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Journal of Housing Economics 14 (2005) 315–335

JOURNAL OF HOUSING ECONOMICS

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Central cities and housing supply: Growth and decline in US cities

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Received 25 August 2004
Available online 21 October 2005

Abstract

Many older American cities lost population during the last three decades of the twentieth century, but while cities such as Boston or New York saw numbers of dwelling units remain stable or even increase, others such as Buffalo, St. Louis, Cleveland, Detroit, and Pittsburgh lost large fractions of their dwelling units. This study decomposes decadal population changes from 1970 through 2000 for 351 US cities into household size, housing unit, and occupancy rate effects and finds substantial stock declines (as high as 50%) in many cities. It then develops a supply and demand model to model central city housing unit supply elasticities, with special emphasis on "kinked supply"—inelastic in the negative direction and elastic in the positive directions. Supply elasticities for housing unit *decreases* were between +0.03 and +0.13. For housing unit *increases* the elasticities were between +1.05 and +1.08.

Keywords: Housing supply; Central cities; Kinked supply; Population change

JEL classification: R00; R31

In this first decade of the 21st century residents of American cities may drive past blocks, if not miles, of empty lots or demolished dwellings that once contributed to high densities. Cities such as Buffalo, St. Louis, Cleveland, Detroit, and Pittsburgh lost at least half of their populations between 1950 and 2000. Urban analysts have concentrated on

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doi:10.1016/j.jhe.2005.09.001

demand factors to explain decentralization, but housing supply has had a major impact on this depopulation.

This article begins by separating decadal changes in central city population into household size, housing unit, and occupancy rate effects. It shows how population size and number of dwelling units may not move together and that central city population decreases in the 1970s had different root causes than those in the 1990s. It then looks more closely at the supply of dwelling units by deriving and estimating a simple supply and demand model to be estimated with the *State of the Cities* database.[1] The model pays particular attention to ‘‘kinked supplies,’’ asymmetric supply responses in the negative and positive directions.

1. Urban structure and housing supply

Since 1970, population decreases for many US central cities have far exceeded population changes in the surrounding metropolitan areas, and urban analysts have often used central city population as a measure of the health of the city, on the premise that desirable places will attract additional residents (see for example, Chernick and Reschovsky, 2001). Urban analysts have most often linked central city depopulation to the ‘‘traditional’’ or to the ‘‘flight from blight’’ models (Mieszkowski and Mills, 1993). In the traditional model, growing populations, higher incomes, and generally cheaper transportation lead to increased land or housing demand by urban residents, taking them greater distances from places where they work or shop. With flight from blight, residents or employers (Persky and Wiewel, 2000) seek more land, but also flee perceived or real problems in central cities related to crime, race-related issues, or public service quality.

Housing capital stock has generally served a passive role in urban analytical models. Most central place models refer to land use and land rents, with capital stocks adjusting to the differing rents. Early density models implied malleable capital stock, allowing population density to adjust over the long run (see for example Brueckner, 1987). Harrison and Kain (1974), in contrast, derive a population density model that assumes buildings last forever.

The differences between malleable and indestructible capital are important. Malleable capital implies relatively complete adjustment to changes in values or rents. However, housing units represent durable long-lived capital, which is generally configured as it was built, and may easily last 50–100 years or more. Glaeser and Gyourko (2005) argue that urban housing supply is asymmetric, leading to kinked supply. GG expect highly elastic responses to positive shocks, because additional units can be built if desired, but they expect inelastic responses to negative shocks because existing homes are durable, that is, ‘‘once it’s built, it’s built.’’ A positive demand shock would generate more units and people in a central city, but only a modest housing price increase. A negative demand shock, in contrast, would cause housing price to fall, but induce little change in housing stock or population. GG do not estimate supply elasticities for this kinked supply function, but their model suggests elasticities close to 0 in the negative direction, but considerably larger in the positive direction.

The housing supply literature provides a variety of estimates. Green and Malpezzi (2003, p. 6) describe a US construction industry with a large number of very small producers, implying close to constant returns to scale for new units. Using such a theoretical framework, Muth (1968) estimates one of the earliest supply elasticities at approximately

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[1] This database is accessible at http://socds.huduser.org/, accessed (most recently) April 22, 2004.

+14. In a survey DiPasquale (1999) concludes that: (1) new supply appears to be price elastic, with estimates between +3.0 and positive infinity; (2) higher income households appear more likely to improve their homes than to do nothing, but they are more likely to move than to improve their current units; (3) repair and renovation expenditures are inelastic with result to income and price. Green and Malpezzi (2003) also provide an updated review of the relevant literature subsequent to DiPasquale's survey.

Mayer and Somerville (MS) examine price elasticities for new construction using quarterly panel data. Their estimates from national data (Mayer and Somerville, 2000b) relate a 10% rise in real prices to a 0.8% increase in the housing stock, which is accomplished by a temporary 60% increase in the annual number of starts, spread over four quarters. With local area supply functions (Mayer and Somerville, 2000a) they find that the aggregated national data may slightly overestimate price elasticity of new construction and underestimate the time required to respond to price shocks.

The literature thus suggests supply price elasticities that vary somewhere between zero and infinity! The analysis proposed here links density and population declines through the longevity of housing. After units are built, population adjusts due to changes in housing stock or changes in household size. Supply functions for occupied units are identified through a supply–demand model in which units may enter the housing supply through construction, or leave the occupied housing supply through vacancy, abandonment, or demolition.

The model estimates decadal changes in numbers of central city housing stocks for the 1970s, 1980s, and 1990s. With symmetric supply price elasticity, estimates vary from about +0.60 to almost +1.00. However, if parameter values are allowed to differ with the direction of the change (if kinks are permitted), elasticities for contracting cities are small, between +0.03 and +0.13. Supply elasticities are significantly larger, between +1.05 and +1.08, for expanding cities.

2. Demographic changes and housing supplies in the 1970s, 1980s, and 1990s

Central city population and housing supply are linked, but they are not identical and they do not always move together. Patterns of household formation and household size changed substantially in the last third of the twentieth century, and particularly in the 1970s. This section uses Census data to measure changes in (occupied) housing units, showing: (1) that populations often fell even though numbers of dwelling units either stayed constant or rose; and (2) that even with long-lived housing capital, numbers of dwelling units declined in many central cities between 1970 and 2000, and often substantially.

The linkage between population and supply begins by decomposing population changes P into changes in numbers of dwelling units U, occupancy rates O, and number of people per occupied dwelling unit, S. For dates t and $t+1$ (referring here to 10 year intervals):

$$P_t = U_t O_t S_t, \tag{1}$$

$$P_{t+1} = U_{t+1} O_{t+1} S_{t+1}. \tag{1'}$$

For decadal data, with "bars" indicating mean values,

$$\begin{aligned}\Delta\ \text{Population} &= P_{t+1} - P_t = U_{t+1}O_{t+1}S_{t+1} - U_tO_tS_t \\ &= \underset{\text{[Absolute Size Effect]}}{\overline{UO}(S_{t+1} - S_t)} + \underset{\text{[Absolute Housing Effect]}}{\overline{SO}(U_{t+1} - U_t)} + \underset{\text{[Absolute Occupancy Effect]}}{\overline{US}(O_{t+1} - O_t)}\ .\end{aligned} \tag{2}$$

One can also express (2) in percentage terms such that:

$$
\begin{aligned}
Pct.\ \varDelta \text{ in population} &= \frac{P_{t+1}-P_t}{\bar{P}} \\
&= \underset{\text{[Relative Size Effect]}}{\frac{S_{t+1}-S_t}{\bar{S}}} + \underset{\text{[Relative Housing Effect]}}{\frac{U_{t+1}-U_t}{\bar{N}}} + \underset{\text{[Relative Occupancy Effect]}}{\frac{O_{t+1}-O_t}{\bar{O}}}, \text{or} \\
\hat{P} &= \hat{S}+\hat{U}+\hat{O}, \qquad (2')
\end{aligned}
$$

with "hats" referring to percentage changes, or relative size, housing and occupancy effects, respectively. For decades, percentage changes are calculated at interval means; for example, $\hat{P}=\frac{P_t-P_{t-1}}{(P_t+P_{t-1})/2}$, following Goodman and Thibodeau (1998).

