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Is there an S in urban housing supply? or What on earth happened in Detroit? ☆

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ABSTRACT

This article examines the substantial housing stock declines between 2000 and 2010 in many major US central cities. It updates an analysis first formulated in the 1970s, of an S-shaped housing supply curve, to explain decreases in absolute housing stocks. Explanatory variables include Metropolitan Statistical Area standardized rents, center city prior occupancy rates, regional unemployment rates, and a set of regional and state dummy variables. The analysis provides strong evidence of a lower tail of the S, and more tentative evidence of an upper tail. Market fundamentals explain a considerable portion of the large housing stock losses, but in several cities loss of dwelling units and housing abandonment were worse than could be explained by the fundamentals.

In his classic *A Preface to Urban Economics*, Wilbur Thompson (1965) argued that cities of over half a million in population were unlikely to lose population:

> . . . tremendous amounts of fixed capital have been sunk in social and private overhead in the very large urban area – streets, sewers, schools, water mains, electric power lines, stores and housing – so that even if the area's productive facilities for export are worn out or technically obsolete, public service and utility costs are low enough to make it uneconomic to abandon so much immobile capital. *No nation is so affluent that it can afford to throw away a major city*. (p. 23, emphasis added)

In this perspective, the 2010 Census shows a continuing pattern of housing destruction in many central cities. Detroit in 1970 had 529,012 total dwelling units; by 2010 this number had fallen by 34.0% to 349,170. The number of occupied units fell by 45.9% from 497,748 to 269,445. Similar declines characterize St. Louis, Cleveland, and other central cities in the American Northeast and Midwest. Urban and regional theory discusses adjustments in central city population and housing stock, but outside of natural disasters such as the effects of 2005 Hurricane Katrina on New Orleans, changes of this magnitude are nearly unprecedented in the United States. Moreover, housing stock losses and population declines in Detroit, Cleveland, and Flint, for example, have made it difficult to deliver public services to a population spread out at less than half the density of only forty years ago.

This article explains changes in housing stock in US central cities from 2000 to 2010. It proposes and tests econometrically an S-shaped housing supply curve to explain the decreasing housing stocks for a sample of 315 US central cities.[1] It also devises a measure of abandonment of vacant

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[1] See database details at Census web site at http://www.census.gov. The American Factfinder engine (http://factfinder2.census.gov/main.html) was used to access the data. Data inconsistencies precluded analyses of Honolulu and Louisville. New Orleans is one of the 315 sample cities and its inclusion (despite the damage from Hurricane Katrina) provides perspective, as the other cities cannot blame a natural disaster for their housing problems. Detroit, for example, lost more total units and occupied units from 2000 to 2010 than did New Orleans. All analyses excluding New Orleans (available on request) produced nearly identical results.

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Table 1
Changes in total units – 1970–2010.

	1970–1980	1980–1990	1990–2000	2000–2010	Sum	% Change
Detroit	−57,784	−61,381	−35,383	−25,294	−179,842	−34.00
St. Louis	−36,467	−7,209	−18,911	171	−62,416	−26.18
Cleveland	−24,716	−15,316	−9024	−7557	−56,613	−21.43
Buffalo	−9689	−4525	−6567	−11,876	−32,657	−19.66
Pittsburgh	−10,658	−9394	−7264	−6323	−33,639	−17.72
Newark	−6046	−18,931	−2399	9503	−17,873	−14.03
New Orleans	18,088	−1998	−11,422	−22,789	−18,121	−8.71
Rochester	−2882	−1553	−1495	−2413	−8343	−7.91
Cincinnati	116	−3813	−3361	−4318	−11,376	−6.60
Baltimore	−2623	1001	−4421	−2360	−8403	−2.75
Chicago	−32,881	−43,140	17,431	46,018	−12,572	−1.04
Philadelphia	11,908	−11,162	−13,941	10,003	−3192	−0.47
Akron	919	−474	872	−754	563	0.59
Birmingham	9220	2983	−5885	−2588	3730	3.54
Milwaukee	7506	423	−5144	6830	9615	3.91
Norfolk	3820	3742	−4430	884	4016	4.41
Toledo	12,972	−1309	−2435	−1465	7763	5.96
Washington	−1536	−247	−3972	24,081	18,326	6.58
Minneapolis	1645	3481	−4491	10,461	11,096	6.64
St. Paul	3164	6506	−2051	5500	13,119	12.18
Kansas City MO	−437	9689	166	20,205	29,623	15.41
New York	24,361	36,826	194,069	198,307	453,563	15.55
Oakland	3630	4335	2549	12,597	23,111	15.76
Boston	8928	8699	325	22,114	40,066	17.24
San Francisco	5896	10,692	15,799	34,177	66,564	21.45
Los Angeles	111,721	109,208	34,687	81,165	336,781	31.26
Atlanta	7894	3627	3468	38,734	53,723	31.44
Seattle	8018	18,357	20,419	39,818	86,612	39.03
Miami	20,554	−2495	2478	38,507	59,044	47.25
Memphis	46,409	3928	22,522	21,071	93,930	47.45
Denver	34,124	11,303	10,864	35,805	92,096	47.55
Indianapolis	30,817	36,092	31,985	28,623	127,517	50.53
Omaha	7480	17,921	21,942	12,259	59,602	50.55
Tulsa	34,441	19,595	2582	6616	63,234	51.88
Tampa	13,158	15,063	6018	22,133	56,372	55.95
Wichita	16,687	18,268	16,812	15,610	67,377	67.42
Dallas	87,020	74,317	18,056	33,996	213,389	70.37
Portland OR	16,038	30,072	38,348	29,143	113,601	74.82
Nashville-Davidson (balance)	31,781	39,905	22,503	31,221	125,410	85.19
Oklahoma City	38,609	34,716	15,224	29,902	118,451	85.54
Columbus OH[a]	54,197	40,785	48,712	44,903	188,597	103.42
Houston	250,641	46,539	53,387	114,806	465,373	108.92
Fort Worth	16,778	38,183	16,308	80,698	151,967	109.24
Jacksonville	39,193	53,409	41,169	58,364	192,135	110.33
San Diego	100,647	87,250	35,771	51,437	275,105	114.19
San Jose	80,283	42,457	21,938	33,015	177,693	130.33
El Paso	41,600	34,064	24,622	34,625	134,911	145.54
Tucson	46,869	44,272	25,743	23,625	140,509	157.43
San Antonio	74,294	86,583	66,678	93,423	320,978	157.91
Phoenix	112,509	111,671	72,237	98,862	395,279	202.84

[a] Major growth in study period due to annexations of neighboring areas.

housing stock that researchers can easily construct from Census vacancy data. It then seeks to find whether a set of fundamental factors explains the housing stock decline that occurred in many of the traditional central cities, and to characterize the cities that perform significantly worse than the regression models predict.

1. Population and housing units

Central city populations have plummeted in the past 40 years in many of the older US cities.[2] Detroit, Cleveland, St. Louis, and Buffalo have less than half of their peak populations of the 1950s. Even Chicago which has served as a destination for its surrounding states has lost substantial population. Chicago's loss of 200,418 residents between 2000 and 2010 was eclipsed only by Detroit's loss of 237,493.

