumption and no utility from housing, household indifference across locations would require

$$w_i - r_i = w_j - r_j. \quad (21)$$

If, for arguments sake, we assume that $h_i = h_j = 1$, then this equation can be rewritten as

$$\frac{w_i - r_i h_i}{w_i} = \left(\frac{w_j - r_j h_j}{w_j} \right) \left(\frac{w_j}{w_i} \right). \quad (22)$$

¹⁸For recent examples see Davis and Martin (2006), Lustig and van Nieuwerburgh (2006), and Piazzesi, Schneider, and Tuzel (2006).

¹⁹Recent examples include Glaeser and Gyourko (2006) and Gyourko, Mayer, and Sinai (2006).

This equation states that the food expenditure share in MSA i is only equal to the food expenditure share in MSA j when the per-capita incomes in the two MSAs are identical. If income dispersion occurs, expenditure shares change.

Another related line of research seeks to understand the impact of local supply constraints on local house prices.²⁰ According to the theory we have outlined, supply constraints in San Francisco or New York help pin down the level of house prices everywhere, but are not at all responsible for the gap in house prices between San Francisco or New York and other metro areas. The intuition behind this result is simple: Suppose more housing units are built in San Francisco. Without any population movement, this would lower prices in San Francisco. But, if San Francisco prices are relatively low, people move out of Madison (say) and into San Francisco. This population movement lowers prices in Madison and keeps San Francisco prices relatively high. At the end of the day, in equilibrium the price of housing in San Francisco relative to Madison is only a function of the relative per-capita incomes and amenities in these two MSAs: Given an expenditure share on housing of 0.25, the exact time- t equilibrium relationship is, in fact

$$\frac{r_{SF}}{r_M} = \left(\frac{a_{SF} w_{SF}}{a_M w_M} \right)^{4.0} \quad (23)$$

As mentioned earlier, theory tells us that areas with high income and great amenities will always appear to have tight supply constraints, in the sense that per-capita housing will be relatively low. This has to be the case. If per-capita housing in these high-income and high-amenity areas was also relatively high, then people would move in. In our model, supply constraints ensure that not everyone lives in a few select MSAs such as New York, Boston, or San Francisco.

A third and distinct line of research tests to see if MSA-level house price indexes increase at the same rate as MSA-level per-capita income.²¹ The model, in fact, tells us that the rental price per unit increases at the same rate as per-capita income only when the per-capita housing remains constant: See equation (13). Equation (13) bluntly states that any regression of a rental price index

²⁰For example see Malpezzi (1996), Glaeser, Gyourko, and Saks (2004), and Quigley and Raphael (2005).

²¹See Malpezzi (1999), Lamont and Stein (1999), Case and Shiller (2004), and Gallin (2006) to name just a few examples.

on per-capita income should include as an additional regressor real per-capita housing. Further, the constant term in a price-on-income regression will not substitute for the per-capita housing term, since per-capita housing will not remain constant when the growth rate of income varies across regions. Rather, our theory suggests that per-capita housing adjusts in such a way so that, holding amenities constant, the relative growth rate of rental prices in any MSA is equal to 4 times the relative growth rate of per-capita income in that MSA – see equation (23).

When we bring this model to the data and uncover the relative growth to amenities that each MSA has experienced, we find that for many MSAs, growth in amenities relative to the average has not been constant over time. We also find that relative growth in amenities is strongly negatively correlated with relative growth in per-capita income. This suggests that a fourth line of research starting with Roback (1982)²² that uses regressions of house prices on income and possibly other MSA characteristics (such as weather) to identify the level of amenities in MSAs may be misleading. In our framework, amenities are what they have to be to equate the allocations and prices predicted by the theory with the allocations and prices observed in the data. The fact that relative growth in amenities and wages are negatively correlated implies to us that regressions may yield biased results. This is not unlike the TFP literature in macroeconomics, in which basic theory dictates that the residual in a production function (TFP) will be correlated with the inputs (capital and labor), implying that neither TFP nor capital’s share of income can be uncovered as the outcome of a simple regression of output on observed inputs (Blundell and Bond 2000). Unlike the macroeconomics literature, we do not have any theory yet that is suggestive as to why growth in amenities and per-capita income should be negatively correlated, and view this as a necessary next step.

