Urban Decline and Durable Housing

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Abstract

Urban decline is not the mirror image of growth, and durable housing is the primary reason the nature of decline is so different. This paper presents a model of urban decline with durable housing and verifies these implications of the model: (1) city growth rates are skewed so that cities grow more quickly than they decline; (2) urban decline is highly persistent; (3) positive shocks increase population more than they increase housing prices; (4) negative shocks decrease housing prices more than they decrease population; (5) if housing prices are below construction costs, then the city declines; and (6) the combination of cheap housing and weak labor demand attracts individuals with low levels of human capital to declining cities.

I.   Introduction

Across space and over time, the population of a city is almost perfectly correlated with

the size of its housing stock. Regressing the logarithm of the number of housing units on the

logarithm of population in any of the last four census years always yields estimated elasticities

and R^2's very near one. In every decade since the 1960s, the correlation coefficient between log

changes in housing units and population is above 0.9.

Despite the tight link between the housing sector and population change, the modern

literature on urban dynamics (e.g., Glaeser, et. al. (1992); Eaton and Eckstein (1997); Black and

Henderson (2000)) typically ignores housing and the physical side of cities altogether. An

implicit assumption of this research is that new housing is elasticity supplied and that housing

quickly disappears in cities with declining productivity levels.   But even if new housing can be

elastically supplied, old housing does not disappear quickly. Housing may be the quintessential

durable good, as homes often are decades, if not a century old.

Because homes can be built quickly, but disappear slowly, urban decline is not the mirror

image of growth. Understanding the impact of durable housing is critical to comprehending the

urban decline that is prevalent among many of our larger cities. Eleven of the fifteen largest

cities in 1950 lost population over the ensuing 50 years; eight of them—Baltimore, Buffalo,

Cleveland, Detroit, Philadelphia, Pittsburgh, St. Louis, and Washington, DC--lost population in

each decade.

In this paper, we present a simple model of urban decline and durable housing and test

the implications of that model. Figure 1 illustrates our framework. The housing market is

characterized by a kinked supply curve which is highly elastic when prices are at or above

construction costs and highly inelastic otherwise. Because housing is durable, a negative demand

shock like that drawn from D to D_1 leads to a large fall in price, but little change in quantity.

Given the extremely tight relationship between housing units and population, declining cities

initially suffer price declines, not population losses. As long as housing is elastically supplied, a

positive demand shock, shown by the shift from D to D_2, will cause new housing units to be supplied at roughly constant cost so that there will be an increase in population accompanied by little change in price.

This asymmetric response to positive and negative demand shocks that arises from the durable nature of housing is consistent with all the key stylized facts about urban growth and decline. For example, housing durability can explain the highly skewed nature of urban growth one sees in the data, where expansion can be extremely rapid (Las Vegas's population grew by 61.6% in the 1990s), but decline much less so (Hartford had the largest population loss of -13.9% among cities with at least 100,000 people at the beginning of the 1990s). Durable housing largely explains why decline typically is such a lengthy process. The eight consistently declining cities referenced above remain large places even after five consecutive decades of population loss.

As Figure 1 suggests, a durable housing model predicts that increases in population will be associated with small increases in prices, but that decreases in population will be associated with large decreases in prices. The data support this prediction. Durable housing also suggests that exogenous forces predicting urban growth will have large effects on population and small effects on prices. Conversely, exogenous forces that predict urban decline will have small effects on population and big effects on prices. Using the weather as a source of exogenous changes in the attractiveness of cities, we find support for these predictions.

Durability also implies that a negative shock to a city's productivity will continue to cause population declines over many subsequent decades. This is consistent with our results which show the degree of persistence in population change among declining cities is double that for growing cities. Housing durability also implies that the distribution of house prices should predict future growth, and not merely because high house prices reflect future price appreciation. Population growth is indeed much lower in cities with larger fractions of their housing stocks valued below the cost of new construction. This is not a causal connection, but it does suggest the role the housing market plays in mediating urban growth.

In addition, durable housing helps account for the connection between urban decline and poverty. The simple correlation between the family poverty rate in 1999 and population growth in the 1990s for places with at least 100,000 residents is -0.48. When urban productivity falls, the most active members of the labor force will naturally flee, but durable housing ensures that their homes will then be occupied by those that are less connected to the labor market. As our model suggests, the correlation between poverty and population decline disappears after controlling for the presence of abundant, cheap housing. This finding may help us understand why declining cities so often are centers of social distress.

The next section provides a simple model of urban growth with durable housing that derives the asymmetry illustrated in Figure 1. Section III takes the various implications of that model to the data, providing the empirical detail behind the key features of urban decline. Section IV shows that our 'bricks and mortar' perspective on decline is robust to other possible explanations, including those associated with the presence of other durable and fixed factors, as well as filtering in the housing market. A brief summary concludes the paper.

II.   Spatial Equilibrium and a Framework

Rosen (1979) and Roback (1980, 1982) provide the foundation for our understanding of inter-city differences in wages and rents. In their long-run, equilibrium framework, some individuals are mobile enough to eliminate utility differences across space. For similar people, this implies:

(1)   Wages + Amenities -   Housing Costs =   Reservation Utility.

This "no arbitrage" relationship defines a spatial equilibrium where differences in housing costs across cities must reflect differences in earnings and/or differences in amenities for a given individual. Using 1980 census data for illustrative purposes, we estimate a simplified version of

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the Rosen/Roback specification in which city-level median house values are regressed on median

family income and the barest of amenity measures--mean January temperature--for 102 cities

with 1980 populations of at least 150,000:

(2) Median House Price= -155,954+ 4.56*Median Family Income + 1441*January Temperature,
            (21,623) (0.46)   (219)

where all monetary variables are in 2000 dollars, standard errors are in parentheses, and the

R^2=0.60. Figure 2 graphs median house prices against the fitted values from this regression.

There are many valid criticisms of this type of regression and a more thorough analysis would use

exogenous sources of labor demand and allow for individual heterogeneity as in Blomquist, et. al.

(1988) and Gyourko and Tracy (1991), but the results highlight the empirical power of the Rosen-

Roback equilibrium concept. High housing prices generally are associated with either high

incomes or a more attractive (i.e., warmer) climate.

But just as Figure 2 is consistent with the Rosen-Roback framework, it also contains the

puzzle that motivates our analysis. The dashed horizontal line at $97,794 represents the estimated

cost of a modest quality, 1,200 square foot home in 2000 dollars. [The measurement of

construction costs is discussed below in detail.] In at least one quarter of the sample, median

housing prices are well below this level. For housing prices to be low enough for people to live

in low wage, low amenity places like Buffalo, Detroit, Philadelphia, and St. Louis, houses in

those cities must sell for much less than they cost to build. Thus, the spatial equilibrium for

people cannot be a static equilibrium for the housing market.

The solution to the puzzle is that places can have housing values below construction costs

because once homes are built, there is no lower bound on their prices until they fall to zero. The

cities of the Rustbelt once had amenities and wages that justified new construction. They no

longer do, but the cities remain because their homes last. To understand America's spatial

equilibrium, we must embed the Rosen-Roback framework in a dynamic setting with durable

housing. In doing so, we draw on a rich literature on durability and urban development, but we focus on urban decline, while previous research overwhelmingly has dealt with urban growth.[1]

Starting from equation (1) above, we assume that every person who chooses to live in a given house receives each period a city-specific wage level "W", a city-specific amenity level "A", a location-specific amenity level "a", and pays rent "r". We assume everyone is a renter, but equivalently, each resident can be thought of as an owner-occupier if 'r' represents the user cost of housing. We normalize the reservation utility to zero and denote $\theta \equiv W + A$, so that free mobility implies $\theta + a = r$. On the margin, the rent paid equals the sum of the benefits associated with city-specific and location-specific traits.

There is a supply of N lots for each value of a < $\bar{a}$. These location-specific amenities could capture distance to the city center in a conventional monocentric city model or other positive amenities in a richer urban model such as Lucas and Rossi-Hansberg (2002). Each lot can only contain one house, and each house is identical and can contain one person.

To capture depreciation, we assume houses occasionally need to be rebuilt and that the cost of rebuilding is the same as the cost of new construction. At the level of the city, this assumption approximates a more continuous decay process, with lower algebraic costs. If current rent is a sufficient statistic for predicting future rents (which we assume), then a lot will be developed or rebuilt when its rent rises above a cutoff rent $\underline{r}$. If a lot's rent falls below $\underline{r}$, then a home that had been developed will not be rebuilt if it collapses. Population declines occur when homes on developed lots whose rents have fallen below $\underline{r}$ collapse.