Table 1 shows a severe long-term loss of central city housing capital. Detroit suffered a net loss of 180,000 dwelling units, or more than one in three between 1970 and 2010. St. Louis's loss from 1970 to 2000 paralleled that of Detroit in percentage terms. Even with a very modest gain between 2000 and 2010, St. Louis lost on net over one in four units between 1970 and 2010. Cleveland lost more than one in five.

[2] Henceforth the article uses "cities" and "central cities" interchangeably. Where necessary, it distinguishes cities from their larger surrounding metropolitan areas.

Table 2
Changes in occupied units – 1970–2010.

	1970–1980	1980–1990	1990–2000	2000–2010	Sum	% Change
Detroit	−64,260	−59,431	−37,629	−66,983	−228,303	−45.87
St. Louis	−37,431	−13,117	−17,855	−5019	−73,422	−34.07
Cleveland	−30,106	−18,510	−9149	−23,148	−80,913	−32.57
Buffalo	−16,998	−4518	−13,716	−10,184	−45,416	−28.75
New Orleans	15,072	−18,200	16	−46,093	−49,205	−25.71
Pittsburgh	−11,952	−12,584	−9744	−7522	−41,802	−23.48
Newark	−10,113	−19,360	−170	3160	−26,483	−21.88
Cincinnati	−2125	−3335	−6247	−14,675	−26,382	−16.51
Rochester	−6641	−990	−4608	−1972	−14,211	−14.04
Baltimore	−7589	−4,930	−18,488	−8093	−39,100	−13.53
Birmingham	7384	−1822	−6634	−9400	−10,472	−10.49
Akron	−1016	−653	193	−6404	−7880	−8.60
Chicago	−43,228	−68,236	36,754	−16,368	−91,078	−8.01
Philadelphia	−22,364	−16,706	−13,004	9665	−42,409	−6.60
Toledo	7671	−2159	−1958	−9195	−5641	−4.50
Milwaukee	4836	−1278	−8352	−1967	−6761	−2.85
Norfolk	1060	1676	−3268	275	−257	−0.30
Minneapolis	666	−1176	1670	1188	2348	1.46
Washington	−9395	−3509	−1296	18,369	4169	1.59
St. Paul	2121	4026	1860	−1108	6899	6.63
Kansas City MO	−1131	2405	6380	8425	16,079	9.12
New York	−48,342	30,871	202,187	88,196	272,912	9.62
Oakland	2831	2864	6269	3001	14,965	10.78
Atlanta	289	−6801	12,395	16,995	22,878	14.10
Boston	839	10,007	11,064	13,171	35,081	16.12
San Francisco	3782	6628	24,116	16,111	50,637	17.15
Los Angeles	107,783	82,175	58,007	42,756	290,721	28.30
Miami	13,620	−3794	3946	24,119	37,891	31.46
Memphis	40,426	−645	20,892	−377	60,296	31.73
Seattle	13,369	17,233	21,797	25,011	77,410	37.56
Indianapolis	24,338	31,838	28,162	12,092	96,430	40.90
Denver	26,235	−614	28,283	23,872	77,776	41.97
Tampa	10,737	9197	9958	11,197	41,089	43.31
Tulsa	32,585	10,056	10,273	−1768	51,146	45.33
Omaha	763	15,380	22,896	5889	51,428	46.25
Dallas	74,107	46,971	49,791	6224	177,093	63.03
Wichita	17,521	12,943	15,838	12,731	59,033	63.62
Portland OR	13,929	28,378	36,513	24,809	103,629	71.51
Nashville-Davidson (balance)	29,164	29,014	28,816	21,599	108,593	77.34
Oklahoma City	32,979	18,661	25,746	25,799	103,185	81.22
Columbus OH[a]	44,107	39,862	44,521	30,068	158,558	91.63
Houston	209,572	14,130	101,096	64,698	389,496	99.07
Jacksonville	34,836	44,882	43,115	38,607	161,440	99.86
Fort Worth	14,044	24,256	26,804	67,574	132,678	102.08
San Diego	94,129	85,036	44,595	32,401	256,161	112.88
San Jose	78,838	40,594	26,411	24,768	170,611	130.48
Tucson	41,040	37,419	30,206	12,499	121,164	143.86
El Paso	39,980	32,378	21,518	34,831	128,707	145.95
San Antonio	68,253	67,772	78,723	74,168	288,916	151.48
Phoenix	98,675	85,141	95,913	48,972	328,701	176.62

[a] Major growth in study period due to annexations of neighboring areas.

If total units mirror housing supply, then occupied units may mirror demand. Table 2 shows that by 2010, Detroit had lost 45.9% of its occupied 1970 housing units, St. Louis 34.1%, and Cleveland 32.6%. Many of these central cities and their surrounding metropolitan areas participated disproportionately in the 2008–2010 "Great Recession", but these losses of occupied units reflect a continued loss of capital stock. In contrast to highly publicized housing removal of the 1950s and 1960s from urban renewal or highway construction, by 2010 several major cities contained large swaths of vacant and/or abandoned housing resulting largely from market forces. This loss of housing capital also affected neighborhood quality, tax base, and the delivery of public services.

Vacant and abandoned housing may represent different points on a continuum, in that most abandoned housing starts as vacant housing. Cities that are efficient at tearing down abandoned units may show lower vacancy rates, although the numbers and changes in occupied units are unaffected. After examining 2000–2010 decadal changes in housing stock, the analysis will consider measures of housing abandonment and their determinants for 2010.

2. Housing in urban models

The modern treatment of urban housing followed the development of central place theory in the Alonso–Muth–Mills tradition (Brueckner, 1987). Early versions referred solely to land demand which increased with distance to the central place, and analysts found it straightforward to add housing to the models, with land as a factor of production. Smaller units and taller central city buildings followed from the high land rents there. At greater distances from the central place, cheaper land led to larger floor space and to one- and two-floor buildings (and consequently lower densities), rather than multi-level buildings. Cities would adjust in land area and population, depending on transportation costs to the center and residents' incomes.

Even modest dwelling units may last over 100 years, and developers may find it difficult and expensive to assemble sites or to tear down existing units. Urban theorists debated whether durability of housing capital undermined the long-run equilibrium conditions implied by the standard central place model. Harrison and Kain (1974) showed that downward sloping rent and density functions occur even in a model in which housing lasts forever.

Others including Ingram and Kain (1973) and McDonald (1979) examined long-lived housing in urban areas. McDonald notes that the high costs of tearing down dwelling units make central city redevelopment unattractive compared to development at the urban periphery. However, even with the recent physical destruction of dwelling units in many cities, low rents, poor provision of public services, or difficulties in site assembly, have made redevelopment infeasible. These difficulties have led activists to advocate "urban farming" on the vacant land, although the problems of site preparation, scale economies, and entrepreneurial expertise appear to make that alternative economically unviable as well.

3. An S-shaped supply curve

Recent housing supply analysis has assumed that urban housing stock lasts for a very long time. Glaeser and Gyourko (2005) discuss asymmetric models in which existing housing supply is price-inelastic, but new housing supply is more elastic (see Green and Malpezzi 2003, pp. 19–21). Goodman (2005a,b) posits and verifies a kinked housing supply curve with higher supply price elasticity in the positive direction. Fig. 1 illustrates this feature, with large numbers of small, competitive, housing suppliers at price *C*.