7 Conclusions

We have engineered this model to be simple, on purpose, so we could analytically explore its full set of predictions. The simplicity has also enable us to derive model-consistent estimates of

²²See Glaeser, Kolko, and Saiz (2001) for a recent example.

changes to real per-capita housing and city amenities, data which we have made available to the general public at http://morris.marginalq.com/davis_om.html. Our model, like all models, has many obvious holes, three of which we state now. First, in the model we allow the per-capita stock of housing in any MSA to costlessly adjust from one period to the next. In reality, it may be quite difficult to subdivide or combine residences from period to period. Second, we have abstracted from heterogeneity in household preferences or income-generating ability, but recent work has shown that this heterogeneity may play a role in explaining some of the fluctuations we observe in housing markets.²³ Third, most households in the U.S. own their housing units, whereas in the model all households are renters. This has enabled us to ignore the potential impact of wealth effects on decisions, but these wealth effects may be of real importance.²⁴ We conclude from this that more work needs to be done.

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²³See Ortalo-Magné and Rady (2006).

²⁴For example, Ortalo-Magné and Pratt (2007) explicitly link the presence of local supply constraints with homeownership.

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Table 1: Median Ratio of Annual Gross Rental Expenditures to Annual Household Income, 1980, 1990, and 2000, and Change in Log Real BLS Price Index for Tenant Rents from 1980-2000

MSA (from DCH)	Population 2004 (Millions)*	Median Ratio:			100 x Change in Log Real Tenant Rent Index (1980-2000)
		1980	1990	2000	
New York-Northeastern NJ	18.75	0.23	0.24	0.24	20.80
Los Angeles-Long Beach, CA	12.90	0.25	0.27	0.26	14.30
Chicago, IL	9.39	0.22	0.24	0.23	27.10
Philadelphia, PA/NJ	5.80	0.24	0.25	0.24	18.30
Dallas-Fort Worth, TX	5.70	0.23	0.23	0.23	2.80
Miami-Hialeah, FL	5.36	0.27	0.29	0.28	-6.30
Houston-Brazoria, TX	5.18	0.22	0.21	0.22	0.10
Atlanta, GA	4.80	0.23	0.24	0.24	20.80
Detroit, MI	4.49	0.22	0.25	0.23	-0.20
Boston, MA-NH	4.42	0.24	0.25	0.24	25.80
San Francisco-Oakland-Vallejo, CA	4.15	0.25	0.27	0.24	42.30
Seattle-Everett, WA	3.17	0.24	0.24	0.25	2.10
Minneapolis-St. Paul, MN	3.11	0.24	0.25	0.23	5.20
San Diego, CA	2.94	0.27	0.28	0.27	13.90
St. Louis, MO-IL	2.77	0.23	0.24	0.22	-0.80
Pittsburgh, PA	2.40	0.23	0.24	0.24	15.20
Denver-Boulder, CO	2.33	0.24	0.25	0.25	13.20
Cleveland, OH	2.13	0.23	0.24	0.24	5.00
Portland, OR-WA	2.06	0.26	0.24	0.24	4.50
Cincinnati-Hamilton, OH/KY/IN	2.06	0.21	0.23	0.21	5.80
Kansas City, MO-KS	1.93	0.22	0.23	0.21	9.20
Milwaukee, WI	1.51	0.21	0.25	0.22	11.00
Honolulu, HI	0.90	0.25	0.25	0.26	6.90
Average		0.24	0.25	0.24	11.17
Standard Deviation		0.016	0.017	0.017	11.14

* 2004 population data taken from table CA04 of the BEA Regional Accounts.

Table 2: Sample Size of all Renting Households, and Sample Size, Average Monthly Gross Rent and Average Annual HH Income for Renting Households at the Median Rent-to-Income Ratio, 2000 DCH

MSA (from DCH)	Sample Size, All Renters	Sample Size at Median Rent-Income*	Monthly Rent at Median Rent-Income*	HH Income at Median Rent-Income*
New York-Northeastern NJ	22,299	1,095	\$844	\$42,426
Los Angeles-Long Beach, CA	16,839	910	\$803	\$36,973
Chicago, IL	7,249	412	\$714	\$36,889
Philadelphia, PA/NJ	3,574	214	\$682	\$34,254
Dallas-Fort Worth, TX	5,084	334	\$718	\$38,154
Miami-Hialeah, FL	2,276	138	\$622	\$26,571
Houston-Brazoria, TX	4,043	231	\$656	\$35,567
Atlanta, GA	3,551	198	\$757	\$37,892
Detroit, MI	2,862	142	\$621	\$32,884
Boston, MA-NH	3,933	210	\$841	\$42,231
San Francisco-Oakland-Vallejo, CA	5,926	321	\$1,013	\$50,150
Seattle-Everett, WA	2,647	155	\$872	\$41,752
Minneapolis-St. Paul, MN	1,626	89	\$667	\$34,939
San Diego, CA	3,639	198	\$812	\$36,306
St. Louis, MO-IL	1,875	102	\$547	\$29,237
Pittsburgh, PA	1,257	52	\$503	\$24,969
Denver-Boulder, CO	1,988	120	\$702	\$33,777
Cleveland, OH	2,244	115	\$646	\$32,426
Portland, OR-WA	1,682	91	\$707	\$35,328
Cincinnati-Hamilton, OH/KY/IN	1,014	69	\$478	\$26,618
Kansas City, MO-KS	1,289	97	\$609	\$34,103
Milwaukee, WI	1,276	74	\$617	\$33,181
Honolulu, HI	641	27	\$967	\$44,866
Average			\$713	\$35,717
Standard Deviation			\$136	\$5,986