These formulations provide several insights.

(A) For central cities with built up housing, relatively little vacant land, and most often, the inability to annex adjoining areas, population changes may stem from changes in household size even with little change in the number of units.[2] This process was a major determinant of central city population declines of the 1970s, when the average number of persons per household across the United States fell from 3.14 to 2.75, or by 12.1%.[3]

(B) If numbers of households increase, holding population constant, more dwelling units will be required, but it may be difficult to provide them in built up areas. For example, a 1000 square foot unit with one bathroom and one kitchen for a couple cannot be split costlessly into two 500 square foot units (*each* with a bathroom and a kitchen) for two singles; a new unit may be necessary. Alternatively, in many older cities, small units with one bath may no longer be desirable, and the cities might benefit from combining small units, also a costly alternative. The 1970s substantial declines in household size often led to central city population declines, because they were not offset either by increases in numbers of units or in occupancy rates.[4]

(C) With population declines, central city housing, generally older and possibly more depreciated than suburban housing, may fall in quality such that the lower market-clearing rents reduce its viability as an investment. The distinction between

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[2] An initial goal of this analysis was to look at central cities' abilities to annex, and the resulting impact on population change and housing supply. Most changes in central city boundaries occurred prior to the 1970s; central city-suburb boundaries were quite stable between 1970 and 2000.

[3] This compared to declines of −5.7% in the 1960s, −4.7% in the 1980s, and −1.4% in the 1990s. Sweet (1984) lists six reasons for the 1970s' unprecedented decline: (1) young people increasingly delayed marriage; (2) rates of separation and divorce increased; (3) remarriage rates began to stabilize and decline after a period of increase; (4) mortality of the elderly declined; (5) persons of all ages and marital statuses continued their increased propensities to form their own households rather than to share the households of others; and (6) large baby boom cohorts replaced the very small Depression cohorts so that in 1980 there were 39% more 20–34-year-olds than in 1970.

[4] Demographers such as Sweet (1984) have analyzed household size for the nation as a whole, but only Berry (1980) addressed impacts of household size on central cities, and his work was largely descriptive.

> occupancy rate and total number of units allows analysts to distinguish between vacant/abandoned (but potentially available) units, and those that have been torn down. Both represent reductions in market-clearing housing supply. [5]

This study examines 351 cities from the *State of the Cities* database of the United States Department of Housing and Urban Development for 1970, 1980, 1990, and 2000. In some areas two or more central cities defined by population and commuting patterns can be identified (e.g., the Detroit MSA has Detroit, Dearborn, and Pontiac). In almost all cases (excepting Minneapolis-St. Paul and Kansas City, Kansas and Missouri), the "major" central city was used, with the other central city included in metropolitan area computations (but *not* included as suburbs).

Tables 1A–C explore the Eq. (2′) effects for 1970s 20 largest central cities over the subsequent three decades. The 1970s mean population change for these cities was −3.9% and mean household size change was −12.1%, indicating that even with constant housing supplies, population would have fallen by over 8%. Boston's double-digit population decline (−13.0%), for example, stemmed *entirely* from decreased household size (−13.4%). Moreover, housing supplies did not always move in the same directions as populations. Milwaukee and Chicago, 90 miles apart, both experienced population losses of between 11 and 12%. Occupied units in Milwaukee increased by slightly more than 2% whereas Chicago decreased by almost 4%. Of the 20 largest cities, six experienced declines in units and 8 experienced declines in occupied units.[6]

In the 1980s (Table 1B), mean population change for the 20 cities was +1.1%, and the household size effect eased substantially with a mean decrease of −1.9%. Nonetheless, seven cities experienced declines in units and 10 experienced declines in occupied units. The 1990s were similar (Table 1C), with eight cities experiencing declines in total units and seven experiencing declines in occupied units. Although household size declines were major contributors to central city population declines in the 1970s, they had much smaller impacts in the 1980s and 1990s.

In sum, Table 1 reveals that population declines in the 1970s were most often driven by reductions in household size, and these population declines occurred even though supplies of units were increasing. The household size decreases had much smaller impacts in the 1980s and 1990s. There were also substantial supply *decreases* in many cities over the three decades. Six of the 20 largest cities experienced declines in occupied housing units in *each* of the three decades, led by Detroit (a three-decade decline of −34.3%) and St. Louis (−33.8%). Of the 351 cities, 63 had three-decade declines in occupied units; East St. Louis Illinois had the largest percentage loss, −52.2%.

What happened to these units? Economic theory suggests that the marginal process of depreciation ultimately leads to the discrete events of abandonment and/or demolition (Bender, 1979). Ingram and Kain (1973) identify two causes for units to be withdrawn from the market when their value falls toward zero. First, the amount of physical capital

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[5] One might point to the re-use of central city "brownfields" or the removable of vacant or low density housing to build higher density dwellings. However, the potential gains must be considerable to offset the costs of tearing down existing dwellings (even if abandoned) and/or cleaning up environmental contamination.

[6] Occupied units will be used to measure supply in regression analyses. Parallel analyses (available on request) were conducted with total, rather than occupied, units, with virtually identical results. Correlation of the two measures was +0.99, 0.97, and 0.98 for the three decades respectively.

Table 1
Decomposition of central city population changes by decade—20 largest cities (1970)