A demand increase from D_1 to D_2 (in Fig. 1) raises the quantity supplied, with only modest changes in unit price. A demand decrease from D_1 to D_3, in contrast, decreases the price of the existing housing capital. Goodman (2005a,b) finds that central city housing unit supply elasticities in cities with declining numbers of units varied from 0.00 to +0.25 in the 1970s, 1980s, and 1990s. Cities with increasing numbers of units showed elasticities close to +1.0 during those decades, with suburbs having supply elasticities well over +1.0.

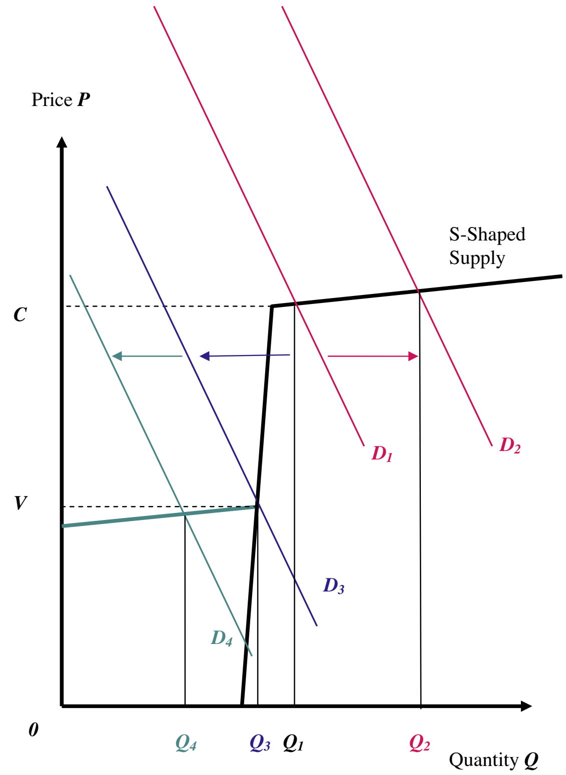

Fig. 1. An S-Shaped Supply Function.

How can theory explain the thousands of dwelling units becoming economically useless and abandoned, or simply disappearing? An extension to the "kinked supply" suggests that as long as dwelling owners or landlords can cover their average variable costs, they will maintain the units. If demand falls even lower, owners and landlords who cannot even cover the variable costs associated with their units may abandon them totally.[3] Rather than a single kink in the supply curve, this would lead to an S shape.

The lower "tail" of Fig. 1 illustrates the process. When rental revenue falls below operating costs *V*, units will be withdrawn from the market. This can be seen in vacancy or abandonment depending on the local policies regarding property tax payment of and housing code enforcement. The nearly vertical supply curve may reflect existing housing supply. Above price *C*, increased housing production responds to increased demand.

A demand increase from D_1 to D_2 thus elicits quantity increase Q_2–Q_1. A decrease from D_1 to D_3 reduces prices or rents, but still covers variable costs, so little housing Q_3–Q_1 leaves the market. However a further decrease in demand to D_4 may make large numbers of existing units economically unviable. While one can consider the move from occupancy to vacancy to abandonment as a continuum (most abandoned units start as vacancies), a sustained

[3] I thank Tony Yezer for this insight. deLeeuw and Struyk (1975) developed a similar model for urban housing policy simulations.

demand fall from D_1 to D_4 in this model can lead to the withdrawal of large numbers of units Q_1–Q_4.

The Census does not explicitly measure abandoned housing, but one can examine the changes in total numbers of units, or total numbers of occupied units. This implies that, all else equal, where rent levels are higher, landlords will more likely cover variable costs, and fewer units will actually leave the stock.

4. Housing vacancy and abandonment

Housing stock vacancy and abandonment interact in a complex manner. Belsky (1992) summarizes a substantial literature on rental vacancy rates, which tend to exceed owner-housing vacancy rates due to renter mobility. Dwelling vacancies provide an inventory of unsold goods, leading to city- or region-specific "natural rates" of vacancy. In such models, movements above (below) the natural rate result in downward (upward) pressure on rents. Gabriel and Nothaft (2001) find that the duration and incidence of vacancies, and the natural vacancy rates, vary across metropolitan areas with housing costs, housing stock heterogeneity, tenant mobility, and population growth. Hagen and Hansen (2010), for the Seattle housing market, find a decline in the natural vacancy rate following the introduction and growth of the Internet. The natural vacancy rates vary significantly by geographic subarea, but not by apartment type.

The abandonment literature, focusing on landlord decisions, is less rich. White (1986) cites Salins (1980) and Sternlieb and Burchell (1973), noting that landlords respond to lower rents by seeking systematically to reduce expenses. They begin by delaying or dropping non-essential repairs. Subsequently, they may default on mortgage obligations. Landlord default may lead lenders to foreclose depending on the lenders' desires to own the buildings. A third step is for landlords to stop paying property taxes. From a tax standpoint, this constitutes abandonment.

White's discussion goes no further than tax-related abandonment, although in her presentation, city government may take over the property. A fourth step would have the landlord simply walk away from the property without anyone taking over, allowing the possibility that some residents may continue to live there as squatters. Sometime thereafter the property becomes uninhabitable or abandoned; sometime after that it disappears from the market housing stock and it may disappear through the removal of plumbing, fixtures, wiring, and/or siding, or altogether.

This article seeks to distinguish between vacancy and abandonment. A natural vacancy rate does not reflect long-term withdrawal from the market, but rather a failure to match demand and supply and current market prices. Vacancy above the natural rate would most likely correlate with abandonment, but cities with more active clearance programs may show lower vacancy rates, although they have no less habitable housing than cities that are showing higher rates.

The 2010 Census does not enumerate abandoned units, but it does list reasons for vacancy: (1) for rent; (2) rented, not occupied; (3) for sale only; (4) sold, not occupied; (5) for seasonal, recreational, or occasional use; and (6) all other vacant. The first five categories arguably represent units that are participating in the market, while *other vacant* status "can also indicate difficulty on the part of the enumerators to determine the status for these vacant units" (Mazur and Wilson, 2010), and may serve as a proxy for vacant units that have been abandoned. This provides another testable hypothesis that in metropolitan areas with higher rents, landlords will more likely cover variable costs, with fewer of the vacant units having owner and market status unknown, and presumably abandoned. Abandonment rate A is defined as category (6), divided by all vacancies (categories 1 through 6).

Table 3 measures vacancy and abandonment of vacant units for selected cities. Table 3a examines the 20 largest cities, showing vacancy rates that vary from slightly over 0.0404 (in San Jose, CA) to 0.2283 in Detroit. Abandonment rates correlate with the vacancy rates (coefficient of 0.61), but they are not identical. For example, Philadelphia shows a vacancy rate of 0.1051, and Dallas a vacancy rate of 0.1134. However Philadelphia's abandonment rate is 0.4114, compared to Dallas's 0.1747. Of these large cities, Charlotte shows the lowest abandonment rate (0.1790) and Detroit the highest (0.5093).