* Sample consists of renter households with a rent-income ratio within 0.01 percentage points of the median rent-income ratio for that MSA.

Table 3: Log Changes in Real Per-Capita Income, Real Rental Prices, Real Per-Capita Housing, and Real Aggregate Housing, 1980-2004

MSA (from BEA)	$\Delta \log w_{i,t}$	$\Delta \log \hat{r}_{i,t}$	$\Delta \log h_{i,t}$	$\Delta \log H_{i,t}$
	(1)	(2)	(3)	(4)
New York-Northern New Jersey-Long Island, NY-NJ-PA	0.499	0.297	0.202	0.338
Los Angeles-Long Beach-Santa Ana, CA	0.269	0.285	-0.015	0.295
Chicago-Naperville-Joliet, IL-IN-WI	0.440	0.350	0.090	0.244
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	0.482	0.236	0.245	0.346
Dallas-Fort Worth-Arlington, TX	0.372	-0.018	0.389	1.017
Miami-Fort Lauderdale-Miami Beach, FL	0.339	0.026	0.313	0.811
Houston-Sugar Land-Baytown, TX	0.368	0.045	0.323	0.809
Atlanta-Sandy Springs-Marietta, GA	0.453	0.171	0.283	1.000
Detroit-Warren-Livonia, MI	0.407	0.016	0.391	0.425
Boston-Cambridge-Quincy, MA-NH	0.637	0.383	0.255	0.368
San Francisco-Oakland-Fremont, CA	0.495	0.483	0.012	0.253
Seattle-Tacoma-Bellevue, WA	0.400	0.007	0.393	0.801
Minneapolis-St. Paul-Bloomington, MN-WI	0.443	0.105	0.339	0.683
San Diego-Carlsbad-San Marcos, CA	0.447	0.316	0.131	0.579
St. Louis, MO-IL	0.411	0.034	0.377	0.477
Pittsburgh, PA	0.361	0.170	0.190	0.092
Denver-Aurora, CO	0.392	0.118	0.274	0.740
Cleveland-Elyria-Mentor, OH	0.308	0.080	0.228	0.210
Portland-Vancouver-Beaverton, OR-WA	0.322	0.016	0.305	0.731
Cincinnati-Middletown, OH-KY-IN	0.487	0.081	0.406	0.564
Kansas City, MO-KS	0.415	0.143	0.272	0.518
Milwaukee-Waukesha-West Allis, WI	0.449	0.165	0.283	0.364
Honolulu, HI	0.254	0.086	0.168	0.332
Average	0.411	0.156	0.255	0.522
Standard Deviation	0.085	0.138	0.117	0.260

Table 4: Correlation of Log Changes in Real Per-Capita Income, Real Rental Prices, Per-Capita Real Housing, and Aggregate Real Housing, 1980-2004

	$\Delta \log w_{i,t}$	$\Delta \log \hat{r}_{i,t}$	$\Delta \log h_{i,t}$	$\Delta \log H_{i,t}$
$\Delta \log w_{i,t}$	1.00			
$\Delta \log \hat{r}_{i,t}$	0.54	1.00		
$\Delta \log h_{i,t}$	0.09	-0.79	1.00	
$\Delta \log H_{i,t}$	-0.07	-0.54	0.59	1.00

Table 5: Relative Growth in Real Per-Capita Income, Real Rental Prices, and Real Amenities, 1980-2004