		1970 Population	% Δ Population	% Δ HH size	% Δ Occupancy rate	% Δ units	% Δ Occupied units
(A) 1970–1980							
New York	NY	7,894,851	−11.00	−9.29	−2.55	0.83	**−1.72**
Chicago	IL	3,362,825	−11.24	−7.37	−1.12	−2.76	**−3.88**
Los Angeles	CA	2,816,111	5.21	−4.76	0.11	9.86	**9.97**
Philadelphia	PA	1,948,609	−14.32	−10.79	−5.30	1.75	**−3.54**
Detroit	MI	1,511,336	−22.69	−8.96	−2.26	−11.55	**−13.81**
Houston	TX	1,232,407	25.66	−16.89	−3.43	45.36	**41.92**
Baltimore	MD	905,759	−14.06	−11.41	−1.80	−0.86	**−2.66**
Dallas	TX	844,189	6.85	−16.52	−1.82	25.10	**23.28**
Washington	DC	756,510	−16.94	−13.32	−3.09	−0.55	**−3.64**
Cleveland	OH	751,046	−26.75	−13.97	−3.10	−9.82	**−12.91**
Indianapolis	IN	744,570	−6.06	−15.85	−1.70	11.51	**9.81**
Milwaukee	WI	717,124	−11.96	−13.97	−0.99	3.01	**2.02**
San Francisco	CA	715,674	−5.26	−6.54	−0.61	1.88	**1.27**
San Diego	CA	696,566	22.77	−11.82	−0.21	34.56	**34.35**
San Antonio	TX	654,289	18.27	−12.25	−0.56	30.90	**30.34**
Boston	MA	641,053	−12.97	−13.35	−3.38	3.77	**0.38**
Memphis	TN	623,755	3.56	−15.69	−1.78	20.98	**19.21**
St. Louis	MO	622,236	−31.46	−12.63	−2.48	−16.56	**−19.04**
New Orleans	LA	593,471	−6.25	−13.81	−0.76	8.33	**7.58**
Phoenix	AZ	581,600	30.35	−11.94	−3.03	44.80	**41.77**
(B) 1980–1990							
New York	NY		3.49	2.39	−0.14	1.24	**1.10**
Chicago	IL		−7.65	−1.21	−2.70	−3.74	**−6.44**
Los Angeles	CA		16.07	9.11	−1.80	8.78	**6.98**
Philadelphia	PA		−6.27	−3.54	−1.09	−1.64	**−2.73**
Detroit	MI		−15.72	−1.01	−0.79	−13.93	**−14.72**
Houston	TX		2.20	−0.12	−4.32	6.64	**2.32**
Baltimore	MD		−6.67	−4.90	−2.10	0.33	**−1.77**
Dallas	TX		10.76	−1.65	−5.01	17.39	**12.38**
Washington	DC		−5.05	−3.65	−1.31	−0.09	**−1.40**
Cleveland	OH		−12.64	−3.79	−2.25	−6.61	**−8.86**
Indianapolis	IN		4.26	−7.28	−0.45	11.98	**11.53**
Milwaukee	WI		−1.29	−0.76	−0.70	0.17	**−0.53**
San Francisco	CA		6.41	4.22	−1.13	3.32	**2.19**
San Diego	CA		23.67	0.28	0.75	22.65	**23.40**
San Antonio	TX		17.43	−5.77	−3.91	26.99	**23.08**
Boston	MA		1.99	−2.49	0.94	3.54	**4.48**
Memphis	TN		−5.73	−5.45	−1.87	1.59	**−0.28**
St. Louis	MO		−13.27	−5.64	−4.02	−3.63	**−7.65**
New Orleans	LA		−11.49	−2.27	−8.34	−0.89	**−9.22**
Phoenix	AZ		21.85	−4.22	−4.83	30.75	**25.91**
(C) 1990–2000							
New York	NY		8.95	2.03	0.61	6.31	**6.92**
Chicago	IL		3.95	0.43	1.99	1.53	**3.52**
Los Angeles	CA		5.83	1.18	2.02	2.64	**4.65**
Philadelphia	PA		−4.38	−2.21	−0.09	−2.09	**−2.18**
Detroit	MI		−7.75	2.85	−1.57	−9.02	**−10.60**
Houston	TX		18.03	2.90	8.06	7.11	**15.17**

Table 1 (*continued*)

		1970 Population	% Δ Population	% Δ HH size	% Δ Occupancy rate	% Δ units	% Δ Occupied units
Baltimore	MD		−12.23	−5.33	−5.45	−1.47	**−6.92**
Dallas	TX		16.55	4.91	7.86	3.81	**11.67**
Washington	DC		−5.91	−5.39	0.93	−1.45	**−0.52**
Cleveland	OH		−5.53	−0.84	−0.58	−4.11	**−4.69**
Indianapolis	IN		6.68	−2.53	−0.34	9.54	**9.20**
Milwaukee	WI		−5.08	−1.55	−1.49	−2.05	**−3.53**
San Francisco	CA		7.03	−0.56	2.88	4.72	**7.59**
San Diego	CA		9.67	−0.74	2.41	8.01	**10.41**
San Antonio	TX		20.06	−1.46	4.77	16.78	**21.55**
Boston	MA		2.55	−2.17	4.60	0.13	**4.73**
Memphis	TN		6.31	−2.39	0.02	8.68	**8.70**
St. Louis	MO		−13.02	−1.58	−1.24	−10.21	**−11.45**
New Orleans	LA		−2.50	−2.51	5.24	−5.23	**0.01**
Phoenix	AZ		29.30	6.46	7.15	15.87	**23.02**

Source: State of the Cities Database, accessible at http://socds.huduser.org/, accessed (most recently) April 22, 2004.

embodied in the structure may approach zero, which Ingram and Kain term "scrapping," a supply side adjustment. Second, some structures may still embody physical capital, but they are withdrawn when the value of that capital approaches 0, a demand side adjustment. Changes in decadal housing stocks represent net adjustments, initial stock less number of units leaving, plus number of units entering or reentering. In cities with zero net change, new or renovated units offset those units that have left the market.

Much of the literature has found overall annual dwelling depreciation rates between 1 and 2% (Gravelle, 1999). These estimates are typically: (1) net of maintenance expenditures; and (2) uncorrected for selection bias because units that depreciate fastest drop out of the stock first (Hulten and Wykoff, 1980). Murray et al. (1991) and Neels and Rydell (1981) estimated annual depreciation rates between 6 and 8% for rental housing using Experimental Housing Allowance Program data from the 1970s. Malpezzi et al. (2001) correct published depreciation estimates, based on a study by Winfrey (1935) and the analyses of Hulten and Wykoff. Malpezzi, Shilling, and Yang calculate an average adjustment factor across property types of 2.4, implying that correcting for sample selection would more than double the rate of net depreciation.

Applying these factors to Gravelle's survey findings suggests gross annual depreciation rates of roughly 2.5–5%. Compounded annually, a 2.5% depreciation rate yields a 22.3% decline per decade. The rate of stock decline is related to the initial value of the stock, the age of the stock, and the amount of new construction.[7] One can conclude that many central cities have seen very little new construction or remodeling to buffer the gross depreciation of the stock over the last three decades of the twentieth century.

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[7] McDonald (1979, Chapter 8) emphasizes demolition costs, so that demolition with replacement will most likely occur at locations where housing demand increases. This would explain "tear-downs and rebuilds" in desirable parts of many cities. He puzzles however over the "long lags observed in some inner city areas between building abandonment, demolition, and replacement," when speculation leaves land vacant for long periods, and what causes the speculation.

3. A supply and demand model

This section seeks to model the decadal changes in dwelling units discussed in Table 1 which showed that central city housing supply (measured in occupied units) has adjusted substantially in both positive and negative directions throughout the United States. A simple correlation over the 351 cities of the three-decade rates of change in occupied units and real median house values is +0.35, suggesting that the changes in central city housing supplies can be explained in a supply and demand context.

Whereas most "open city" central place models (e.g., Brueckner, 1987) implicitly assume that all land or dwelling units that are demanded will be supplied, it seems appropriate here to address the issue that the units that are supplied will be demanded. The open city analyses suggest that people migrate among areas, with the resulting land value and wage adjustments equalizing utility. My analysis of the changes in numbers of units uses a structural model of supply of housing stock and demand for housing services, where a unit of stock provides a unit of services. The model implies migration among metropolitan areas, with residents and investors choosing a metropolitan area, and then purchasing or investing in either central city or suburban locations.