Table 3b lists the 13 cities in the full sample of 315 with abandonment rates of vacant units greater than 0.500 for 2010. Youngstown, Ohio shows the highest rate, with 0.647. Flint, Buffalo, Dayton, and New Orleans all have rates over 0.500.

5. Regressions analyses of supply determinants

Ideally, this analysis would reflect a structural model with changes in quantities and in prices. The findings here are fundamentally reduced form, examining relative changes in quantities, for several reasons:

1. As of 2013, the Census has not released 2010 housing price data for the individual cities, and comprehensive price indices are available for only a small number of the major housing markets.
2. This author views substantive reason to doubt 2010 Census self-enumerations of housing rents or values, when large proportions of those units consisted of foreclosures or short sales. In many markets, over half of the units changing hands fell into these categories.
3. Using lagged values of some of the important variables as instruments helps avoid simultaneity bias. In a cross-sectional analysis, lagged rent indices for 2001, for example, are almost certainly correlated with 2010 rents, but they are not simultaneously determined with the variables to be explained.

Eq. (1) examines determinants of ratios of outcome variables y_{2010} to y_{2000}.

$$\ln(y_{2010}/y_{2000}) = a_0 + a_1 * O_{2000} + a_2 * M_{2007-2009} + g(R)[\text{or}\, h(R)] + \sum_{i=1}^{i=\#\text{Regions, states}} a_{4i} S_i + e_a \tag{1}$$

Table 3
Vacancy, abandonment of vacant units, and rents.

City	(a) 2010 Population	(b) Vacancy rate	(c) Abandonment rate	(d) MSA 1 BR rent
a. Twenty largest central cities				
New York	8,175,133	0.0775	0.2949	922
Los Angeles	3,792,621	0.0678	0.1984	663
Chicago	2,695,598	0.1246	0.3160	711
Houston	2,099,451	0.1232	0.1908	529
Philadelphia	1,526,006	0.1051	0.4114	657
Phoenix	1,445,632	0.1277	0.1832	544
San Antonio	1,327,407	0.0851	0.2508	461
San Diego	1,307,402	0.0638	0.1496	716
Dallas	1,197,816	0.1134	0.1747	647
San Jose	945,942	0.0404	0.1927	1,199
Jacksonville	821,784	0.1179	0.3092	565
Indianapolis	820,445	0.1255	0.3636	500
San Francisco	805,235	0.0826	0.2638	1,221
Austin	790,390	0.0829	0.1547	645
Columbus	787,033	0.1061	0.3097	506
Fort Worth	741,206	0.0977	0.2256	521
Charlotte	731,424	0.0940	0.1790	626
Detroit	713,777	0.2283	0.5093	598
El Paso	649,121	0.0471	0.2995	480
Memphis	646,889	0.1423	0.2945	499
b. Cities with abandonment rate over 0.500				
Youngstown	66,982	0.1897	0.6472	429
Benton Harbor	10,038	0.1804	0.6248	420
Gary	80,294	0.2062	0.5754	574
Jamestown NY	70,145	0.0544	0.5704	427
Flint	102,434	0.2114	0.5389	464
Camden	77,344	0.1369	0.5364	657
Buffalo	261,310	0.1567	0.5355	453
Monroe, LA	48,815	0.1033	0.5289	371
Cumberland, MD	20,859	0.1549	0.5287	446
Dayton	141,527	0.2114	0.5194	463
Detroit	713,777	0.2283	0.5093	598
Steubenville	18,659	0.1478	0.5057	370
New Orleans	343,829	0.2514	0.5038	447

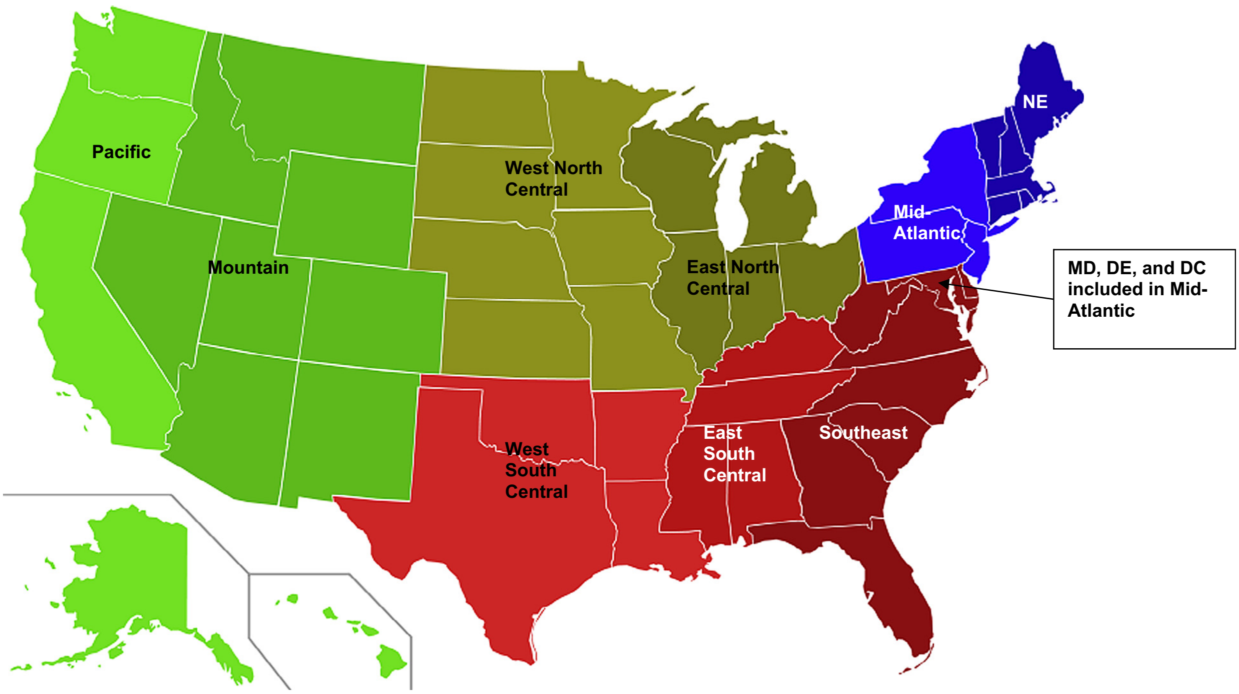

Fig. 2. Census geographic regions used for regional indicators.

The occupancy rates O for 2000 build a history into the model. Higher 2000 central city occupancy rates might imply tighter markets, and the desirability of building and marketing new units. While the housing stock is located within city boundaries, city residents may work elsewhere in the MSA, and other MSA residents may likewise work in the city. MSA-level unemployment rates M for 2007–2009 indicate the general economic climate in the region. Regional and state level dummy variables S_i as noted in Fig. 2 reflect particular regional and state economic factors (the Southeast is the omitted region), and their predicted values and residuals, as above, may reflect predictability and performance.

The S-shape housing supply model requires a nonlinearity of the relationship between variable cost, and number of housing units. The measure of landlords' variable costs is the 2001 MSA-level median rent R for one-bedroom rental units (which correlates at a 0.99 level with the one bedroom 2001 MSA Fair Market Rents).