MSA (from BEA)	Per-Capita Income*	Rental Prices*	Amenities*
	(1)	(2)	(3)
New York-Northern New Jersey-Long Island, NY-NJ-PA	0.089	0.141	-0.053
Los Angeles-Long Beach-Santa Ana, CA	-0.142	0.128	0.174
Chicago-Naperville-Joliet, IL-IN-WI	0.029	0.194	0.019
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	0.071	0.080	-0.051
Dallas-Fort Worth-Arlington, TX	-0.039	-0.174	-0.004
Miami-Fort Lauderdale-Miami Beach, FL	-0.072	-0.130	0.039
Houston-Sugar Land-Baytown, TX	-0.043	-0.111	0.015
Atlanta-Sandy Springs-Marietta, GA	0.042	0.014	-0.039
Detroit-Warren-Livonia, MI	-0.004	-0.140	-0.031
Boston-Cambridge-Quincy, MA-NH	0.227	0.226	-0.170
San Francisco-Oakland-Fremont, CA	0.084	0.326	-0.002
Seattle-Tacoma-Bellevue, WA	-0.011	-0.150	-0.026
Minneapolis-St. Paul-Bloomington, MN-WI	0.033	-0.052	-0.045
San Diego-Carlsbad-San Marcos, CA	0.036	0.159	0.004
St. Louis, MO-IL	0.000	-0.123	-0.031
Pittsburgh, PA	-0.050	0.014	0.054
Denver-Aurora, CO	-0.019	-0.038	0.009
Cleveland-Elyria-Mentor, OH	-0.102	-0.076	0.083
Portland-Vancouver-Beaverton, OR-WA	-0.089	-0.140	0.054
Cincinnati-Middletown, OH-KY-IN	0.076	-0.075	-0.095
Kansas City, MO-KS	0.004	-0.013	-0.007
Milwaukee-Waukesha-West Allis, WI	0.038	0.009	-0.036
Honolulu, HI	-0.157	-0.071	0.139
Average	0.000	0.000	0.000
Standard Deviation	0.085	0.138	0.072

* Column (1) is $\Delta \log w_{i,t} - \Delta \log w_t$, column (2) is $\Delta \log \hat{r}_{i,t} - \Delta \log \hat{r}_t$, and column (3) is $\Delta \log a_{i,t} - \Delta \log a_t$.

Table 6: Correlation of Relative Growth in Real Per-Capita Income, Real Rental Prices, and Real Amenities, 1980-2004

	$\Delta \log w_{i,t} - \Delta \log w_t$	$\Delta \log \hat{r}_{i,t} - \Delta \log \hat{r}_t$	$\Delta \log a_{i,t} - \Delta \log a_t$
$\Delta \log w_{i,t} - \Delta \log w_t$	1.00		
$\Delta \log \hat{r}_{i,t} - \Delta \log \hat{r}_t$	0.54	1.00	
$\Delta \log a_{i,t} - \Delta \log a_t$	-0.92	-0.15	1.00