For simplicity of exposition, we do not assume a specific stochastic process for θ. Rather, we take the existence of a minimum rent level as given, and initially consider the time

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[1] The literature is voluminous. Important primary contributions include Arnott (1980), Braid (1988), Brueckner (1980, 1981), Hochman and Pines (1982), and Wheaton (1982). See Brueckner (2000) for a recent review. The closest research to ours is that on filtering, where houses cheapen as they age. We compare our results to that implied by a filtering story later in the paper.

path of the city between two periods, where $\theta = \theta_0$ in the first period and $\theta = \theta_0 + \Delta$ in the

second time period. To avoid unnecessary complications, we further assume that θ has not risen

above the maximum of θ_0 and $\theta_0 + \Delta$ at any point and that Δ is small enough in absolute value

so that $\overline{a} + \theta_0 + \Delta > \underline{r}$, which ensures that some houses will be rebuilt if they collapse. We

further assume that all construction and reconstruction decisions are taken at the end of the period

after observing $\theta_0 + \Delta$.[2]

If $\Delta > 0$, then new construction will occur on all lots with amenity levels greater than

$\underline{r} - \theta_0 - \Delta$. Population will rise by ΔN in this case. If $\Delta < 0$, then no new construction will

occur, and homes with amenity levels less than $\underline{r} - \theta_0 - \Delta$ which collapse will not be rebuilt.

Assuming a proportion δ of all homes collapse, the total population loss is $\delta \Delta N$. While the rent

for any given lot will increase or decrease by Δ, changes in supply will impact changes in the

average rent in the city. When $\Delta > 0$, ΔN new homes will be built. These marginal homes

have relatively low amenity levels and new construction of these homes will cause average rent in

this city to only rise by $.5\Delta$. When $\Delta < 0$, the city sheds low amenity units, but since housing

supply only falls by $\delta \Delta N$, average rent declines by more than $.5\Delta$. In the extreme case where

no homes collapse, the average rent declines by Δ.

This framework captures the asymmetry that gives us the supply curve shown in Figure

1, and leads to the first proposition (all proofs are in Appendix 2):

Proposition 1: If Δ is a random variable that is symmetrically distributed across cities around a

nonnegative number and no other parameters differ across cities, then:

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[2] A more complex model that specifies a stochastic process for θ as in Dixit and Pindyck's (1994) real options framework is available at http://post.economics.harvard.edu/faculty/glaeser/papers.html. While many of those model details differ, no key results are affected. In particular, a calibration exercise also available on the web page shows that option value is not a key driver of development.

(a) The distribution of city population growth will be skewed in the sense that the mean is greater than the median.

(b) The coefficient estimated when the change in housing price is regressed on the change in population is greater when population is declining than population is growing.

(c) If $\Delta = \beta z$, then the derivative of population growth with respect to z will be greater when z>0 than when z<0. The derivative of price growth with respect to z will be greater when z<0 than when z>0.

The proposition emphasizes that durable housing predicts a skewed distribution of city growth rates because durability means that cities decline slowly. Negative shocks will tend to impact prices more than population and positive shocks will impact population more than prices. As a result, the relationship between price growth and population growth will be concave.

We now include two growth periods to make predictions about persistence and the correlation between housing prices and future urban dynamics. In this case, we assume that the value of θ changes from $\theta_0 + \Delta$ to $\theta_0 + \Delta + \Delta_2$ between the second and third periods (with $Cov(\Delta, \Delta_2) = 0$). Proposition 2 holds if we further assume that θ has not risen above the maximum of θ_0, $\theta_0 + \Delta$, and $\theta_0 + \Delta + \Delta_2$ between the second and third periods, and that some houses will be rebuilt even if they collapse at the end of the third period.

Proposition 2:

(a) The derivative of current population growth with respect to lagged population growth will be greater when lagged growth is negative than when it is positive.

(b) The growth rate of the city between the second and third periods declines with the share of its housing stock with rents below $\underline{r}$.

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Decline is more persistent than growth because durability means that it can take decades for negative urban shocks to be fully reflected in urban population levels. While cities are experiencing long, slow declines, they will have an abundance of very cheap housing, the existence of which will statistically predict future decline.

To examine the interaction between urban decline and the human capital composition of the city, we now allow for high and low human capital workers. Low human capital workers receive wages of W, have a reservation utility outside of the city of zero, and receive amenity flows of A+a from living at a particular site in the city. High human capital types have wages equal to $(\phi+1)W$, have a reservation utility equal to $\overline{U}$ and receive utility from amenities equal to $(\phi+1)(a+A)$. The taste for amenities increases with wages to allow for the possibility that high wage people are willing to spend more to obtain things such as better schools or proximity to work. Everyone still consumes one unit of housing.

Given these assumptions, low human capital workers are willing to pay rent of $W+A+a$ and high human capital workers are willing to pay rent of $(1+\phi)(W+A+a)-\overline{U}$. High human capital workers are willing to pay more for homes where $a > \overline{U}/\phi - \theta$. As long as $\overline{a} > \overline{U}/\phi - \theta > \underline{r} - \theta$, there will be individuals of both types in the city, and we assume that is the case. The share of high skill workers in the city will equal $\dfrac{\overline{a}+\theta-\overline{U}/\phi}{\overline{a}+\theta-\underline{r}}$. If we then make the same assumptions about changes in θ as in the initial proposition, Proposition 3 follows:

Proposition 3: The proportion of city workers that are high skilled rises less with an increase in city population growth than it declines with a decrease in city population of equal magnitude.

This proposition suggests that we should expect to see declining skill levels in shrinking cities. The intuition of this proposition is that when W or A declines, this loss is offset by a decrease in housing prices. But skilled people particularly value a robust labor market and high amenities, so they leave even though durable housing keeps the overall size of the population roughly constant.

III.   Testing the Implications of the Model

In order to take the implications of the model to the data, we use a sample of municipal jurisdictions with at least 30,000 residents in 1970. There are 321 cities with consistent data over the three decades of the 1970s, 1980s, and 1990s in our sample. The core house price and population data are from the decennial censuses. All other variables are described more fully below or in the Appendix 1.

The first implication of Proposition 1 is that that population growth should be skewed, with the mean exceeding the median. Summary statistics for the 963 decadal population growth rates available between 1970 and 2000 for our 321 cities show a mean growth rate that is 86% greater than the median—9.1% versus 4.9%, respectively. Cities expand much more rapidly than they contract. A similar pattern holds, with the mean being about twice as large as the median, if we examine the 642 twenty-year or the 321 thirty-year population growth rates of our cities. If housing was not durable, we would expect to see much more of a quantity response in declining cities over longer time spans, reducing the asymmetry predicted by our model.

The second implication of Proposition 1 is that price changes are more sensitive to population changes when the latter is negative. While there obviously is no causal linkage implied here, a concave relationship between price appreciation and population growth is an important testable hypothesis implied by our framework. To investigate this issue, we regress percentage growth in housing prices (all prices are in 2000 dollars) on a transformation of its population growth as shown in equation (3) below. Population growth is entered in piecewise linear form to allow for differential effects in expanding versus growth cities. Thus, the

POPLOSS$_{i,t}$ variable takes on a value of zero if city i's population grew during decade t and equals city i's actual population rate decline if the city lost population during the relevant decade. Analogously, the POPGAIN$_{i,t}$ variable equals zero if the city lost population during time period t and equals the actual population growth rate if the city gained population. Whenever observations are pooled across decades, we include time dummies (δ_t) to allow for different intercepts across decades and correct for intertemporal correlation in the error terms associated with multiple observations on the same city over time. The actual specification estimated is:

(3) House Price Appreciation Rate(%)$_{i,t} = \alpha_0 + \alpha_1$*POPLOSS$_{i,t} + \alpha_2$*POPGAIN$_{i,t} + \delta_t + \varepsilon_{i,t}$,

where $\varepsilon_{i,t}$ is the standard error term.

The first panel of Table 1 reports results from a specification that pools the 963 observations on decadal price and population growth that we have for our 321 city sample. Among cities that lost population, the estimate of α_1 indicates an elasticity of price change with respect to population of 1.8. Thus, a one percentage point greater rate of population decline is associated with nearly a two percentage point greater decline in real house prices over the decade. Among cities that are gaining population, the elasticity of real house price change with respect to population change is only 0.23. As the F-test statistic reported in the last column shows, these effects are statistically different from one another.