Column (d) in Table 3 lists these rents for the two samples of cities. Casual observation suggests that the rent levels correlate negatively with vacancy rates and vacancy/abandonment rates, although there are substantial variations. The rents applied to cities in column 3b (high vacancy, high abandonment), are notably smaller than those in column 3a (the larger cities).

Functions g or h account for the expected nonlinearity with respect to rent R, either with cubic polynomials or piecewise linear estimation. Two transformations are used:

$$\text{Cubic} - g(R) = g_1 R + g_2 R^2 + g_3 R^3 \tag{2a}$$

$$\begin{aligned}\text{Piecewise} - h(R) = h_1 R + h_2(&R - 420 \mid R > 420, \\ &0 \text{ otherwise}) + h_3(R - 600 \mid R > 600, \\ &0 \text{ otherwise})\end{aligned} \tag{2b}$$

These transformations are tested against a linear form with two restrictions (either $g_2 = g_3 = 0$, or $h_2 = h_3 = 0$). For an S-shaped relation, in each case, as rent increases, the impact of the variable costs would increase at a decreasing rate. For the cubic case (Eq. (2a)), this implies $g_1 > 0$, with g_2 and g_3 combining for a negative effect. For the piecewise regression (Eq. (2b)), it implies $h_1 > 0$ with $h_2 < 0$, and $h_3 > 0$. Significance tests are distributed $F_{2,315-k}$, with k equal to the number of linear parameters estimated in the unrestricted case.

The median 2001 MSA rent was \$478, and the knot (or break point) at \$420 put the lowest 25% of the distribution in the first piece of the regression. Approximately 16% of the medians exceeded \$600. The estimation results were not sensitive to small variations in the construction of these segments.[4]

[4] Other methods included fourth-degree (quartic) polynomials and cubic splines with continuous derivatives. The quartic polynomials suffered from severe multicollinearity of the terms. The cubic splines (with exogenous knots at 420 and 600, or knots calculated by the program) added little to the explanatory power of the piecewise estimates (adjusted R^2s were lower and coefficient estimates were very similar). Examples of each are available on request.

Census-based regional dummies provide important geographical and economic variation. The East North Central region (Ohio, Michigan, Indiana, Illinois, Wisconsin), for example, suffered through the "Great Recession" and Michigan and Ohio may have suffered worse than that. Other analyses include dummies for New York State, California, Florida, Illinois, Texas and Pennsylvania. The cumulative impacts are minor, and nowhere does any other state variable have a significant impact, or an impact as large as Ohio or Michigan.

Both the predicted values of these regressions and their residuals will merit attention. The predicted values reflect responses to these sets of economic "fundamentals." The residuals could reflect lesser or better performance, given the set of fundamentals.

Since one of the major issues involves the actual disappearance of dwelling units U, Table 4 examines dwelling unit ratio $\ln(U_{2010}/U_{2000})$. Column (a) has a linear rent term, column (b), a cubic rent term, and column (c) a linked rent term. In all three regressions a higher 2000 occupancy rate correlates strongly with an increase (or smaller decrease) in number of housing units. The MSA three-year unemployment rate correlates positively with total housing change, possibly indicating that the unemployed are staying in the community (and occupying housing).

Regional effects show all regions performing worse than the Southeast, with the Northeast at slightly over 87%. The East North Central region was about 9.5% lower than the Southeast, with Michigan and Ohio an additional 8.2% and 6.7% lower.

The important tests compare price terms in columns (b) and (c) with the linear and insignificant term in column (a). The F tests of 5.75 and 5.73, respectively (as well as the reductions of the standard errors) reject the null hypothesis of linearity. Moreover the negative coefficients on terms g_2 (the quadratic term of the polynomial function) and h_2 (the second interval of the piece-wise function), indicate decreasing marginal impacts of price changes, with the supply curve becoming more vertical. Conventional supply price elasticities are:

Elasticities Rent	Linear	Polynomial	Piecewise
350	0.0015	0.2516	0.3026
400	0.0018	0.2082	0.3458
500	0.0022	0.0950	0.0636
600	0.0026	−0.0310	0.0763

The "top of the S" is not as well-formed as the bottom. Glaeser et al. (2005) contend that land use and building code regulations may thwart normal supply responses of housing markets to increased demand. While the normal supply curve may have an S shape as postulated, these artificial constraints may truncate some of the upper part of the S.

Tests of this conjecture use the Wharton Residential Land Use Regulatory Index (WRLURI), developed by Gyourko et al. (2008). The authors collected and factor analyzed 11 regulatory dimensions, selecting the first factor as the

Table 4
Determinants of total housing change.

Dep Var: Ln (U_{2010}/U_{2000})	(a) Linear (N = 315)	(b) Cubic (N = 315)	(c) Linked (N = 315)	(d) Linked (N = 304)	(e) Linked (N = 304)	(f) Linked (N = 216)
Intercept	**−1.25645***	**−1.84499***	**−1.56344***	**−1.60519***	**−1.60319***	**−1.19806***
	0.23238	0.31730	0.26458	0.27222	0.27264	0.39871
Occupancy rate – 2000	**1.46856***	**1.43059***	**1.40491***	**1.45814***	**1.45735***	**0.85272***
	0.25127	0.24792	0.24855	0.25785	0.25823	0.35126
Wharton index						**0.59653***
						0.24103
Occupancy rate x Wharton index						**−0.61886***
						0.25566
Mean MSA unemployment	**0.01117***	**0.01088***	**0.01090***	**0.01073***	**0.01063***	**0.01498***
Rate 2007–2009, M	0.00393	0.00388	0.00388	0.00392	0.00394	0.00450
Median Rent 1 BR Unit, R	**4.39E-06**	**0.00273***	**0.00086***	**0.00085***	**0.00085***	**0.00118***
	0.00005	0.00104	0.00039	0.00039	0.00039	0.00052
R greater than \$420/mo.			**−0.00074**	**−0.00072**	**−0.00072**	**−0.00109**
			0.00044	0.00044	0.00044	0.00058
R greater than \$600/mo.			**−0.00027**	**−0.00027**	**−0.00025**	**−0.00018**
			0.00016	0.00017	0.00017	0.00019
R greater than \$600/mo. × Wharton					**−0.000032**	
					0.000073	
R^2/1000		**−0.00365***				
		0.00153				
R^3/1,000,000		**0.00148***				
		0.00069				
Northeast	**−0.13795***	**−0.13183***	**−0.13347***	**−0.13577***	**−0.13681***	**−0.11451***
	0.02680	0.02650	0.02647	0.02803	0.02818	0.03446
Mid-Atlantic	**−0.10613***	**−0.10217***	**−0.10604***	**−0.10849***	**−0.10940***	**−0.12000***
	0.02306	0.02288	0.02273	0.02309	0.02322	0.02564
East South Central	**−0.05649***	**−0.03521**	**−0.03306**	**−0.03322**	**−0.03330**	**0.00378**
	0.02644	0.02678	0.02699	0.02715	0.02719	0.03592
West South Central	**−0.05596***	**−0.03653**	**−0.03800**	**−0.03853**	**−0.03866**	**−0.01730**
	0.02194	0.02236	0.02228	0.02244	0.02247	0.02737
East North Central	**−0.09995***	**−0.09223***	**−0.09367***	**−0.09880***	**−0.09898***	**−0.09515***
	0.02265	0.02243	0.02246	0.02289	0.02293	0.02819
West North Central	**−0.09780***	**−0.08505***	**−0.08492***	**−0.08687***	**−0.08705***	**−0.05068**
	0.02498	0.02491	0.02490	0.02513	0.02516	0.03055
Mountain	**−0.02213***	**−0.02057**	**−0.01965**	**−0.01523**	**−0.01543**	**−0.01753**
	0.02509	0.02470	0.02475	0.02519	0.02523	0.02801
Pacific	**−0.08948***	**−0.08237***	**−0.08302***	**−0.07790***	**−0.07629***	**−0.08735***
	0.02396	0.02369	0.02367	0.02427	0.02460	0.02934
Michigan	**−0.09532***	**−0.10056***	**−0.10179***	**−0.09629***	**−0.09569***	**−0.09706***
	0.03649	0.03596	0.03598	0.03635	0.03643	0.04090
Ohio	**−0.07701***	**−0.07317***	**−0.07155***	**−0.06554**	**−0.06529**	**−0.06269**
	0.03425	0.03375	0.03379	0.03416	0.03421	0.03698
R^2	0.3145	0.3399	0.3398	0.3477	0.3481	0.3914
Adjusted R^2	0.2849	0.3068	0.3067	0.3137	0.3117	0.3392
SEE	0.09888	0.09729	0.09730	0.09784	0.09798	0.09543