I adapt a model following Mills and Hamilton (1994) in which demand for housing units Q^D is related to the housing services rental price R, income per capita Y, and metropolitan population N. Supply of housing units Q^S is related to the value of housing stock V and other supply shifters G^k, including factor costs, climate, or degree of labor market unionization, which would usually be characterized with city-, state-, and/or regional binary variables.[8] The use of both R and V does not indicate a tenure choice model, but rather a model in which units could either be owned or rented. Quantity supplied equals quantity demanded in Eq. (5) and in long run equilibrium (6), market rents and house values are related by user cost ρ, which includes the effects of foregone interest, property taxes, and expected capital gains. In equation form:

$$\text{Demand for Housing Units}: \ln Q_t^D = \alpha \ln Y_t + \beta \ln R_t + \delta \ln N_t + \varepsilon_t^D, \tag{3}$$

$$\text{Supply of Housing Units}: \ln Q_t^S = \gamma \ln V_t + \sum_k \eta_k G_t^k + \varepsilon_t^S, \tag{4}$$

$$\text{Product Market Equilibrium}: \ln Q_t^S = \ln Q_t^D, \tag{5}$$

$$\text{Capital Market Equilibrium}: \ln R_t = \ln V_t + \ln \rho_t. \tag{6}$$

Price elasticity β is expected to be negative with the other behavioral elasticities positive. The signs of shifters η_k are indeterminate.[9]

The model is well suited for examining long-term changes in housing values, rents, and prices. The short term may feature substantial adjustment costs, but Table 1 indicates substantial quantity responsiveness over ten year intervals.[10] Solving for Q and V yields:

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[8] Malpezzi (1996), for example, has developed indices of regulatory stringency, but they are available for only a subset of the 351 cities studied, and not for all three decades.

[9] Malpezzi and Maclennan (2001) develop a model that leads to similar reduced form parameters.

[10] The literature is not consistent here. Topel and Rosen (1988) and Mayer and Somerville (2000b) find that long and short run investment supply converge in about a year, which seems unusually fast. DiPasquale and Wheaton (1994) estimate an adjustment rate of 2%, implying 35 years to reach a new equilibrium. DiPasquale (1999) characterizes this adjustment rate as "too slow."

$$\ln V_t = \frac{\alpha}{\gamma-\beta}\ln Y_t + \frac{\beta}{\gamma-\beta}\ln \rho_t + \frac{\delta}{\gamma-\beta}\ln N_t - \sum_k \frac{\eta_k}{\gamma-\beta} G_t^k, \text{ or} \tag{7}$$

$$\ln V_t = \vartheta_1 \ln Y_t + \vartheta_2 \ln \rho_t + \vartheta_3 \ln N_t - \sum_k \vartheta_k G_t^k, \tag{7$'$}$$

$$\ln Q_t = \gamma \ln V_t + \sum_k \eta_k G_t^k. \tag{8}$$

Eqs. (7′) and (8) are estimated in difference form to explain the decadal changes.

Differencing the values and the rents approximates a "repeat" index for units in the housing stock at the beginning and at the end of the decade and adjusts for systematic differences in unit size or quality across cities. It would seem most important in explaining decadal housing supply responses, for example, that in the 1970s the real Baltimore median house values increased by 30.6% (from \$42,938 in 1970 to \$58,431 in 1980) while those in Cleveland decreased by 16.0% (from \$72,136 in 1970 to \$61,464 in 1980).[11]

Vector G^k is characterized by binary variables including city and regional effects that do not change by decade, so differencing Eqs. (7′) and (8) eliminates these fixed effect shifters. To the extent that adjustments are incomplete, parameter estimates will be biased downward.

$$\begin{bmatrix} \hat{V}_1 \\ \hat{Q}_1 \\ \hdashline \hat{V}_2 \\ \hat{Q}_2 \\ \hdashline \hat{V}_3 \\ \hat{Q}_3 \end{bmatrix} = \begin{bmatrix} \boldsymbol{\vartheta}_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & \boldsymbol{\gamma}_1 & 0 & 0 & 0 & 0 \\ \hdashline 0 & 0 & \boldsymbol{\vartheta}_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & \boldsymbol{\gamma}_2 & 0 & 0 \\ \hdashline 0 & 0 & 0 & 0 & \boldsymbol{\vartheta}_3 & 0 \\ 0 & 0 & 0 & 0 & 0 & \boldsymbol{\gamma}_3 \end{bmatrix} \begin{bmatrix} \hat{\mathbf{z}}_1 \\ \hat{V}_1 \\ \hdashline \hat{\mathbf{z}}_2 \\ \hat{V}_2 \\ \hdashline \hat{\mathbf{z}}_3 \\ \hat{V}_3 \end{bmatrix} + \begin{bmatrix} u_1^V \\ u_1^Q \\ \hdashline u_2^V \\ u_2^Q \\ \hdashline u_3^V \\ u_3^Q \end{bmatrix}. \tag{9}$$

"Hats" ^ indicate percentage changes in decades 1 (1970s), 2 (1980s), and 3 (1990s). Vectors ϑ and γ are parameters for the value and quantity equations, **z** represents vectors of explanatory variables, and the dashed lines separate decades. Three estimation methods are used.

1. *Indirect least squares (ILS)*. A two-stage ILS estimator will first estimate the value change equation $\hat{V}$ in each decade, and then use the fitted value in the quantity change equation $\hat{Q}$. The parameters from Eqs. (7′) and (8) are identified in this procedure.
2. *Three stage least squares (3SLS)*. Following Greene (2003, p. 405) a generalized least squares (GLS) method will provide consistent and efficient estimators of both equations.
3. *Multi-decade 3SLS*. Limiting estimates to a given decade ignores the correlation of decadal changes (1970s errors might plausibly be correlated with 1980s or 1990s errors.) This third method will attempt to estimate the six equations as a system for the three decades to compare results with the decade-by-decade 3SLS method.

Section 4 will provide symmetric (the same in each direction of housing stock change) supply elasticities for the entire sample. Section 5 will provide separate estimates for cities with decreases and increases in occupied units to determine whether supply elasticities are asymmetric.

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[11] All house value, rent, and income changes are derived from constant (\$2000) dollar measures by deflating current dollars by the Consumer Price Index. Percentage changes are calculated with the midpoint method.

The variables chosen are guided by "open city" analyses (e.g., Brueckner, 1987) suggesting that over time people migrate among areas, with resulting land value and wage adjustments serving to equalize utility. The model implies migration among metropolitan areas, with residents and investors purchasing or investing in a metropolitan area, and then choosing either central city or suburban locations. Metropolitan population increases N imply increased dwelling unit demand both in cities and suburbs, and increased rents and values in both. Central city median incomes Y that change at the same rate as the suburbs would not have differential impacts on demand.[12]

A straightforward application of the capital market equilibrium Eq. (8) would use the rent/value ratio for ρ. However, the theoretical derivation of ρ contains *expected* capital gains, which are not identical either to current or to past house value appreciation, even though analysts often use current or recent appreciation as proxies [Green and Malpezzi, 2003, (p.57) note that there is no "generally accepted" way to measure these expectations]. In static equilibrium, rent/value ratios and housing values might be jointly determined, but proposed *user cost* measure, $D = Pct.\ \Delta\rho_c - Pct.\ \Delta\rho_s$, differences the rent/value both within the central city and the suburbs and examines the central city changes relative to the *suburbs*. Relative increases in central city user cost imply higher rents, hence lower quantity demanded, given the same changes in housing values, through Eq. (3).