The second panel in Table 1 indicates that there is no economically meaningful change in this pattern if the specification is estimated using longer-run price and population changes between 1970 and 2000. Figure 3 then plots the fitted versus actual price appreciation rates from this specification, with the observations sorted by population growth.[3] While the prediction of

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[3] The plot of the results from the first specification in Table 1 using decadal changes exhibits much the same pattern, but it is more difficult to read because of the multiple observations on cities across decades. It should also be noted that the strongly concave relationship between price changes and population changes in Figure 3 is not dependent upon a few outliers. For example, dropping the initially relatively small cities of Glendale, AZ, and Mesa, AZ, (populations 36,305 and 62,929, respectively) which grew by about 500% between 1970 and 2000 does not materially change the results.

our model is statistically validated, Figure 3 illustrates that there are a small set of cities,

primarily along the coast of California, but also including Seattle and Boulder, with extremely

high rates of real house price growth. These places experience positive demand shocks which

drive up prices more than population. In Glaeser, Gyourko, and Saks (2004), we argue that these

places face binding regulatory constraints on new construction.[4]

We now examine the final implication of Proposition 1—that a specific positive

exogenous shock will have a greater impact on population growth than will a specific negative

exogenous shock, and that the negative exogenous shock will have a greater impact on price

appreciation than a positive exogenous shock. While most shocks to the attractiveness of urban

areas are difficult to measure and are unobservable to us as econometricians, Glaeser and Shapiro

(2003) suggest that the weather is one likely observable source of exogenous variation in the

demand for particular locales. The weather is powerfully associated with city population growth,

with the simple correlation between mean January temperature and growth in our cities has

ranged from 0.47 to 0.73 in the three decades since 1970. Obviously, the weather of cities is not

changing. Rather, rising incomes or factors such as improving air conditioner technology have

increased the relative importance of the weather as an urban amenity. In the context of the

model, this could be formalized by assuming that $A=v*X$, where v is the taste for the weather and

X is the weather. The shock comes through a change in v, not a change in X.

Proposition 1, part c, suggests a specification that permits estimation of separate slopes

for negative shocks and positive shocks. As 35.5% of our sample of decadal observations on

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[4] As this relationship involves two endogenous variables, we also estimated the reverse regression of
population changes on price changes (entered in piecewise linear form so that separate effects can be
estimated for cities experiencing declining versus rising real house values). The pooled regression of
decadal population growth on decadal real price growth does yield a larger coefficient when house price
appreciation is positive as our model predicts, but it is not statistically significantly different from that
found for when real prices decline. This specification suffers from three problems. First, there is greater
measurement error of house prices than of population, and that error is in the explanatory variable in this
case. Second, there is no natural break point for price changes at zero, especially since construction costs
are declining in real terms in many markets, including some with expanding populations (see Gyourko and
Saiz (2004)). Third, differences in supply elasticities among attractive cities further compromise the
reverse regression, as suggested by small number of primarily California cities noted above that have
extremely high house price appreciation without commensurate population growth.

population growth were negative over the 1970s, 1980s, and 1990s, we assume that the lowest

35.5% of mean January temperatures can be thought of as reflecting a negative population shock

from the weather. This cutoff implies that all cities with mean January temperatures above

29.1°F received a positive shock from the weather, and cities with temperature levels colder than

that experienced a negative shock. Our model does not require this particular choice, but the

results are robust to reasonable alternative cutoff points.

With this transformation, the weather 'shock' is entered in piecewise linear fashion as the

COLD and WARM variables in the population growth rate and house price appreciation rate

regressions described in equations (4) and (5). Specifically, the variable $COLD_i$ takes on a value

of zero if city i's mean January temperature is greater than 29.1°F , and equals the city's actual

mean January temperature, otherwise. $WARM_i$ equals zero if city i is colder than 29.1°F on

average in January and equals the city's actual mean January temperature, otherwise.

(4) Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*COLD$_i$ + α_2*WARM$_i$ + α_3*δ_t + $\varepsilon_{i,t}$

(5) House Price Appreciation Rate(%)$_{i,t}$ = β_0 + β_1*COLD$_i$ + β_2*WARM$_i$ + β_3*δ_t + $\gamma_{i,t}$.

As before, we allow for different decadal intercepts when pooling observations across decades.

However, robust standard errors based on clustering at the metropolitan area level, not the city

level, are reported here because there is no variation in reported temperature within a

metropolitan area.

The first panel of results in Table 2 finds the strong convexity of population change with

respect to weather shocks predicted by Proposition 1c. Among colder cities, there is no

statistically or economically meaningful relationship between being more (or less) cold and

population growth. The result is quite different for warmer places. Among these cities, being

warmer is strongly associated with greater population growth. The coefficient of 0.0069 implies

that an increase of 16 degrees Farenheit, which is the interquartile range of mean January

temperatures for warmer cities (from 36°F to 52°F), is associated with a 10.8% higher decade

population growth rate. That is an economically meaningful effect, as the mean decadal increase in population for the warm cities is 13.5%. The F-test results reported in the last column of the panel show that we can conclude with high confidence that the impacts of these negative and positive 'weather shocks' on population growth are different.

The next panel of Table 2 reports results for house price appreciation. As predicted by Proposition 1, part c, there is a concave relationship between price changes and weather shocks. A negative shock has a greater impact on price than does a positive shock of equal magnitude. Among colder places, a 10 degree higher temperature is associated with a 6 percent greater rate of house price growth (0.0060*10=0.06), with the same increase among warmer cities being associated with only a 2.3 percent higher rate of price appreciation (0.0023*10=0.023). While this is consistent with our model, the F-test results reported in the last column show the effects are different at only the 88% level.

Table 3 addresses the first part of Proposition 2 that housing durability should make population decline especially persistent because it can take many decades for negative shocks to be fully reflected in the size of the housing stock and population. As in Table 1, we allow the estimation of differential effects of growth versus decline so that the POPLOSS and POPGAIN variable are as defined as above. Because we are interested in persistence, current period population growth is regressed on lagged growth (where the t-1 subscript signifies the decade prior to t) and estimate the specification shown in equation (6).

(6) $Population\ Growth\ Rate(\%)_{i,t} = \alpha_0 + \alpha_1 * POPLOSS_{i,t-1} + \alpha_2 * POPGAIN_{i,t-1} + \alpha_3 * \delta_t + \varepsilon_{i,t}$

The use of lags results in the loss of one decade of data (the 1970s) and reduces the number of observations to 642 as described in Table 3.

The coefficient on past growth when growth was negative is twice that when past growth was positive. Among cities that declined in the previous decade, a one percent greater population loss is associated with a one percent larger population decline this decade. The positive

coefficient of about 0.46 on the lagged value of POPGAIN indicates that there is some

persistence for cities that were growing, too. However, we can comfortably reject the null

hypothesis that these are the same effects (see column 3 of Table 3). These findings reflect the

permanence of decline among American rustbelt cities especially. There were 39 U.S. cities with

at least 100,000 people in 1950 that lost population during the 1950s. Of these, 33 declined in the

1960s, 37 declined in the 1970s, 22 declined in the 1980s, and 23 declined in the 1990s.

The final implication of Proposition 2 implies that cities with an abundance of cheap

housing that is priced below current replacement cost will not tend to grow as much in the future.

This connection is not causal. Cities with relatively large fractions of housing priced below

construction cost have suffered significant economic shocks that are the true drivers of decline.

To measure the fraction of a city's housing stock that is priced below the cost of new

construction, we use data on self-reported housing values from the *Integrated Public Use*

Microdata Series (*IPUMS*) maintained by the Minnesota Population Center at the University of

Minnesota and compare those prices to the costs of building the physical unit in 1980 and 1990

using information provided by the R.S. Means Company, a consultant to the home building

industry.[5] We focus on single unit residences that are owner occupied. The construction cost

data are available per square foot of living area for single-family homes in a wide variety of

cities.[6] These data include material costs, labor costs, and equipment costs for four different

qualities of single unit residences. No land costs are included. We developed cost series for a

one story, modest quality house, with an unfinished basement, the average cost associated with

four possible types of siding and building frame, and of different sizes in terms of living area (i.e.,

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[5] Two publications are particularly relevant for greater detail on the underlying cost data: *Residential Cost Data*, 19th annual edition, (2000) and *Square Foot Costs*, 21st annual edition (2000), both published by the R.S. Means Company.