Coefficient in **bold**; standard error in roman.
* Significant at 5% level.

WRLURI and standardizing it with a mean of zero and a standard deviation of one.[5] The first test interacts the index with the highest rent (over \$600) piece of the piece-wise estimator. Higher index values index reflect more regulation, and one expects a negative coefficient on the interaction term.

Columns (d) and (e) examine the interaction. Because 11 of the cities with rents over \$600 have missing values, column (d) re-estimates column (c) for sample of 304, with almost identical parameter estimates and significance levels. The column (e) interaction term is negative (more stringent regulation reduces the response) but it is small and not significant.

The second test interacts the Wharton index with lagged occupancy rates rather than rent. Growing but elastically supplied cities may have low vacancy (high occupancy) rates but not necessarily high rent. Theory predicts a negative interaction; that is, higher occupancy (lower vacancy) interacts with more stringent regulation to reduce the supply reaction. Column 4f shows a significant negative interaction. A one percentage point increase in the lagged occupancy rate implies about twice the impact (0.0116) in a city with relatively loose regulation (index of −0.5) than in a city with an (more stringent) index value of +0.5 (impact of 0.0054).

Table 5 examines the determinants of percentage changes in occupied units, O, or $\ln(O_{2010}/O_{2000})$. The most important determinant was the occupancy rate in 2000, indicating that weak markets in 2000 continued to be weak throughout the decade in terms of the percentage

[5] The WRLURI is not available for 99 of the 315 cities although its interaction would lead to a value of 0 in most of them. Of the cities with mean rents exceeding \$600, Chicago has the lowest value (most permissive regulation) of −1.174; Barnstable, Massachusetts has the highest of 4.335.

Table 5
Determinants of occupied housing change.

Dep Var: Ln (O_{2010}/O_{2000})	(a) Linear (N = 315)	(b) Cubic (N = 315)	(c) Linked (N = 315)	(d) Linked (N = 304)	(e) Linked (N = 304)	(f) Linked (N = 216)
Intercept	**−1.29205***	**−1.72929***	**−1.51570***	**−1.61151***	**−1.60566***	**−1.34167***
	0.24159	0.33387	0.27849	0.28501	0.28484	0.42412
Occupancy rate – 2000	**1.54298***	**1.52682***	**1.49888***	**1.61106***	**1.60875***	**1.03273***
	0.26124	0.26086	0.26162	0.26997	0.26977	0.37364
Wharton index						**0.65835***
						0.25639
Occupancy rate x Wharton index						**−0.69465***
						0.27195
Mean MSA unemployment Rate 2007–2009, M	**0.00470**	**0.00442**	**0.00445**	**0.00442**	**0.00412**	**0.00865**
	0.00409	0.00408	0.00408	0.00411	0.00411	0.00479
Median rent 1 BR unit, R	**−8.89E-05**	**0.00196**	**0.00054**	**0.00053**	**0.00053**	**0.00111***
	5.40E-05	0.00110	0.00041	0.00041	0.00041	0.00055
R greater than $420/mo.			**−0.00059**	**−0.00060**	**−0.00060**	**−0.00118**
			0.00046	0.00046	0.00046	0.00062
R greater than $600/mo.			**−0.00011**	**−0.00009**	**−0.000036**	**−0.00005**
			0.00017	0.00018	0.000182	0.00020
R greater than $600/mo. × Wharton					**−0.000091**	
					0.000076	
R^2/1000		**−0.00286**				
		0.00161				
R^3/1,000,000		**0.00122**				
		0.00073				
Northeast	**−0.11166***	**−0.10698***	**−0.10838***	**−0.11256***	**−0.11560***	**−0.09507***
	0.02787	0.02789	0.02786	0.02935	0.02944	0.03666
Middle Atlantic	**−0.05710***	**−0.05320***	**−0.05745***	**−0.06162***	**−0.06428***	**−0.07038***
	0.02398	0.02407	0.02393	0.02417	0.02426	0.02727
East South Central	**−0.02819**	**−0.01532**	**−0.01348**	**−0.01433**	**−0.01458**	**0.02498**
	0.02749	0.02818	0.02841	0.02843	0.02841	0.03821
West South Central	**−0.04279**	**−0.03129**	**−0.03251**	**−0.03402**	**−0.03442**	**0.00367**
	0.02281	0.02352	0.02346	0.02349	0.02348	0.02911
East North Central	**−0.08132***	**−0.07705***	**−0.07831***	**−0.08680***	**−0.08733***	**−0.09350***
	0.02355	0.02360	0.02364	0.02397	0.02395	0.02998
West North Central	**−0.08263***	**−0.07565***	**−0.07518***	**−0.07941***	**−0.07992***	**−0.04385**
	0.02597	0.02621	0.02620	0.02631	0.02629	0.03250
Mountain	**−6.35E-05**	**0.0008**	**0.0020**	**0.00451**	**0.00395**	**0.00483**
	0.02608	0.02599	0.02605	0.02637	0.02635	0.02980
Pacific	**−0.04242**	**−0.03795**	**−0.03862**	**−0.03414**	**−0.02940**	**−0.03315**
	0.02491	0.02492	0.02492	0.02541	0.02570	0.03121
Michigan	**−0.11486***	**−0.11780***	**−0.11860***	**−0.11041***	**−0.10868***	**−0.08863***
	0.03794	0.03784	0.03787	0.03806	0.03806	0.04351
Ohio	**−0.10236***	**−0.09987***	**−0.09854***	**−0.08922***	**−0.08848***	**−0.07455**
	0.03561	0.03551	0.03557	0.03577	0.03575	0.03933
R^2	0.3022	0.3117	0.3111	0.3287	0.3320	0.3577
Adjusted R^2	0.2720	0.2771	0.2765	0.2937	0.2948	0.3025
SEE	0.10274	0.10238	0.10242	0.10244	0.10236	0.10151

Coefficient in **bold**; standard error in roman.
* Significant at 5% level.

of population fall due to loss of housing stock. Unlike the determinants of "all unit change" in Table 4, the unemployment rate was small and statistically insignificant in all regressions.