Given the potential simultaneity of ρ and house value, however, I consider an alternative instrumental estimator for the user costs, based on the assumption that rent/value ratios at the beginning of the decade reflect expectations of changes in housing value through the decade. In Eq. (10), subscripts c and s refer to the central city and the suburbs respectively, and G_k refers to regional dummy variables:[13]

$$D = Pct.\ \Delta\rho_c - Pct.\ \Delta\rho_s = \phi_0 + \phi_c\rho_c + \phi_s\rho_s + \sum_k v_k G_k. \tag{10}$$

An initially high ρ_c (low central city value/rent ratio) would be expected to predict a decrease ($\varphi_c < 0.$) in D. Similarly an initially high suburban ρ_s would predict a suburban user cost decrease relative to the CC, or a rise ($\varphi_s > 0$) through the decade in D. Predicted value $\hat{D}$ from Eq. (10) is then used as an alternative measure of user cost in the supply–demand regressions.

4. Symmetric supply elasticities

This section presents symmetric demand and supply estimates for the three decades beginning with indirect least squares (ILS) estimates consistent with Eqs. (7′) and (8). It follows with single decade 3SLS estimators.[14]

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[12] The demand literature (e.g., Goodman, 1990) has shown impacts of household size it to be ambiguous. On the one hand, larger households may "need" more housing; on the other hand, holding incomes constant, they may need to spend more money on other items, leading to less housing. As a result, it was not included. Work in progress on housing supply functions within metropolitan areas, has found its effect to be inconclusive.

[13] Freddie Mac regional categories are used: *Northeast*: NY, NJ, PA, DE, MD, DC, VA, WV, ME, NH, VT, MA, RI, CT; *Southeast*: NC, SC, TN, KY, GA, AL, FL, MS; *North Central*: OH, IN, IL, MI, WI, MN, IA, ND, SD; *Southwest*: TX, LA, NM, OK, AR, MO, KS, CO, NE, WY; *Mountain/West*: CA, AZ, NV, OR, WA, UT, ID, MT, HI, AK.

[14] Multi-decade 3SLS estimators (similar to Table 4) do not always converge. Where they converge, results are similar to the single decade estimates. The multi-decade estimates will be presented for the asymmetric estimates in Table 5.

Table 2 provides summary measures of the structural variables used to estimate Eqs. (7′) and (8) in difference form. Central city median house values V (in \$1999) increased by 22.3, 1.7, and 8.4% for the 1970s, 1980s, and 1990s, respectively. Mean percentage changes in occupied units Q were +19.3, +10.3, and +9.2, for the three decades respectively; these were slightly less than changes in total units in the 1970s and 1980s, and slightly more in the 1990s.

Metropolitan populations N grew by 15.4% in the 1970s, 10.0% in the 1980s and 11.9% in the 1990s. Central city median incomes Y grew less than suburban incomes in the 1970s (by −9.3%) and 1990s (−2.6%), but slightly more (+4.2%) in the 1980s. User cost ρ, median rent divided by median value, grew in the central cities relative to the suburbs in all three decades with differential increases of 9.9, 1.5, and 4.0%, respectively.

Table 3 estimates instrumental Eq. (10) by decade. The impacts of initial user costs ρ_c and ρ_s have expected (and significant) signs, and initial suburban rent/value ratios have

Table 2
Descriptive measures of regression variables

Variable ($N = 351$)	1970–1980		1980–1990		1990–2000	
	Mean	SD	Mean	SD	Mean	SD
Pct. Δ central city value[a]	0.2228	0.1999	0.0167	0.2976	0.0843	0.2133
Pct. Δ central city occupied units	0.1929	0.2071	0.1031	0.1373	0.0917	0.1367
Pct. Δ central city units	0.2044	0.2033	0.1134	0.1309	0.0859	0.1326
Pct. Δ relative income[b]	−0.0927	0.2440	0.0421	0.1084	−0.0264	0.1026
Pct. Δ relative ρ[c]	0.0991	0.1583	0.0152	0.1184	0.0405	0.0904
Pct. Δ metropolitan population	0.1545	0.1435	0.0997	0.1218	0.1193	0.0956

[a] All values in \$1999.

[b] % Δ in central city income less % Δ in suburban income.

[c] % Δ in central city user cost less % Δ in suburban user cost.

Table 3
Instrumental estimates for change in user cost

	1970s	1980s	1990s
Constant	**−0.0818**	**−0.2042**	**0.0350**
	0.0503	0.0380	0.0258
Initial central city ρ_c	**−31.9274**	**−21.7090**	**−14.3670**
	6.1158	4.6882	3.5237
Initial suburban ρ_s	**60.4806**	**67.1892**	**20.6449**
	7.3586	7.6502	6.1847
South	**−0.0515**	**−0.0341**	**−0.0189**
	0.0218	0.0173	0.0156
Midwest	**0.0416**	**0.0473**	**−0.0211**
	0.0217	0.0165	0.0155
Southwest	**0.0156**	**−0.0701**	**−0.0135**
	0.0245	0.0177	0.0168
Mountain/west	**−0.1006**	**0.0331**	**−0.0602**
	0.0233	0.0208	0.0155
SER	0.1325	0.1042	0.0868
R^2	0.3118	0.2386	0.0928

Coefficients in **bold**; standard errors in roman type.

larger impacts on subsequent user cost changes than central city rent/value ratios in all three decades. Evaluating each equation with the constant and the mean values of ρ_c and ρ_s yields expected increases in central city user costs relative to the suburbs. The regional dummy variables are significant in various equations, but only the South has a consistent (negative) sign across the three decades, and it is not significant in the 1990s.

In Table 4A, the ILS estimators calculate percentage change in median house value, with the fitted value then used as a regressor for the percentage change in occupied units. Columns (1)–(3) use the rent/value measures for change in ρ, providing supply elasticities of +1.10, +0.58, and +0.42 for the 1970s, 1980s, and 1990s, respectively, with a mean elasticity of +0.70 and a median of +0.58.[15] Columns (4)–(6) use the instrumental user cost estimates from Table 3, for supply elasticities of +1.29, +0.92, and +0.73, respectively, with a mean of +0.98, and a median of +0.92.

The single decade iterative 3SLS method in Table 4B provides improved estimates of the reduced form demand parameters, with supply coefficients remaining constant. The iterative process converges for all three decades. Using rent/value ratios for ρ, demand elasticities for price, per capita income, and metropolitan population are −0.25, +0.16, and +0.86, respectively. The 1970s, 1980s, and 1990s 3SLS price elasticities of −0.22, −0.33, and −0.40 are smaller in absolute value than the corresponding ILS estimates, and considerably more stable. With the Eq. (10) instruments, the demand price elasticities do not differ significantly from 0. Income and population elasticities are slightly smaller than with the rent/value ratios.