[6] Given that construction costs are reported on a per square foot basis, we need to convert housing values into the same metric. Unfortunately, the census does not report unit size. Hence, we turn to the *American Housing Survey* (*AHS*) which does report the square footage of living area. We impute unit size in the IPUMs data via the results of a regression analysis of square footage on a vector of physical traits common to the *AHS* and census data sets. See Appendix 1 for those details.

small or less than 1,550ft^2, medium or between 1,550ft^2 and 1,850ft^2, and large or between

1,850ft^2 and 2,500ft^2).

House price and construction cost data were successfully matched for 123 cities in 1980

and 92 cities in 1990. Nationally, 42% of single unit housing in our cities was valued below the

cost of new construction in 1980. In 1990, the fraction was 31%. There is substantial variation

across regions. The fraction is very low for homes in Western region cities, but nearly 60% of

Northeastern and Midwestern homes in our sample were valued below replacement cost in 1980.

At the city level, Los Angeles, San Diego, and Honolulu have well under 10% of their single

family housing stocks priced below construction cost in 1980 or 1990. In contrast, some of the

older, manufacturing cities such as Flint and Gary have two-thirds or more of their single family

stocks valued below replacement cost in both decades.[7]

This ratio of market value-to-replacement cost is akin to a Tobin's q-value for a city's

housing stock. However, Tobin's q increases with the premium over replacement cost, while our

variable rises in value the greater the fraction of the housing stock priced below cost. In equation

(7), which describes a regression of decadal city population growth on this measure of market

value-to-replacement cost at the beginning of the decade, this variable is labeled '–HouseQ$_{i,t\_}$',

where the minus sign in front indicates that a higher value is associated with more, not fewer,

units being valued below physical construction costs. The t_ subscript indicates that the value is

from the beginning of the relevant decade.

(7) *Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*-HouseQ$_{i,t\_}$ + α_2*δt + $\varepsilon_{i,t}$.*

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[7] The data are adjusted to account for the depreciation that occurs on older homes, to account for general
inflation when making comparisons across different years, to account for the fact that research shows
owners overestimate the value of their homes, and to account for regional variation in the presence of key
house attributes that have a major impact on value. Appendix 1 discusses these and other data construction
issues in detail. See our 2001 working paper for the complete listing of each city's distribution of house
price relative to construction costs.

After pooling observations across the two available decades of construction cost data, the first column of Table 4 reports that our estimate of α_1 is -0.27. This highly statistically significant result (standard error of 0.042) implies that for every 10% more of the housing stock that is priced below the cost of new construction, the growth rate of population is reduced by 2.7%. This is over half the median decadal growth rate of 4.9% and almost one-third of the 9.1% mean decadal rate of population growth among our 321 cities. Moreover, the mean value of –HouseQ is 37.3%, with a standard deviation of 25.3%, so that a standard deviation increase in the fraction of the city housing stock that is priced below physical construction costs is associated with almost a 7% lower population growth rate. The distribution of house prices strongly predicts future population growth.

A reasonable criticism of any regression involving housing prices and urban dynamics is that these correlations exist only because housing prices reflect expectations about future housing price growth, which is itself a function of future urban growth. We address this concern in two ways. First, we have examined the correlation between the share of the city's housing stock that is priced below the cost of new construction at the beginning of a decade and the growth of real house prices over the ensuing ten years. If the expectations hypothesis is relevant here, we would expect this relationship to be negative, but it is in fact slightly positive. Second, as the current median housing price should reflect some of any expectations about future housing price changes, controlling for house price should help mitigate the problem. When house price at the beginning of the decade is included with a host of other controls, the coefficient on the fraction of the stock priced below construction costs is essentially unchanged at -0.267, as reported in the second column of Table 4.

We close this section by addressing the connection between human capital and urban decline described in Proposition 3. Declining cities are both poor and have high levels of less well-educated workers. Glaeser, Kahn and Rappaport (2002) argue that the tendency of the poor to live close to city centers is driven by a desire to economize on transport costs, especially car

ownership. Their work helps explain patterns of wealth and poverty across jurisdictions within a metropolitan area, but it cannot account for the variation across metropolitan areas because the costs of car ownership, especially for poorer or low skill households, probably do not differ all that much across growing versus declining cities.

In our empirical analysis of whether cheap, durable housing can account for the relationship between urban decline and falling human capital levels, we use a conventional measure of education, the share of college graduates in the city's adult population (defined as those at least 25 years of age), to reflect the skill level of the area. In the regression specifications below, the variable $\Delta COL_{i,t}$ represents the change in city i's college graduate share over decade t. We begin by documenting that there is, in fact, a significantly higher rate of loss of college graduates the greater the rate of population loss among declining cities. As before, we use a transformation of population growth to permit estimation of different effects for expanding versus shrinking cities so that the $POPLOSS_{i,t}$ and $POPGAIN_{i,t}$ variables are as defined above. Because data availability allows us to pool observations across all three decades in our sample, the usual time dummies are included, with robust standard errors estimated based on clustering by city. The first column of Table 5 reports the results of estimating equation (8),

(8) $\Delta COL_{i,t} = \alpha_0 + \alpha_1 * POPLOSS_{i,t} + \alpha_2 * POPGAIN_{i,t} + \alpha_3 * \delta_t + \varepsilon_{i,t}.$

Among cities losing residents, a greater rate of loss is associated with a significant drop in population share of the highly educated, while there is no significant correlation between the extent of population growth and the college-educated share among growing cities. The F-test results also show that we can be sure these effects are, in fact, different. Given the units of observation, the estimated α_1 coefficient of 8.28 implies that a 10 percent greater rate of population decline over a decade is associated with a 0.83 percentage point lower share of college graduates. There is just over a three percentage point gap between the average college graduate share in expanding versus declining cities in our sample (16.9% among cities that were losing

population in a given decade versus 20.2% for those gaining residents), so this estimated impact can account for a significant fraction of the average difference we see in this local attribute.

If the model underlying Proposition 3 is correct and cheap housing is relatively more attractive to those with lower wages (and presumably, less skill), then controlling for the distribution of house prices at the end of the time period should weaken or eliminate the correlation pattern just identified. The middle column of Table 5 reports results where the log of median house price at the end of each decade is added to the basic regression in equation (8). Simply controlling for one measure of central tendency of city house prices eliminates the relationship between the rate of population loss and the college graduate share among declining cities. The relevant F-test statistics comparing the two effects shows that we cannot reject the null that there is no difference in effects across growing versus declining cities once we control for end of period house prices.

If other local traits generated the same result, that would cast doubt on our contention that it is cheap housing that attracts or retains the poor in declining cities. We could not find any other variable that could do so. The findings in column three of Table 5 report the results after including a host of other local controls (besides house prices) including the log of city population, the family poverty rate, weather conditions, region dummies, and changes in Hispanic population shares. These variables have very little impact on the relationship between decline and skill composition of the residents, and the specification still is estimated precisely enough that we can reject the null that there are no differences in impacts across the two types of cities. In sum, the housing price control, and no other local variable, has the effect of eliminating the connection between human capital and urban decline.[8]

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[8] We repeated the exercise using the change in the share of non-high school graduates and found that controlling for the distribution of house prices also can account for the correlation between this measure of human capital and city growth. In addition, we experimented with two income-based measures of human capital—median family income and the poverty rate—to similar effect. Admittedly, these two variables are problematic because if rising population levels are caused by rising labor demand, then we should expect to see a positive relationship even if the housing factors that drive our model are not important. Nonetheless,

IV.   Alternative Explanations: Is the 'Bricks and Mortar' Perspective on Urban Decline Robust?

In this section, we consider alternative explanations for our findings, including long-lived physical plant or infrastructure, immobile people, and filtering in the housing market. Some of these hypotheses are potentially complementary with our durable housing framework. In all cases, we attempt to discern which is more consistent with the facts describing urban decline.