The results are qualitatively comparable for both the cubic and the piecewise formulation. The addition of the nonlinear terms reduces the standard error of estimate, although the impact is not quite as large as with the findings in Table 4 (for total units).

The evidence again supports an S-shape at low rents. Linear regression 5a actually shows a negative relationship between rent and change in occupied units. It is easiest to compare the coefficients in the piecewise regressions. In regression 5c, $h_1 = 0.00054$ with $h_2 = -0.00059$, with the combined impact of -0.000005, above rent of $420.

The regulatory impacts are similar to Table 4 (all units). Column (d) uses the sample of 304, and it is virtually the same as the larger sample. Unlike Table 4, however, the interaction between regulation and high rent for occupied units (column e) reduces the overall standard error of estimate. Because the regression segments are heavily multicollinear by construction, standard errors are inflated and significance levels are small, but for occupied units (Table 5) evidence of the "top of the S" is slightly stronger than for all units (Table 4).

Similar to the "all units" analysis, regression 5f interacts the Wharton index with lagged occupancy and again shows a significant interaction. A one percentage point increase in the lagged occupancy rate in a city with relatively loose regulation (index of -0.5) implies about twice the

Table 6
Abandonment rate from vacant units.

Dep Var: abandonment rate (N = 315)	(a) Linear	(b) Linked	(c) Cubic	(d) Cubic-2
Intercept	**0.29057***	**0.62035***	**0.74640***	**0.82193***
	0.03670	0.14066	0.19955	0.18396
Mean MSA unemployment	**0.00639**	**0.00634**	**0.00622**	**0.00604**
Rate 2007–2009, *M*	0.00342	0.00334	0.00334	0.00307
Median rent – *central city*				**−0.00071***
				0.00010
Median rent 1 BR Unit, *R*	**−0.00017***	**−0.00094***	**−0.00198***	**−0.00129**
	0.00004	0.00034	0.00092	0.00085
R greater than $420/mo.		**0.00058**		
		0.00038		
R greater than $600/mo.		**0.00036***		
		0.00014		
R^2/1,000			**0.00214**	**0.00196**
			0.00136	0.00125
R^3/1,000,000			**−0.00073**	**−0.00071**
			0.00061	0.00057
Northeast	**0.00939**	**0.00648**	**0.00649**	**−0.01965**
	0.02362	0.02310	0.02312	0.02157
Middle Atlantic	**0.14183***	**0.13970***	**0.14007***	**0.09327***
	0.01986	0.01940	0.01949	0.01902
East South Central	**0.01807**	**−0.00614**	**−0.00381**	**−0.00744**
	0.02363	0.02391	0.02369	0.02181
West South Central	**0.05370***	**0.03393**	**0.03322**	**0.03519**
	0.01961	0.01974	0.01977	0.01820
East North Central	**0.04779***	**0.04127***	**0.04003***	**0.03036**
	0.01972	0.01939	0.01931	0.01782
West North Central	**0.03234**	**0.01980**	**0.01896**	**0.01467**
	0.02154	0.02125	0.02123	0.01955
Mountain	**−0.03865**	**−0.03905**	**−0.03901**	**−0.02799**
	0.02170	0.02120	0.02114	0.01952
Pacific	**−0.02289**	**−0.02768**	**−0.02774**	**−0.00182**
	0.01974	0.01931	0.01930	0.01811
Michigan	**0.08157***	**0.08796***	**0.08684***	**0.07849***
	0.03251	0.03177	0.03170	0.02920
Ohio	**0.13351***	**0.12667***	**0.12837***	**0.10307***
	0.02992	0.02930	0.02918	0.02707
R^2	0.3762	0.4097	0.4117	0.5032
Adjusted R^2	0.3514	0.3821	0.3843	0.4783
Standard error	0.08830	0.08620	0.08610	0.07921

Coefficient in **bold**; standard error in roman.
* Significant at 5% level.

impact on changes in occupied units (0.0138) as it does where the index value is +0.5 (impact of 0.0069).

The abandonment A model is:

$$A = b_0 + b_1 * M_{2007-2009} + g^b(R)\ [\text{or } h^b(R)] + \sum_{i=1}^{i=\#\text{Regions, states}} b_{3i}S_i + e_b \tag{3}$$

Eq. (3) omits the lagged occupancy rate. The abandonment measure is negatively related to occupancy, so including lagged occupancy would be similar to explaining current abandonment with lagged abandonment. (Analyses using lagged occupancy provided better explanatory power, but the behavioral and regional impacts were almost identical, and it is a cleaner model without it.). Functions g^b and h^b were specified in the same manner as Eqs. (2a) and (2b).

In Table 6 MSA unemployment rates M are positively correlated to abandonment rates A, although the impacts are small and only marginally significant. Linear regression 6a shows a monotonically negative rent impact, yielding an elasticity at the mean ($508 per month) of −0.32. The nonlinear terms again improve the regression, with $F_{2,300}$ for piece-wise regression (b) of 8.51, and $F_{2,300}$ for cubic equation (c) of 9.06. Regressions 6b and 6c, both containing nonlinear terms, show higher elasticities at lower rents, indicating that the lower rents are consistent with increased abandonment at increasing rates.

The median one-bedroom rents R are price measures standardized at the MSA level, but in several central cities median rents (for all rental units of all sizes) are considerably lower. In the Detroit MSA, for example, the one-bedroom rent is $598, but in the City of Detroit, the median rent is $470. For Cleveland the one-bedroom rents and central city median rents are $555 and $449 respectively, and for Chicago, $711 and $599. These disparities suggest that in many MSAs central city dwelling units are older and represent lower quality structure or neighborhood than the MSA measures.

Regression 6d adds the median central city rent providing considerable explanatory power, particularly for older cities. Detroit, Cleveland, and Chicago, show greatly re-

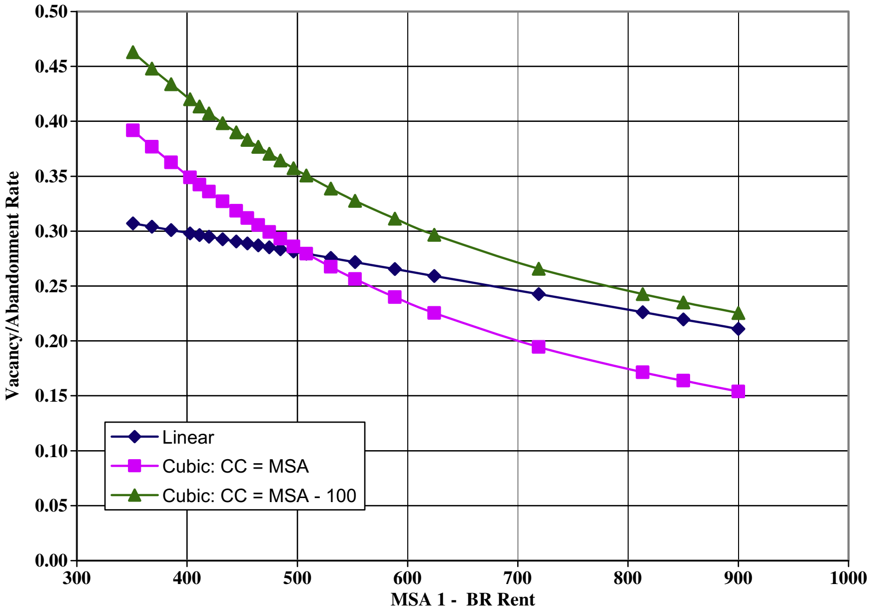

Fig. 3. Vacancy/abandonment vs. rents.