In sum, the estimated supply price elasticities are substantial considering that existing housing stock provides long-lived and non-malleable housing stock. The three-decade means vary from +0.70 to +0.98 (medians vary from +0.58 to +0.92), using a single parameter for both growing and declining cities. The estimates with instrumental user costs yield slightly higher supply price elasticities and slightly lower demand price elasticities than the rent/value terms.[16]

5. Asymmetric (kinked) supply elasticities

This section allows for asymmetric relationships between housing stock and house values depending on whether the stocks increase or decrease. If supply elasticities vary asymmetrically with direction of the change, then single parameter estimates will lead to larger prediction errors, particularly in the negative direction. Given the potential for joint determination with the untransformed rent/value ratio, the instrumental Eq. (10) methods will be used for subsequent analyses (estimates with rent/value are similar and available on request).

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[15] The supply elasticities are stable, but other structural parameters calculated from the reduced form estimates are less stable with occasionally incorrect signs. In such cases it seems appropriate to report the median along with the mean estimate for three-decade estimates.

[16] Many variables were used in the initial regressions, including central city minority percentages, which were treated as supply shifters in the structural equations, implying that suppliers may avoid building units, or may abandon units more quickly, in cities with high or increasing minority percentages. There was little impact, possibly because many cities had large minority percentages at both the beginnings and ends of decades. I return to this issue in Section 6.

Table 4
Joint estimation of supply and demand for occupied dwelling units

	Untransformed ρ			Instrumental ρ		
	(1) 1970–1980	(2) 1980–1990	(3) 1990–2000	(4) 1970–1980	(5) 1980–1990	(6) 1990–2000
(A) Single decade—indirect LS						
Dep: % Δ value						
Constant	**0.1569**	**−0.0305**	**0.0765**	**0.1424**	**−0.0412**	**0.0901**
	0.0148	0.0205	0.0173	0.0184	0.0217	0.0236
Pct. Δ relative ρ	**−0.3551**	**−0.6367**	**−0.8476**	**−0.2197**	**−0.5119**	**−1.3574**
	0.0566	0.1291	0.1139	0.1033	0.2711	0.3897
Pct. Δ relative income	**0.0144**	**0.2142**	**0.3276**	**0.0657**	**0.3178**	**0.4146**
	0.0364	0.1393	0.0996	0.0372	0.1415	0.1045
Pct. Δ metropolitan population	**0.6622**	**0.4801**	**0.4261**	**0.7005**	**0.5246**	**0.5043**
	0.0611	0.1237	0.1059	0.0641	0.1287	0.1114
SER	0.1607	0.2782	0.1880	0.1685	0.2863	0.1990
Dep: % *Δ* occupied units						
Constant	**−0.0523**	**0.0933**	**0.0566**	**−0.0942**	**0.0877**	**0.0305**
	0.0181	0.0066	0.0090	0.0186	0.0061	0.0097
VHAT	**1.1008**	**0.5824**	**0.4168**	**1.2890**	**0.9197**	**0.7264**
	0.0714	0.0600	0.0680	0.0752	0.0708	0.0843
SER	0.1600	0.1220	0.1301	0.1528	0.1129	0.1243
Elasticities						
Supply	1.1008	0.5824	0.4168	1.2890	0.9197	0.7264
Demand price	−0.6060	−1.0207	−2.3178	−0.3628	−0.9646	2.7588
Demand income	0.0246	0.3434	0.8958	0.1085	0.5989	−0.8426
Demand metropolitan population	1.1302	0.7697	1.1652	1.1571	0.9885	−1.0250
Three decade average elasticities						
	Mean	Median		Mean	Median	
Supply	0.7000	0.5824		0.9783	0.9197	
Demand price	−1.3148	−1.0207		0.4771	−0.3628	
Demand income	0.4213	0.3434		−0.0451	0.1085	
Demand metropolitan population	1.0217	1.1302		0.3736	0.9885	
(B) Single decade—3SLS						
Dep: % *Δ* value						
Constant	**0.1201**	**−0.1184**	**−0.0025**	**0.1126**	**−0.0672**	**−0.0262**
	0.0128	0.0189	0.0159	0.0145	0.0190	0.0172
Pct. Δ relative ρ	**−0.1641**	**−0.3632**	**−0.4874**	**0.0008**	**0.0460**	**0.0589**
	0.0449	0.1031	0.1092	0.0669	0.1264	0.2869
Pct. Δ relative income	**0.0451**	**0.2578**	**0.3621**	**0.0617**	**0.1430**	**0.3045**
	0.0264	0.0987	0.0873	0.0239	0.0722	0.0801
Pct. Δ metropolitan population	**0.7965**	**1.3014**	**0.9732**	**0.7496**	**0.7745**	**0.9731**
	0.0557	0.0943	0.0939	0.0606	0.0993	0.0896
SER	0.1630	0.2941	0.1957	0.1686	0.2880	0.2067
Dep: % *Δ* occupied units						
Constant	**−0.0523**	**0.0933**	**0.0566**	**−0.0942**	**0.0877**	**0.0305**
	0.0230	0.0116	0.0099	0.0275	0.0163	0.0140
% *Δ* Value	**1.1008**	**0.5824**	**0.4168**	**1.2890**	**0.9197**	**0.7264**
	0.0909	0.1059	0.0748	0.1110	0.1879	0.1213
SER	0.2037	0.2153	0.1431	0.1686	0.2995	0.1790

(*continued on next page*)

Table 4 (*continued*)

	Untransformed ρ			Instrumental ρ		
	(1) 1970–1980	(2) 1980–1990	(3) 1990–2000	(4) 1970–1980	(5) 1980–1990	(6) 1990–2000
Elasticities						
Supply	1.1008	0.5824	0.4168	1.2890	0.9197	0.7264
Demand price	−0.2161	−0.3322	−0.3963	0.0011	0.0404	0.0404
Demand income	0.0593	0.2358	0.2944	0.0794	0.1258	0.2089
Demand metropolitan population	1.0489	1.1903	0.7913	0.9654	0.6809	0.6675
Three decade average elasticities						
	Mean	Median		Mean	Median	
Supply	0.7000	0.5824		0.9783	0.9197	
Demand price	−0.2513	−0.2161		0.0273	0.0404	
Demand income	0.1618	0.1316		0.1380	0.1258	
Demand metropolitan population	0.8611	0.7913		0.7713	0.6809	

Coefficients in **bold**; standard errors in roman type

The asymmetric supply functions were estimated with the three methods described in Section 3. Separate systems of Eqs. (7′) and (8) were estimated for cities with increased and decreased numbers of occupied units, using ILS and single decade 3SLS methods. In the 1970s, 300 cities experienced occupied unit increases; 50 cities experienced decreases (one with inconsistent data was dropped). The 1980s saw 265 (86) cities with increases (decreases); in the 1990s, 269 (82) cities increased (decreased).

Estimating the three-decade constrained 3SLS method requires the same numbers of cities with increases (decreases) in each decade. Some cities with increases in one decade had decreases in other decades, so the samples were divided into those 289 cities with *mean* three-decade increases, and those 62 cities with mean decreases. Mean three-year percentage changes were +17.0% in the positive direction and −4.6% in the negative direction. Because these sample stratification criteria are not strictly comparable to the single decade cases, parameter estimates are also not strictly comparable. A full six-equation system did not converge, so the 1970s and 1980s were grouped in a four-equation system, adding a two-equation 3SLS estimator for the 1990s.