Durable Plant and Infrastruture

Declining cities might endure because they have durable production infrastructure or long-lived agglomerations of firms (as in Krugman (1991a,b)), not just durable homes. These explanations are not mutually exclusive, as both physical plant and housing could be empirically relevant. To investigate this possibility, we construct a measure of Tobin's q for firms headquartered in our sample of cities, and use it to augment the specification estimated in equation (7) which showed that cities with a low 'housing q' (i.e., those with a large fraction of their owner-occupied stocks valued below replacement cost) have much less future growth. By including a measure of 'corporate q' for the city (described more fully below), we can see whether the data prefer it or house q as a predictor of future growth.[9]

If US Steel's plants are the primary reason that many people still live in Gary, IN, then irreversible industrial investment suggests that Tobin's q for such a firm located in the city should forecast future growth. Tobin's q was created for every publicly traded firm listed in the Compustat files in 1980 and 1990, with q calculated as the ratio of the market value of firm assets divided by the book value of assets as in Gompers, Ishii, and Metrick (2003). While this variable is widely used in financial economics research, it is not straightforward to match it to specific cities in our urban context. Tobin's q is a firm-level measure and companies typically have assets

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these variables may be better measures of human capital than educational degrees, so they were examined for robustness.
[9] We are grateful to the editor, John Cochrane, for suggesting this approach, and to Andrew Metrick for helping with the Compustat data.

in more than one jurisdiction. Compustat does identify the county (not the city) in which the

company is headquartered and we use that to match firms to cities. The 'corporate q' for a city is

the market value-weighted average of individual company q's located in the county in which the

relevant central city is located. In the regression results reported below, we label this variable

CorporateQ.

We are able to match a firm-based q to 206 of the 215 city-year pairs used in the house q

regression reported in Table 4.[10] The average number of firms making up a city's CorporateQ is

23, with a standard deviation of 39. The range of this number is wide, varying from 1 in a

handful of places (e.g., Beaumont, TX; Corpus Christi, TX; Erie, PA; Lorain, OH; Mobile, AL;

South Bend, IN; Springfield, MA, Topeka, KS) to well over 200 in the nation's major cities (e.g.,

Chicago, Los Angeles, and New York). We report results without correcting for the number of

firms in the city's CorporateQ. There are many reasons why weighting by the number of firms is

not necessarily better. Empirically, we find that weighting by firms or market capitalization does

not increase the estimated importance of CorporateQ in our regressions (and weighting by the

number of firms always is associated with a smaller impact).[11]

The average city-level CorporateQ is 1.51, with a standard deviation of 0.82. The median

is 1.26. The lowest corporate q for any city is 0.63, with the maximum being just below 5. Cities

with relatively large fractions of their owner-occupied housing stocks priced below construction

cost tend to have a low value of CorporateQ. Because a high value for -HouseQ reflects a larger

share of housing valued below replacement cost, this means the two variables are negatively

correlated. The simple correlation between the share of a city's housing priced below physical

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[10] The inability to match arises if Compustat does not report any firms being headquartered in the home
counties of one of our cities. They tend to be less populous locales and are spread across the country (e.g.,
they are in California, Louisiana, Michigan, Ohio, Pennsylvania, and Texas).
[11] Measurement error in the ratio of market-to-replacement value of a city's corporate assets need not
decline with the number of firms located in a place. CorporateQ based on the one company headquartered
in Beaumont, TX, could more accurately describe the state of that city's fixed plant than does the analogous
value for Philadelphia, PA, that is based on 32 companies. Not only is the local economy in Philadelphia
more complex, but its firms in the Compustat files sometimes are global entities whose q-values are
influenced by assets far from Philadelphia.

replacement cost and the q of its local companies is -0.24. That correlation is statistically

significant and does not vary much across the two decades for which we have data.

This raises the possibility that a city's corporate q, not its house q, really is behind the

relationship identified above in Table 4. To get at this issue, we begin by reestimating equation

(7) on the slightly reduced number of observations for which we have both house q and corporate

q measures. As the first column of Table 6 shows, the results are vitually unchanged, with a 10%

higher share of the local housing stock that is priced below construction costs at the beginning of

the decade still associated with about 2.7% lower population growth over the decade.

The second regression reported in Table 6 estimates equation (9), which identifies the

correlation between beginning of period CorporateQ and population growth.

(9) *Population Growth Rate(%)$_{i,t}$ = α$_0$ + α$_1$*CorporateQ$_{i,t\_}$ + α$_2$*δ$_t$ + ε$_{i,t}$.*

CorporateQ predicts population growth when we do not control for –HouseQ.

The third regression reported in Table 6 includes both –HouseQ and CorporateQ. The

coefficient on the ratio of corporate market-to-book value declines by over one-third and is no

longer significant at standard confidence levels. The coefficient on the house q control remains

statistically significant and declines only slightly in size. In economic terms, the coefficient on

the city's corporate q implies a standardized marginal effect that is not even half as large as that

for house q.[12] In the final column of Table 6, we report a specification where corporate q is

entered in piecewise linear form to allow estimation of separate effects depending upon whether

the city's corporate q is below or above 1. Having a corporate q below 1 is associated with lower

population growth; having a corporate q above 1 is associated with higher population growth; and

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[12] The standard deviation of the fraction of city housing value below replacement cost is 0.25, while that for corporate q is 0.82. Given the two regression coefficients, the standardized marginal effect for house q is -.06 (~.25*-0.24) and that for corporate q is 0.027 (~0.82*0.033).

the estimated effect of corporate q>1 is significant at the 10% level.[13] The impact of house q is

virtually unchanged.

 While Table 6 provides suggestive evidence that the durability of productive capital

matters, there is no evidence that our house q variable was spuriously reflecting the impact of

installed corporate capital. That said, this latter measure is noisy and it always has the expected

sign in our regressions, so we do not interpret Table 6 as concluding there is nothing to the

durable (non-housing) infrastructure story.

 Other data and implications of the Rosen-Roback model also support the primacy of

durable housing in accounting for the nature of urban decline. If it were true that people

remained in declining cities primarily because a productive installed capital base or a valuable

agglomeration of firms, then we should see signs of that in the labor market. For example, that

physical capital in the production sector should keep wages relatively high and unemployment

relatively low. On the other hand, if declining cities endure primarily because of durable housing,

then wages should be low and offset by low housing costs.

 Recent census data shows that wages are about 10% higher in the fastest growing cities

relative to the slowest growing cities. The unemployment rate is about 40% higher in the slowest

growing cities, so layoff risk does not appear to be lower in declining cities such as Gary, Detroit,

and St. Louis that have abundant installed manufacturing plant. Not only is there no evidence

that remaining residents are compensated via the labor market, the data are clear that housing is

cheap in declining cities. Mean prices for a given size, owner-occupied home (i.e., those with

three bedrooms) are about 50% lower in declining cities according to recent censuses. And, there

is a similar gap in apartment rents. Thus, the data are more consistent with cheap housing, not the

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[13] Changing the breakpoint to the median (1.26) or similar values does not affect the results in any material
way. The coefficients always have the right sign, with a high corporate q predicting higher population
growth at close to standard confidence levels, and the house q variable retaining its economic and statistical
significance.

labor market benefits that would be associated with a productive fixed infrastructure or valuable

agglomeration of firms, keeping people in declining areas.

<p align="center">*Immobile People*</p>

A second alternative hypothesis is that declining cities endure because their residents just

do not move (for whatever reason) after they arrived to take advantage of some initial

agglomeration. In other words, it could be the people, not the homes, that creates the 'stickiness'

generating the important asymmetries in our model. To investigate this possibility, we collected

mobility data from the census. Specifically, we began by calculating in-migration rates for 111

cities using the *1980 Census Public Use Micro-Sample*.[14] Declining cities have less in-migration

than growing cities, as the correlation between the in-migration rate and log population change is

0.60. However, in-migration rates are still remarkably high even in declining cities. For

example, 8.8 percent of Philadelphia's 1980 population, or almost 300,000 residents, had moved

into the city over the previous 5 years. Every city in our sample had five year in-migration rates

that were at least 6 percent of total population, and all but three had in-migration rates in excess

of 8 percent. Extrapolating these numbers over the decade implies that over 15 percent of the

city's residents had moved in during the last 10 years—even in the places experiencing the

greatest net decline in population. If these inflows had stopped, population decline would have

more than doubled in most declining cities. Thus, the data suggest that Americans are fairly

mobile. It is the homes that are fixed.