Table 7
Cities with smaller housing unit change than predicted.

City	2010 Population	Percentage change	Predicted change	Residual
New Orleans	343,829	−0.1202	0.0581	−0.1782
Norfolk	242,803	0.0093	0.1574	−0.1481
St. Paul	285,068	0.0455	0.1657	−0.1202
Modesto	201,165	0.1069	0.2245	−0.1176
Jackson	173,514	−0.0117	0.1025	−0.1142
Salt Lake City	186,440	0.0534	0.1612	−0.1078
Augusta-Richmond	195,844	0.0501	0.1552	−0.1051
Birmingham	212,237	−0.0238	0.0794	−0.1032
Richmond	204,214	0.0642	0.1653	−0.1011
Los Angeles	3,792,621	0.0574	0.1574	−0.1000
Minneapolis	382,578	0.0587	0.1586	−0.0999
Anaheim	336,265	0.0453	0.1383	−0.0930
Dallas	1,197,816	0.0658	0.1556	−0.0898
Memphis	646,889	0.0722	0.1590	−0.0868
Mobile	195,111	0.0380	0.1198	−0.0818
Milwaukee	594,833	0.0267	0.1062	−0.0795
Denver	600,158	0.1255	0.2044	−0.0789
Columbus	189,885	0.0842	0.1626	−0.0784
Tulsa	391,906	0.0357	0.1139	−0.0781
Detroit	713,777	−0.0725	0.0017	−0.0741

Sample equals 100 largest cities.

duced residuals. However the overall impact of rents on abandonment remains almost identical to regression 6c. In regression 6c, a $100 per month decrease in MSA rent increases the abandonment rate by 1.98% points. In regression 6d, a $100 per month decrease in rents (affecting both the MSA and the central city), increases the abandonment rate by 2.00% points (adding coefficients −0.00129 and −0.00071). The quadratic and cubic terms for MSA rent adjust only slightly.

Fig. 3 plots regressions 6a, 6c, and 6d, at mean unemployment rate, and at the regional mean fractions, with 6d assuming that central city rents are $100 less than the MSA as a whole. Comparing either with the linear form again shows the importance of a nonlinear formulation.

6. Performance of cities

The article began by describing housing units losses in many major cities. It then developed explanatory models relating to housing market fundamentals. Examining model prediction errors provides insight into the relative impacts of the regression fundamentals, and other (omitted) variables related to central city housing performance. Ta-

Table 8
Cities with higher abandonment rates than predicted.

City	2010 Population	Abandonment rate	Predicted rate	Residual
New Orleans	343,829	0.5038	0.2996	0.2043
Buffalo	261,310	0.5355	0.3786	0.1569
Shreveport	199,311	0.4584	0.3158	0.1426
Birmingham	212,237	0.4059	0.2936	0.1124
Baltimore	620,961	0.4874	0.3751	0.1123
Indianapolis	820,445	0.3636	0.2519	0.1117
Augusta GA	195,844	0.3807	0.2692	0.1115
West Palm Beach	181,045	0.3002	0.1902	0.1101
St. Louis	319,294	0.4296	0.3252	0.1045
Jackson	173,514	0.4051	0.3033	0.1018
Jacksonville	821,784	0.3092	0.2158	0.0935
Pittsburgh	305,704	0.4523	0.3593	0.0930
Anchorage	291,826	0.2270	0.1359	0.0911
Montgomery	205,764	0.3264	0.2371	0.0893
Worcester	181,045	0.3002	0.2133	0.0870
Detroit	713,777	0.5093	0.4346	0.0747
Las Vegas	583,756	0.2191	0.1474	0.0717
Kansas City MO	459,787	0.3284	0.2570	0.0715
Mobile	195,111	0.3385	0.2698	0.0687
Boston	617,594	0.2269	0.1583	0.0686

Sample equals 100 largest cities.

ble 7 presents the twenty most negative residuals (derived from regression 4c) from the 100 largest central cities. Post-Katrina New Orleans had the largest percentage decrease in housing units, as well as the largest residuals. Most of the other cities in the table had positive percentage changes in units, with the negative residuals coming from lower-than-expected gains. Detroit's loss of 7.25% points was smaller than in previous decades, but still more negative than predicted. Even with the negative regional coefficient, and the negative coefficient for the State of Michigan as predictors, Detroit's housing stock did not perform well.

Table 8 performs a comparable analysis for housing abandonment from regression 6d, here ranked by positive residuals (abandonment worse than expected). Again, New Orleans had the highest residual (the only central city in the sample of 315 with a larger residual was Gary, Indiana, with an abandonment rate of 0.5754 and a residual of 0.2344). Detroit, Baltimore, Buffalo, and St. Louis are all among the twenty largest cities in terms of unexplained abandonment, even with the adjustment from regression 6d for central city housing quality.

7. Conclusions

This study has sought to examine housing stock changes between 2000 and 2010, and 2010 housing abandonment in US central cities. While the entire country experienced major impacts with the housing bubble and bust, there were explicit regional and state impacts, and some cities performed better than others in the same regions and states.

The article tests an S-curve for housing supply. Regressions that allowed varying impacts provide strong support for the S-curve at low rent levels. The findings provide the bottom and the middle third of the "S", but "top of the S" is less well-formed. One explanation involves regulatory impediments to supplier responses to higher rents at the top of the S. A first test, interacting the Wharton index with high rents, provides the right sign and plausible magnitude, although multicollinearity of the rent terms leads to inflated standard errors of the individual parameters. A second Wharton-based test verifies that growing, but elastically supplied, cities can have low vacancy but not necessarily high rent. Another explanation is that the serious economic national recession occurring in the two years leading to the 2010 Census may also have limited supplier response.

The article also considered the determinants of a constructed abandonment index for 2010. The dependent variables were explained in part by prior occupancy rates, current unemployment rates, rent indices serving as proxies for variable costs, central city median rents, and a larger set of regional and state housing dummy variables. Lower rents were found to be consistent with increased abandonment at increasing rates.

With the exception of storm-damaged New Orleans, most of the largest housing stock changes occurred in older cities of the Great Lakes and upper Midwest. Large population and housing stock losses, as well as central city abandonment, impacted Michigan and Ohio above and beyond the regional effects. Market fundamentals help explain many of the changes, but performances of cities like Detroit were generally worse than could be explained by the models. Returning to Wilbur Thompson's opening quote, it appears that indeed large portions of many American central cities have been "thrown away."

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