Table 5A presents the supply elasticity estimates (full system regressions are available on request). For the 1970s, the single decade (column 1) and constrained 3SLS (column 2) supply elasticities in the positive direction are +1.32 and +1.29, respectively. In the negative direction, they are +0.10 (column 3) and +0.26 (column 4), respectively. For the 1980s, the single decade and constrained 3SLS supply elasticities in the positive direction are +0.93 and +0.91, respectively. In the negative direction, they are +0.08 and +0.23, respectively. The 1990s estimates are +1.00 and +0.94 in the positive direction, and −0.10 and −0.09 in the negative direction. Averaged over the three decades, the supply elasticities in the positive direction are +1.08 (single decade), and +1.05 (multi-decade); in the negative direction they are +0.03 and +0.13, respectively.

One could argue that first differencing the equations requires that the parameter values be constant for adjoining panels of observations and hence constant across all three decades. Table 5B, estimated by pooling observations across the three decades (using decade-specific dummy shifters), imposes such a constraint, with the elasticities in both the negative (218 observations) and the positive (836 observations) directions *constant* over the three decades. With this method, the three-decade supply elasticity for occupied units in

Table 5
Asymmetric supply estimates—instrumental variables

	Supply increases		Supply decreases	
	(1)	(2) Constrained	(3)	(4) Constrained
	3SLS	3SLS	3SLS	3SLS
(A) Separate decades				
1970–1980				
N	300	288	50	62
Supply elasticity	**1.3244**	**1.2902**	**0.1004**	**0.2569**
Standard error	0.1470	0.1460	0.0693	0.0486
1980–1990				
N	265	288	86	62
Supply elasticity	**0.9332**	**0.9140**	**0.0849**	**0.2296**
Standard error	0.3703	0.2386	0.0346	0.0320
1990–2000				
N	269	288	82	62
Supply elasticity	**0.9972**	**0.9361**	**−0.1025**	**−0.0899**
Standard error	0.2244	0.1730	0.0341	0.0458
Three decade means	**1.0849**	**1.0467**	**0.0276**	**0.1322**
(B) Pooled estimates—three decades				
N		836		218
Supply elasticity		**1.2373**		**0.0847**
SER		0.1408		0.0292

Coefficients in **bold**; standard errors in roman type.

the positive direction is +1.24. The supply elasticity in the negative direction is +0.08. These estimates, as do all others, support the hypotheses that supply elasticities are considerably higher in the positive than in the negative direction, and that they are very close to 0 (although slightly positive) in the negative direction.

6. Central city performance as measured by housing supply

The housing demand and supply regressions estimated thus far have used a parsimonious specification that sought to identify fundamental determinants of the two functions. Regional and city-specific fixed effects were differenced in the decade-by-decade estimates and possibly subsumed in the constant terms. While the resulting supply elasticities of approximately zero in declining cities, and approximately +1.0 in growing cities, appear plausible, there may be systematic effects that have not been addressed.

This section seeks factors that may explain central city housing performance as measured by housing supply. Decade-by-decade 3SLS system estimates in columns (1) and (3) of Table 5A are used to calculate predicted house values, and then predicted housing supplies. Cities with positive (negative) residuals are characterized as outperforming (underperforming) others with respect to housing supply. This section seeks regional performance determinants that might explain these residuals, and whether other city-specific variables might provide useful insights.

Table 6, column (1), uses regional binary variables and additional binary variables for California and Florida (Northeast is the omitted region) to predict the supply residuals for each decade. In none of the three column (1) regressions did any other region perform sig-

Table 6
Analysis of residuals from asymmetric supply estimates *Dependent variable*: supply residuals (+, outperform; −, underperform)

	(1) OLS	(2) OLS	(3) OLS	(4) OLS—fixed effect
1970–1980				
Constant	**−0.0234**	**−0.2424**		**−0.2224**
	0.0125	0.0481		0.0299
South	**0.0303**	**0.0173**		**0.0177**
	0.0190	0.0189		0.0118
Midwest	**0.0280**	**0.0017**		**−0.0001**
	0.0177	0.0188		0.0117
Southwest	**0.0500**	**0.0283**		**0.0286**
	0.0189	0.0200		0.0124
Mountain/west	**−0.0146**	**−0.0450**		**−0.0427**
	0.0242	0.0244		0.0152
California	**0.1326**	**0.1359**		**0.1366**
	0.0305	0.0299		0.0186
Florida	**−0.0954**	**−0.1238**		**−0.1217**
	0.0279	0.0278		0.0173
Central city population 1970 (×100,000)		**−0.0000**		**−0.0000**
		0.0012		0.0007
% Owner units		**0.2958**		**0.2770**
		0.0704		0.0437
Median central city value 1970 (×$100,000)		**0.1014**		**0.0865**
		0.0323		0.0201
SER	0.1117	0.1085		0.0674
R^2	0.1085	0.1663		0.3276
1980–1990				
Constant	**−0.0234**	**−0.1020**	**−0.0397**	**−0.0846**
	0.0095	0.0320	0.0366	0.0239
South	**0.0737**	**0.0650**	**0.0858**	**0.0675**
	0.0145	0.0146	0.0156	0.0102
Midwest	**0.0244**	**0.0102**	**0.0161**	**0.0120**
	0.0134	0.0143	0.0143	0.0093
Southwest	**0.0157**	**0.0010**	**0.0079**	**0.0030**
	0.0144	0.0152	0.0152	0.0099
Mountain/west	**0.0241**	**0.0066**	**0.0043**	**0.0093**
	0.0184	0.0195	0.0193	0.0126
California	**0.0178**	**0.0185**	**0.0289**	**0.0212**
	0.0232	0.0236	0.0235	0.0153
Florida	**−0.0961**	**−0.1063**	**−0.1080**	**−0.1049**
	0.0212	0.0213	0.0210	0.0137
Central city population 1980 (×100,000)		**−0.0016**	**−0.0039**	**−0.0016**
		0.0010	0.0027	0.0018
% Owner units		**0.1351**	**0.0758**	**0.1162**
		0.0540	0.0562	0.0367
Median central city value 1980 (×$100,000)		**0.0200**	**0.0021**	**0.0122**
		0.0154	0.0162	0.0105
% Black 1980			**−0.1278**	**−0.0115**
			0.0381	0.0248
CC pop * % black 1980			**0.0112**	**0.0000**
			0.0101	0.0066
SER	0.0850	0.0839	0.0828	0.0540
R^2	0.0974	0.1288	0.1576	0.2586

Table 6 (*continued*)

	(1) OLS	(2) OLS	(3) OLS	(4) OLS—fixed effect
1990–2000				
Constant	**-0.0118**	**0.0493**	**0.0983**	**0.0188**
	0.0104	0.0356	0.0396	0.0275
South	**0.0595**	**0.0574**	**0.0708**	**0.0600**
	0.0159	0.0164	0.0171	0.0119
Midwest	**0.0140**	**0.0151**	**0.0161**	**0.0241**
	0.0148	0.0164	0.0163	0.0113
Southwest	**−0.0003**	**0.0016**	**0.0010**	**0.0086**
	0.0158	0.0170	0.0170	0.0118
Mountain/west	**0.0245**	**0.0261**	**0.0141**	**0.0300**
	0.0203	0.0204	0.0208	0.0145
California	**−0.0197**	**−0.0083**	**0.0007**	**−0.0300**
	0.0255	0.0278	0.0278	0.0194
Florida	**−0.1120**	**−0.1065**	**−0.1111**	**−0.1083**
	0.0233	0.0235	0.0234	0.0162
Central city population 1990 (×100,000)		**−0.0017**	**−0.0016**	**−0.0005**
		0.0011	0.0028	0.0020
% Owner units		**−0.0928**	**−0.1456**	**−0.0825**
		0.0621	0.0645	0.0449
Median central city value 1990 (×$100,000)		**−0.0106**	**−0.0171**	**0.0078**
		0.0103	0.0106	0.0074
% Black 1990			**−0.0940**	**0.0283**
			0.0379	0.0264
CC pop * % Black 1990			**0.0013**	**−0.0070**
			0.0103	0.0072
SER	0.0934	0.0931	0.0924	0.0642
R^2	0.0816	0.0955	0.1151	0.1876

Coefficients in **bold**; standard errors in roman type.

nificantly worse that the Northeast. Florida's supply response to house value changes, however, was significantly smaller than other states in the South, in all decades, and under all specifications.