<p align="center">*Filtering in the Housing Market*</p>

A third alternative hypothesis for some of our findings is the filtering of housing. In

filtering models, older houses are cheap because they are old, with Muth (1975) providing the

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[14] The 1980 data are especially well-suited to our needs. No within city moves are included in our in-migration figures using this sample. Moves within a county are included if the given county includes part of the suburbs of the city. Because the public use micro samples require the use of weights, and some observations inevitably contain missing data, we checked the quality of our calculations by comparing the results for the few places in which the city and county are coterminus (e.g., Philadelphia, St. Louis, etc.) with the county-level in-migration rates reported at the county level by the Bureau of the Census in ICPSR Study No. 8471. The findings were nearly identical in all cases.

classic statement on this framework. In our model, older houses are cheap primarily because demand for their location has collapsed. Using the 1999 national file of the *AHS*, we categorized homes of a given quality (defined by the characteristics of being single family, owner-occupied, and with from 2-4 bedrooms) as new or old depending upon whether they had been built within the last 10 years or at least 40 years ago. There is much truth to the filtering story, as in most places, old housing certainly is cheaper than new housing. However, a more detailed examination finds that the really important determinant of price is location, not age.

In declining cities such as Philadelphia and Detroit, old homes are indeed cheap, but the prices of new homes are also quite low. In Philadelphia's case, the median value of homes built within the past ten years was $75,000 versus $60,000 for those at least four decades old. In Detroit, the median value of the newer homes is actually slightly below that of the older homes, at $62,500 versus $70,000. In contrast, in expensive places, the prices of old and new homes are all quite high and there is little or no difference based on age in these places. In Los Angeles, the median new and old home was worth $200,000 according to the 1999 *AHS*. In San Francisco, the median older home was slightly more expensive than the median newer homes, at $350,000 versus $300,000. Filtering of housing down the quality spectrum occurs, but the data emphasize that in declining cities, housing is both cheap and old because demand has collapsed, not because old housing is cheap *per se*. Even new housing is relatively inexpensive in Philadelphia and Detroit and even old housing in San Francisco is quite expensive.

V.   Conclusion

Most of the urban growth literature ignores the physical nature of cities. While the durability of housing may not be a crucial element of urban dynamics for growing cities, it is essential for understanding the nature of urban decline, and many of our major cities are in decline. The supply side of the housing market helps explain why cities decline so slowly even

though they can grow at very fast rates. Durable housing can also explain the striking persistence of urban decline.

Durable housing predicts that exogenous shocks lead to different asymmetric responses of population and house prices. Negative shocks have a relatively small impact on population growth, especially among declining cities, as the durability of housing leads to declines in demand being reflected more in prices than in people. Conversely, the ability to build means that positive shocks have greater impact on growth because new supply dampens the effect on prices. Both asymmetries are borne out in the data. Another implication of durable housing is that the distribution of house prices is an excellent predictor of future population growth. The data show that growth is quite rare in cities with large fractions of their housing stock valued below the cost of new construction.

Finally, the model helps explain why cities in greater decline tend to have lower levels of human capital, as cheap housing is relatively more attractive to the poor. The tendency of declining cities to disproportionately attract the poor is particularly important if concentrations of poverty further deter growth. If low levels of human capital then create negative externalities or result in lower levels of innovation, this becomes particularly troubling because a self-reinforcing process can result in which an initial decline causes concentrated poverty which then pushes the city further downward (e.g., Berry-Cullin and Levitt (1999) and Glaeser et al. (1995)). However, that issue is for future research.

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Appendix 1: Construction of the House Value/Construction Cost Ratio

A number of adjustments are made to the underlying house price data in the comparison of prices to construction costs. These include imputation of the square footage of living area for observations from the *IPUMS* for the 1980 and 1990 census years. Following that, we make three adjustments to the house price data to account for the depreciation that occurs on older homes, to account for general inflation when comparing across years, and to account for the fact that research shows owners tend to overestimate the value of their homes. Finally, we make an adjustment to construction costs in order to account for the wide regional variation in the presence of basements. The remainder of this Appendix provides the details.

First, the square footage of living area must be imputed for each observation in 1980 and 1990 from the *IPUMS.* Because the *AHS* contains square footage information, we begin by estimating square footage in that data set, using housing traits that are common to the *AHS* and *IPUMS* data. This set includes the age of the building (AGE and its square), whether there is a full kitchen (KITFULL), the number of bedrooms (BEDROOMS), the number of bathrooms (BATHROOMS), the number of other rooms (OTHROOMS), a dummy variable for the presence of central air conditioning (AIRCON), controls for the type of home heating system (HEAT, with controls for the following types: gas, oil, electric, no heat), a dummy variable for detached housing unit status (DETACHED), dummy variables for each metropolitan area (MSA), and dummy variables for the U.S. census regions (REGION).

Data frequently was missing for the presence of air conditioning (AIRCON) and the number of other rooms (OTHROOMS). So as not to substantially reduce the number of available observations, we coded in the mean for these variables when the true value was missing. Special dummies were included in the specification estimated to provide separate effects of the true versus assigned data.

Thus, the linear specification estimated is of the following form:

SQUARE FOOTAGE$_i$ = f{AGE$_i$, AGE^2_i, BEDROOMS$_i$, BATHROOMS$_i$, KITFULL$_i$,
OTHROOMS$_i$, AIRCON$_i$, HEAT$_i$, DETACHED$_i$, MSA$_i$, REGION$_i$},

where the subscript i indexes the house observations and separate regressions are run using the

1985 and 1989 *AHS* data. Our samples include only single unit, owned residences in central

cities, and those without extreme square footage values (i.e., we deleted observations with less

than 500 square feet and more than 5,000 square feet of living area (4,000 square feet being the

top code in the 1989 survey)). The overall fits are reasonably good, with the adjusted R-squares

being .391 in the 1985 data and .306 in the 1989 data. The 1985 coefficients are then used to

impute the square footage of the observations from the 1980 *IPUMS*, and the 1989 coefficients

are used analogously for the 1990 *IPUMS* sample.

Once house value is put into price per square foot form, it can be compared to the

construction cost per square foot data from the R.S. Means Company. However, we make other

adjustments before making that comparison. One adjustment takes into account the fact that

research shows owners tend to overestimate the value of their homes. Following the survey and

recent estimation by Goodman & Ittner (1992), we presume that owners typically overvalue their

homes by 6 percent.

A second, and empirically more important, adjustment takes into account the fact that the

vast majority of our homes are not new and have experienced real depreciation. Depreciation

factors are estimated using the *AHS* and then applied to the *IPUMS* data. More specifically, we

regress house value per square foot (scaled down by the Goodman & Ittner (1992) correction) in

the relevant year (1985 or 1989) on a series of age controls and metropolitan area dummies. The

age data is in interval form so that we can tell if a house is from 0-5 years old, from 6-10 years

old, from 11-25 years old, from 25-36 years old, and more than 45 years old. Because slightly

different intervals are reported in the AHS and IPUMS, we experimented with transformations

based on each survey's intervals. The different matching produces very similar results. The

coefficients on the age controls are each negative as expected and represent the extent to which houses of different ages have depreciated in value on a per square foot basis.

Because the regressions use nominal data, we make a further adjustment for the fact that general price inflation occurred between 1980-1985 and 1989-1990. In the case of applying the 1985 results to the 1980 *IPUMS* data, we scale down the implied depreciation factor by the percentage change in the rental cost component of the Consumer Price Index between 1980 and 1985. In the case of applying the 1989 results to the 1990 IPUMS observations, we scale up the implied depreciation factor in an analogous fashion.

The depreciation factors themselves are relatively large. After making the inflation and Goodman-Ittner correction, the results for 1980 suggest that a house that was 6-11 years old was worth $3.17 per square foot less than a new home. Very old homes (i.e., 46+ years) were estimated to be worth $11.94 per square foot less than a new home that year.

Finally, we make an adjustment for the fact that there is substantial regional and cross-metropolitan area variation in the presence of basements. Having a basement adds materially to construction costs according to the Means data. Units with unfinished basements have about 10 percent higher construction costs depending on the size of the unit. Units with finished basements have up to 30 percent higher construction costs, again depending on the size of the unit. Our procedure effectively assumes that units with a basement in the *AHS* have unfinished basements, so that we underestimate construction costs for units with finished basements. Unfortunately, the *IPUMS* data in 1980 and 1990 do not report whether the housing units have a basement. However, using the *AHS* data we can calculate the probability that a housing unit in a specific U.S. census division has a basement. The divisional differences are extremely large, ranging from 1.3 percent in the West South Central census division to 94.9 percent in the Middle Atlantic census division. Thus, in the West South Central census division we assume that each unit has 0.013 basements, and that each unit in the Middle Atlantic division has 0.949 basements. Because of the very large gross differences in the propensity to have basements, this adjustment

almost certainly reduces measurement error relative to assuming all units have basements or that none have basements.