Figure 1: Estimate of Aggregate Rental Expenditure Share from the NIPA

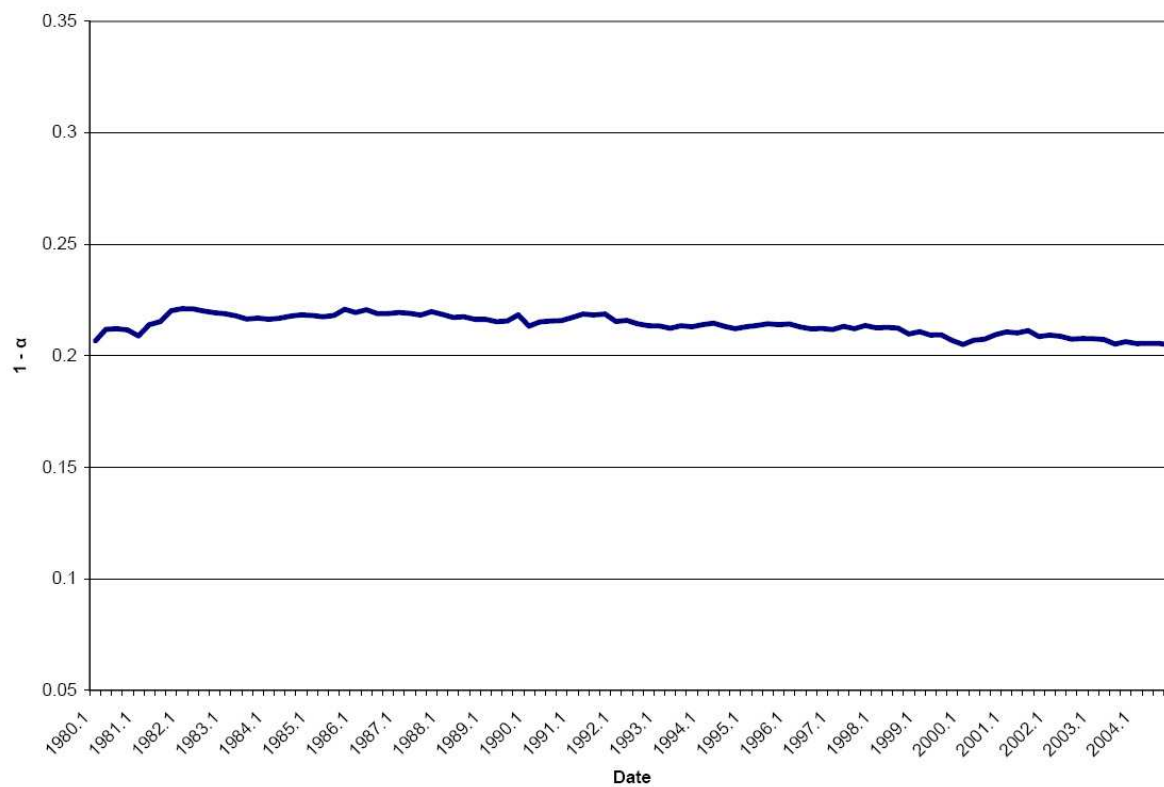


Figure 2: Scatterplot of Relative Growth in Per-Capita Income and Relative Change in Amenities, 1980-2004, for 23 MSAs with BLS Rental Price Index Data

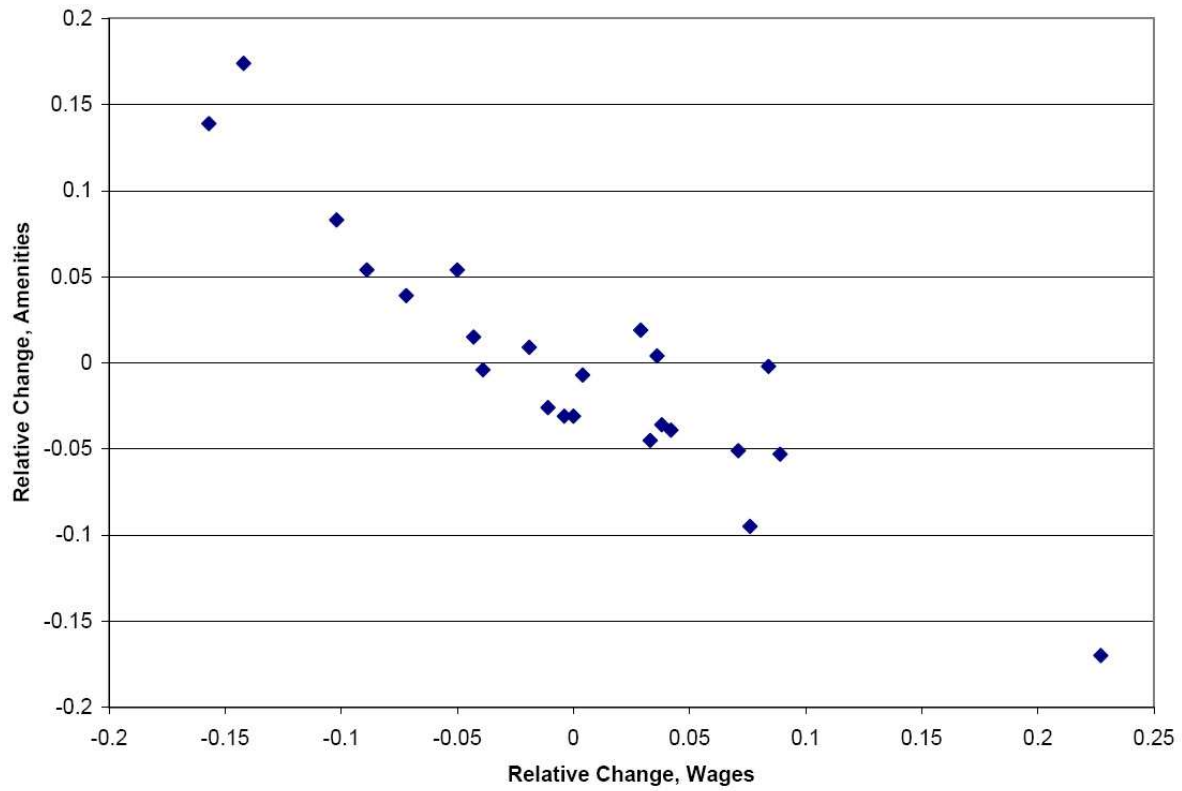


Figure 3: Scatterplot of Relative Growth in Per-Capita Income and Relative Change in Amenities, 1980-2004, for 122 MSAs with OFHEO House Price Index Data