Column (2) includes variables reflecting initial central city population, percentage central city owner units, and median central city house value, at the beginning of the decade. Initial population reflects city size, and to some extent city age (most of the larger cities were settled earlier). Percent owner units explores the possibility that owner units are better maintained than renter units and/or landlords of rental units are more ruthless in demolishing units that are not profitable. Median house value suggests that specific percentage changes in value multiplied by smaller initial values may have left housing values still too small to support vigorous investment (i.e., a 20% increase of a $40,000 median value would raise the value by only $8000, whereas a similar percentage increase on a $200,000 median value would result in a $40,000 increase).

The results are mixed. The central city population variable has a negative, but insignificant coefficient for each decade, suggesting that larger, and generally older, cities did slightly worse than others. The percent owner indicator is significantly positive for the 1970s and the 1980s, but negative (although not significantly so) in the 1990s. Median house value has a positive impact in the 1970s (cities with higher initial values do better), but the variable becomes small and insignificant in the 1980s (slightly positive) and 1990s (slightly negative).

Column 3 introduces variables reflecting the racial percentages. The database did not include 1970 racial percentages, and estimates from elsewhere are not strictly comparable to 1980, 1990 or 2000. For the 1980s and 1990s, initial percentage black was used, and was also interacted with initial central city size. In the 1980s, a city of 100,000 that was 10 percentage points more black than another city of similar size performed about 1.2%, or $[0.10 \times (-0.1278 + 0.0112)]$, worse in the change in occupied units. For the 1990s, the difference was about 0.9% worse. Both differences were statistically significant.

Column (4) provides a fixed affect adjustment from the three decadal observations for each city. Residuals from the three equations in column (2) were averaged, and these city-specific fixed effects subtracted from the dependent variables. Column (2) for the 1970s and column (3) for the 1980s and 1990s are re-estimated. As expected, the unexplained variance falls. Most coefficients are unchanged from the earlier estimates, but the racial impacts in the 1980s and 1990s lose significance, suggesting that the column (3) racial estimates were capturing the city-specific fixed effects, which may be related to race. Those effects are now included in column (4), and suggest that racial impacts independent of city-specific fixed effects do not differ significantly from zero. Detroit, for example, has fixed effects that lead to negative performance, but they are not explicitly related (from 1970 through 2000) to *increased* black percentage.

7. Conclusions and observations

This research: (1) decomposed central city population changes in terms of both household size and number of dwelling units; and (2) estimated the determinants of the numbers of dwelling units in a housing supply relationship. A substantial policy literature has evaluated the "health" of cities by looking at changes in their populations. The decomposition of central city populations indicates that such evaluations may be flawed when the changes in populations are due to natural demographic changes rather than (necessarily) deterioration of the housing stock. Further, the decomposition shows substantial (double digit in many cases) percentage declines in occupied housing units for many American cities over the last three decades of the twentieth century.

Addressing housing supply, models with both symmetric and asymmetric (kinked) responses are then estimated. Those with symmetric supply responses (Table 4) yield elasticities between +0.58 and +0.70, using the rent/value user cost, and between +0.92 and +0.98 for the instrumental estimator. In contrast, models with asymmetric responses (Table 5), as suggested by the longevity of housing capital stocks, provide price elasticities between +1.05 and +1.08 in the positive direction, compared to +0.03 to +0.13 in the negative direction. However, even with relatively inelastic responses in the negative direction, plummeting real house values in the 1970s and 1980s were accompanied by major stock decreases through depreciation, abandonment, demolition, and just not building new housing in cities such as Cleveland, Detroit, and St. Louis. Population declines in the 1970s were due in large part to decreasing household size, but many declines continued into the 1980s and 1990s. House values recovered in the 1990s but remained so low in cities like Detroit and St. Louis that suppliers were still reluctant to invest.[17]

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[17] After a 91% increase from 1990 to 2000, Detroit's \$61,532 median house value (\$1999) was still 8% *less* than its 1970 value of \$66,984.

This study has limitations. Census data contain errors relating to undercounts, and analysts must be cautious about interpreting one or two percentage point changes as more than random error. However, it is hard to believe that counting errors could explain the sizable net losses in housing units in several older cities.

One must also consider errors in owner estimates of house values. Pollakowski (1995) discusses the literature, noting that most studies find owner-occupants overestimating their house values, but that owners who sell their dwellings do not perceive value changes over time differently from those who do not sell. Ihlanfeldt and Martinez-Vazquez (1986) and Goodman and Ittner (1992) provide further discussion.

This is a "units" model and it does not account explicitly for either depreciation or improvement in existing stock. Housing supply can grow in situ through remodeling and addition of space. Assuming that existing housing maintains constant size and quality, if the size (quality) of newly constructed units increases (improves) over a decade, then measuring the number of units almost certainly provides a lower bound on the supply response. The variation of size or quality is probably greater over time than across areas, but the *State of the Cities* database will not provide information that can be used to make an adjustment.

Further, Census "snapshots" from 1970, 1980, 1990, and 2000 (with incomes from 1969, 1979, 1989, and 1999) imply that those particular years represented similar points in the respective economic cycles, and that housing stock changes in intervening years are appropriately described by the end-of-decade measures of value and user cost. The year 1980 provided a historically high inflation rate of 13.5%, and a high unemployment rate of 7.2% relative to the other three years.[18] Pryce (1999) suggests evidence of lower flow supply elasticities during booms due to skilled labor shortages, but it is difficult using the data at hand to link the particular characteristics of 1980 to either the higher supply elasticities of the 1970s or the lower ones of the 1980s.

This study has described central city population losses in terms of households and housing units, and explained the changes in housing units in terms of housing demand and supply. Most importantly, the model provides a new way to estimate housing supply elasticity directly by examining decadal changes across a large set of US cities in a manner that permits inferences about central city housing depreciation, abandonment, demolition, and replacement.

Acknowledgments

The author thanks Jan Brueckner, Ed Coulson, David Crary, George Erickcek, George Galster, and Anthony Pennington-Cross for comments, and Maia Platt for research assistance. He is also grateful to the State Policy Center at Wayne State University for financial support. None are responsible for any errors contained therein.

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[18] Inflation rates for 1970, 1990, and 2000 were 5.8, 5.4, and 3.4%, respectively; unemployment rates for 1970, 1990, and 2000 were 5.0, 5.6, and 4.0%, respectively.

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