After these adjustments, house value 'as if new' is then compared to construction costs to produce the distributions discussed in the text.

Appendix 2: Proofs of Propositions

Proof of Proposition 1: Part (a) If Δ is symmetrically distributed around $\hat{\Delta} \geq 0$ with cumulative distribution $F(\Delta)$, then the mean growth rate is $N\hat{\Delta} - \int_{\Delta=-\infty}^{0}(1-\delta)\Delta dF(\Delta)$, which is greater than the median growth rate, $N\hat{\Delta}$.

(b) When Δ is positive, the change in price always equals 1/(2N) times the change in quantity so the estimated regression coefficient will equal 1/(2N). When Δ is negative, the change in population is $\delta\Delta N$, and the change in rent is $\dfrac{\Delta}{2}\left(1 + \dfrac{(1-\delta)(\overline{a} - \underline{r} + \theta_0)}{\overline{a} - \underline{r} + \theta_0 + \delta\Delta}\right)$ so the estimated regression coefficient equals:

$$\frac{\int_{\Delta<0}\Delta^2\left(1 + \dfrac{(1-\delta)(\overline{a} - \underline{r} + \theta_0)}{\overline{a} - \underline{r} + \theta_0 + \delta\Delta}\right)dF(\Delta) - \left(\int_{\Delta<0}\Delta\left(1 + \dfrac{(1-\delta)(\overline{a} - \underline{r} + \theta_0)}{\overline{a} - \underline{r} + \theta_0 + \delta\Delta}\right)dF(\Delta)\right)\Delta_-}{2\delta N\left[\int_{\Delta<0}\Delta^2 dF(\Delta) - \Delta_-^2\right]} \text{ where}$$

$\Delta_- = \int_{\Delta<0}\Delta.dF(\Delta)$. This is less than 1/(2N) as long as $\int_{\Delta<0}\dfrac{\Delta(\Delta - \Delta_-)}{\overline{a} - \underline{r} + \theta_0 + \delta\Delta}dF(\Delta) > 0$, which

must be true because $\int_{\Delta<0}\Delta(\Delta - \Delta_-)dF(\Delta) > 0$, and $\overline{a} - \underline{r} + \theta_0 + \delta\Delta$ is decreasing in the absolute value of Δ.

(c) When z is positive, the growth in population equals $N\beta z$ so the derivative of growth with respect to z equals $N\beta$. When z is negative, population change equals $\delta N\beta z$, so the derivative of growth with respect to z will equal $\delta N\beta$. When z is positive, the change in rents equals $.5\beta z$, so the derivative of the change in rents with respect to z will equal $.5\beta$. When z is negative, the

change in rents will equal $.5\beta z\left(1 + \dfrac{(1-\delta)(\bar{a} - \underline{r} + \theta_0)}{\bar{a} - \underline{r} + \theta_0 + \delta\beta z}\right)$ and the derivative with respect to z will

equal $.5\beta\left(1 + \dfrac{(1-\delta)(\bar{a} - \underline{r} + \theta_0)}{\bar{a} - \underline{r} + \theta_0 + \delta\beta z} - \dfrac{\delta\beta z(1-\delta)(\bar{a} - \underline{r} + \theta_0)}{(\bar{a} - \underline{r} + \theta_0 + \delta\beta z)^2}\right) > .5\beta$.

Proof of Proposition 2:

(a) For cities that grew during the first time period, next period growth is orthogonal to lagged growth so the estimated coefficient will be zero. If lagged growth is negative, then growth in the next period equals: $(\delta(1-\delta)\Delta + \delta\Delta_2)N$ if $\Delta_2 < 0$, $(\delta(1-\delta)(\Delta + \Delta_2) + \delta\Delta_2)N$ if $-\Delta > \Delta_2 > 0$ and $((1-\delta)\Delta + \Delta_2)N$ if $\Delta_2 > -\Delta$. Differentiation then tells us that expected growth is increasing in Δ or first period growth.

(b) The share of housing with rents below $\underline{r}$ in the second period equals $\dfrac{-\Delta(1-\delta)}{a + \theta_0 - \underline{r} + \delta\Delta}$ which is a monotonically negative function of Δ, or if S is the share with rents below $\underline{r}$, then

$\Delta = \dfrac{-S(\bar{a} + \theta_0 - \underline{r})}{(1 - (1-S)\delta)}$, and if expected growth is rising with Δ then it is falling with S.

Proof of Proposition 3: If the city population grows an amount "x" because of an increase in either W or A, then the share of high skilled workers in the city will increase from

$\dfrac{\bar{a} + \theta_0 - \bar{U}/\phi}{\bar{a} + \theta_0 - r}$ to $\dfrac{\bar{a} + \theta_0 + x/N - \bar{U}/\phi}{\bar{a} + \theta_0 + x/N - \underline{r}}$. The change in the share of skilled workers in the city

will equal $\dfrac{(x/N)(\bar{U}/\phi - r)}{(\bar{a} + \theta_0 + x/N - \underline{r})(\bar{a} + \theta_0 - \underline{r})}$. If the city population declines by an amount "x"

then the share of high skilled workers in the city will decline from $\dfrac{\bar{a} + \theta_0 - \bar{U}/\phi}{\bar{a} + \theta_0 - \underline{r}}$ to

$$\frac{\bar{a} + \theta_0 + x/\delta N - \bar{U}/\phi}{\bar{a} + \theta_0 + x/N - \underline{r}}$$, which implies a change in the number of skilled workers equal to

$$\frac{(x/N)(\bar{U}/\phi - \underline{r})}{(\bar{a} + \theta_0 + x/N - \underline{r})(\bar{a} + \theta_0 - \underline{r})} + \frac{(1-\delta)x}{\delta N(\bar{a} + \theta_0 + x/N - \underline{r})}$$, which is obviously larger in absolute

value than $$\frac{(x/N)(\bar{U}/\phi - \underline{r})}{(\bar{a} + \theta_0 + x/N - \underline{r})(\bar{a} + \theta_0 - \underline{r})}.$$

Table 1: The Relationship Between Price Changes and Population Changes (Proposition 1.b)		
(3) House Price Appreciation Rate$(\%)_{i,t} = \alpha_0 + \alpha_1 * POPLOSS_{i,t} + \alpha_2 * POPGAIN_{i,t} + \delta_t + \varepsilon_{i,t}$		
Results from Pooled Decadal Observations (1970s, 1980s, 1990s combined; n=963; R^2=0.19)		
α_1	α_2	Test for $\alpha_1=\alpha_2$
1.80	0.23	F(1,320)=45.20
(0.20)	(0.05)	Prob>F=0.00
Results from Three-Decade Change (1970-2000; n=321; R^2=0.15)		
α_1	α_2	Test for $\alpha_1=\alpha_2$
1.64	0.09	F(1,320)=55.16
(0.19)	(0.04)	Prob>F=0.00

Notes: Standard errors in parentheses are based on clustering at the city level. There are 321 city clusters in each regression.   Specifications estimated using data on cities with at least 30,000 residents in 1970. There are 963 observations on the pooled decadal changes and 321 observations on the 30-year changes. Population and house prices are obtained from the decennial censuses. Decadal dummy coefficients and intercepts are suppressed throughout. Full results are available upon request. See the text for added detail on the specification.

Table 2: Population and Price Growth and the Weather (Proposition 1.c)		
(4) Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*COLD$_i$ + α_2*WARM$_i$ + α_3*δ_t + $\varepsilon_{i,t}$		
(5) House Price Appreciation Rate(%)$_{i,t}$ = β_0 + β_1*COLD$_i$ +β_2*WARM$_i$ + β_3*δ_t + $\gamma_{i,t}$		
Population Growth Results (Pooled decadal observations from the 1970s, 1980s, and 1990s; n=963; R^2=0.15)		
α_1	α_2	Test for α_1=α_2
0.0008	0.0069	$F(1,261)$=4.79
(0.0020)	(0.0012)	Prob>F=0.03
House Price Appreciation Results (Pooled decadal observations from the 1970s, 1980s, and 1990s; n=963; R^2=0.11)		
β_1	β_2	Test for β_1=β_2
0.0060	0.0023	$F(1,261)$=2.39
(0.0016)	(0.0011)	Prob>F=0.12

Notes: Standard errors in parentheses are based on clustering at the metropolitan area level. There are 262 metro clusters in each regression. Specifications estimated using data on 321 cities with at least 30,000 residents in 1970. There are 963 observations across the three decades of the 1970s, 1980s, and 1990s. Population and house prices are obtained from the decennial censuses. Mean January temperature is a 30-year average that was collected from the 1992 *County and City Data Book*. This variable does not vary over time. Decadal dummy coefficients and intercepts are suppressed throughout. Full results are available upon request. See the text for added detail on the specifications.

Table 3: The Persistence of Population Decline (Proposition 2.a)

(6) Population Growth Rate(%)$_{i,t}$ = α$_0$ + α$_1$*POPLOSS$_{i,t-1}$ + α$_2$*POPGAIN$_{i,t-1}$ + α$_3$*δ$_t$ + ε$_{i,t}$

Results from Pooled Decadal Observations (1980s and 1990s; n=642; R^2=0.51)		
α$_1$	α$_2$	α$_1$=α$_2$
1.001	0.455	F(1,320)=29.03
(0.076)	(0.039)	Prob>F=0.00

Notes: Standard errors in parentheses are based on clustering at the city level. There are 321 city clusters. Specifications estimated using data on 321 cities with at least 30,000 residents in 1970. In this table, population growth rates from the 1980s and 1990s are regressed on transformed lags of their respective growth rates and a single decadal dummy as described in the text. There are 642 decadal observations. All population data was obtained from decennial censuses. The time dummy coefficient and the intercept are suppressed throughout. All results are available upon request.

Table 4: The Distribution of House Prices and Population Growth (Proposition 2.c)	
(7) Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*-HouseQ$_{i,t}$ + α_2*δ_t + $\varepsilon_{i,t}$	
Results from Pooled Decadal Observations (1980s and 1990s; n=215)	
α_2 (from Equation (7))	α_2 (from second specification with added local controls; see the notes to this table for the details)
-0.270 (0.042)	-0.267 (0.084)
R^2=0.20	R^2=0.55

Notes: Standard errors in parentheses are based on clustering at the city level. There are 127 city clusters. Specifications are estimated using data on 215 cities—123 with 1980s data and 92 with 1990s data. Population data are from the decennial censuses. House price data is from the *Integrated Public Use Micro* samples maintained by the University of Minnesota. Single family home construction cost data are from publications of the R.S. Means Company. Various adjustments to both the numerator and denominator are made in creating the ratio of price to construction cost in the –HouseQ variable. See the text and Appendix 1 for the details. The local controls included in the specification reported in the second column include the following: the log of median house price at the beginning of the decade, the percentage of the city housing stock at the beginning of the decade comprised of single unit dwellings, census region dummies, the log of city population at the beginning of the decade, the city's family poverty rate at the beginning of the decade, and 30-year averages for January temperature, July temperature, and annual rainfall. The time dummy coefficient and the intercept are suppressed throughout. All results are available upon request.

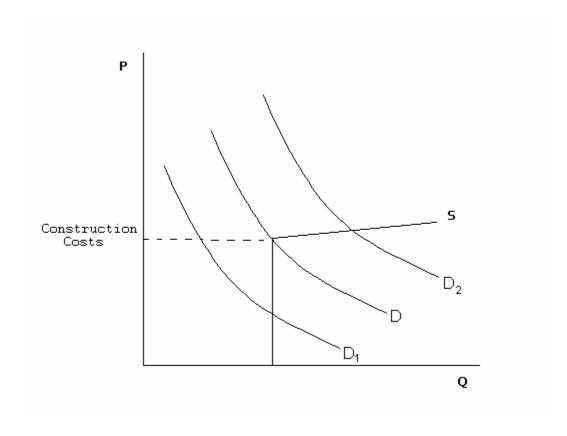| **Table 5: Human Capital, Cheap Housing, and Urban Decline (Proposition 3)**					
$(8)\ \Delta COL_{i,t} = \alpha_0 + \alpha_1{*}POPLOSS_{i,t} + \alpha_2{*}POPGAIN_{i,t} + \alpha_3{*}\delta_t + \varepsilon_{i,t}.$					

Results from Pooled Decadal Observations (1970s, 1980s, and 1990s; n=963)					
Specification #1: Equation (8)		Specification #2: (adds Log Median House Price in city i at the end of the decade to equation (8))		Specification #3: (adds other local controls, excluding Log Median House Price; see the Notes for details)	
α_1	8.28 (1.86)	α_1	0.30 (1.80)	α_1	8.35 (2.03)
α_2	0.83 (0.58)	α_2	-0.25 (0.56)	α_2	1.99 (0.61)
$F(1,320) = 12.75$; Prob>F = 0.00		$F(1,320) = 0.08$; Prob>F = 0.78		$F(1,261) = 9.33$; Prob>F = 0.00	
R^2=0.15		R^2=0.26		R^2=0.25	

Notes: Standard errors in parentheses based on clustering at the city level in the first two specifications and at the metropolitan area level in the third specification. There are 321 city clusters and 262 metro area clusters. Clustering by metropolitan area is done when weather-related variables are included in the specification. Specifications estimated using data on 321 cities with at least 30,000 residents in 1970. The second specification adds median house price (at the end of each decade) to the basic model in equation (8). The third specification includes city population, the family poverty rate, the change in Hispanic population share, weather conditions as reflected in mean January temperature, mean July temperature, and average annual rainfall, and region dummies. College graduate shares and the family poverty rate were obtained from various issues of the *County and City Data Book* and HUD's State of the Cities data system. Population, house prices, and Hispanic share were obtained from the decennial censuses. All weather variables represent 30-year averages that were collected from the *County and City Data Book*. Time dummy coefficients and the intercept are suppressed throughout. All results are available upon request.

Table 6: House q, Corporate q, and City Population Growth

(7) *Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*-HouseQ$_{i,t\_}$ + α_2*δ_t + $\varepsilon_{i,t}$.*

(9) *Population Growth Rate(%)$_{i,t}$ = α_0 + α_1*CorporateQ$_{i,t}$ + α_2*δ_t + $\varepsilon_{i,t}$.*

	Specification			
	(1)	(2)	(3)	(4)
-HouseQ	-0.266 (0.044)		-0.238 (0.043)	-0.242 (0.043)
CorporateQ		0.051 (0.019)	0.033 (0.020)	
CorporateQ<1				-0.104 (0.128)
CorporateQ>1				0.037 (0.021)
Nobs	206	206	206	206
R^2	0.19	0.08	0.22	0.23

Notes: Standard errors in parentheses based on clustering at the city level. There are 124 city clusters. Specifications are estimated using data on 206 cities with non-missing -HouseQ and CorporateQ data in 1980 and 1990. Population data are from the decennial censuses. See the notes to Table 4 for data sources on the construction of the –HouseQ variable. The CorporateQ variable is constructed as the market capitalization-weighted average of firm q's located in the home county of the relevant city. Firm q is constructed as in Gompers, Ishii, and Metrick (2003). See the text for more details. The time dummy coefficient and the intercept are suppressed throughout. All results are available upon request.

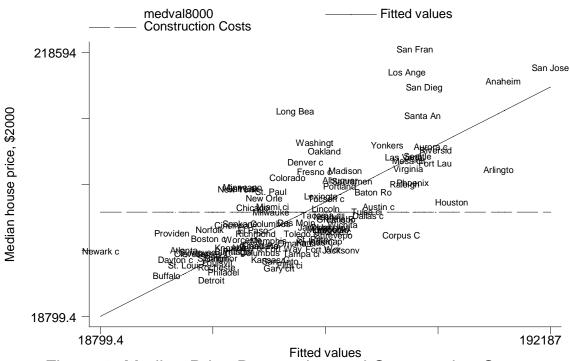**Figure 1: The Nature of Housing Supply and Construction Costs**

Figure 2: Median Price Regression and Construction Costs

Notes:
1. The dashed horizontal line represents the $97,974 construction costs (in $2000) for a modest quality, 1,200 single family home estimated by the R.S. Mean Company.
2. The observation for Honolulu is not plotted for ease of presentation.

Figure 3: Price Appreciation and Urban Growth