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Discussion Paper 001

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RESEARCH PROGRAM: IMPACT OF THE PUBLIC SECTOR ON LOCAL ECONOMIES

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Abstract

An equilibrium price relation is derived for housing capital gains, capable of generating a hedonic, or quality corrected price index, and an index of deterioration. The particular problem considered is the behavior of prices for urban and suburban housing. Hypotheses are formulated on the effect of suburbanization and urban decay on house prices, and price differentials based solely on location. Empirical results are derived by maximum likelihood estimation of housing market equation systems.

HEDONIC PRICES AND AGE DETERIORATION IN URBAN AND SUBURBAN HOUSING*

An observed phenomenon in metropolitan housing markets is a gradual increase of density in the locational tails of the residential population distribution. This process of suburbanization has been explained as caused not only by increasing urban growth but also by a reduction in the relative price of transportation, and by segregation patterns associated with marital status, race and income.[1] The objective is to examine the behavior of housing prices during such a process of suburbanization, to determine whether deterioration patterns differ between urban and suburban housing. In addition, hedonic price indexes for each subcategory are formulated and estimated.

There is substantial prima facie evidence such as the development of slums and ghettos to suggest that urban housing deteriorates relatively more rapidly than suburban housing. However, since the housing stock in the urban core is generally older, such evidence cannot be adjudged except in the context of a model which estimates alternative depreciation patterns within a metropolitan area. From such patterns, policy information can be obtained on tax incentives for new construction, the location of public housing and the computation of real estate tax rates.

Considering hedonic prices, there have been various attempts to construct such indexes for the housing market.[2] As with other hedonic studies, the results have been predicated on restrictive assumptions such as time-independence of preferences and zero interaction between characteristics, with its implications of homothetically separable preferences. Such assumptions are not maintained in our construction of separate hedonic indexes for housing in various locations within the metropolitan area. Tests of equality between the indexes are used to determine whether quality corrected housing can be viewed as homogeneous.

1. Housing Price Determination

A house is a durable good in the sense that it provides services for more than one Hicksian period.[3] The asset does not depreciate completely in one period. Given that observed depreciation patterns depend on such fluctuating characteristics as physical deterioration, obsolescence associated with embodied technical change and preferences by consumers for housing by age, no restriction is placed on the form of the depreciation pattern. In particular, geometric or proportional to capital stock depreciation is not maintained.[4]

The price which a buyer at the current time period is willing to pay for a house is the present value of the discounted service flows of housing over the planned ownership period, plus the present value of the expected resale price. As characterizes actual operation of the housing market, such resale is permissible at any time. Houses are described by a set of characteristics, establishing location in time and space.[5]

Let the price be $p(t,v,z)$ for a house at time t, where v denotes the length of ownership at time t, and z denotes a vector of other characteristics. For current purchasers $v = 0$, but price computations are possible on currently owned housing for which $v > 0$ at time t. The price relation is

$$(1) \qquad p(t,v,z) = \int_t^T w(t+s,\ v+s,\ z)\, e^{-rs}\, ds + p(T,\ v+T-t,\ z)\, e^{-r(T-t)}$$

where $w(t+s,\ v+s,\ z)$ is the value of consumed services of housing at time $t+s$, with length of ownership $v+s$ and characteristics z, and r is the discount rate. The first term on the right of (1) measures the value at current time t of the future stream of housing services consumed, over the period $(T-t)$. The second term represents the present value of the future selling price. Housing capital gains over $(T-t)$ are therefore[6]

$$(2) \qquad k(t,v,z) = p(T,\ v+T-t,\ z)\ e^{-r(T-t)} - p(t,v,z)$$

where $k(t,v,z)$ is the capital gains measure at the current time t.

House purchasers make decisions such that gross capital losses, or the negative of (2), are equal to the value of housing services consumed. This requires

$$(3) \qquad -k(t,v,z) = \int_t^T w(t+s,\ v+s,\ z)\ e^{-rs}\ ds$$

at time t. The integrand $w(t+s,\ v+s,\ z)$, being a value index, can be interpreted as the product of a hedonic price index and a quality index.[7] Under the conditions for a capital aggregate, we have the factorization

$$(4) \qquad w(t+s,\ v+s,\ z) = q(t+s)\ x(v+s,\ t+s,\ z)$$

where $q(t+s)$ is the hedonic price index, or price of an efficiency or constant characteristics unit of housing, and $x(v+s,\ t+s,\ z)$ is the quality index, or efficiency units of service provided per physical unit of housing capital. With no loss of generality, the value index can be factored

(5) $$w(t+s,\ v+s,\ z) = q(t+s)\ g(v+s)\ h(z)\ f(v+s,\ t+s,\ z)$$

where the quality index is represented as the product of a deterioration index dependent on length of ownership $g(v+s)$, a characteristics index $h(z)$ and an interactive effect $f(v+s,\ t+s,\ z)$.

If $f(v+s,\ t+s,\ z) = 1$ the hedonic index can be constructed as a separable aggregate of the constituent characteristics. For housing, such characteristics are exemplified by location, school quality and physical house description. Such a specification implies zero interactive effects between components.[8] This is consistent with homothetically separable preferences in the housing market.[9]

Using the factorization of the house value index (5) and the capital losses condition (3)

(6) $$-\ k(t,v,z) = h(z) \int_t^T q(t+s)\ g(v+s)\ f(t+s,\ v+s,\ z)\ e^{-rs}\ ds$$

becomes the behavioral relation. Assume that static expectations prevail on $q(t+s)$ and $f(v+s,\ t+s,\ z)$. Price increases or decreases for housing services are associated with age rather than time. Any interaction between age and time is assumed to continue over the incremental planned ownership period. This yields

(7) $$-\ k(t,v,z) = h(z)\ q(t)\ f(t,v,z) \int_t^T g(v+s)\ e^{-rs}\ ds$$

for housing capital losses. Define

(8) $$\overline{q}(t) = q(t) \int_t^T g(s)\ e^{-rs}\ ds$$

as the current price of a new house, net of age deterioration. A house aging index can be defined as the relative price of a previously owned house to a new house. This implies, over the planned ownership (T - t)

$$(9) \qquad \bar{g}(v) = \frac{\int_t^T g(v+s)\, e^{-rs}\, ds}{\int_t^T g(s)\, e^{-rs}\, ds}$$

where $\bar{g}(v)$ is the aging or depreciation index. There are three sources of price change in housing strictly attributable to age. First, housing deteriorates with age, providing fewer effective units of service per physical capital unit. This is associated with physical decay of the structure, plumbing and wiring system, and potentially the neighborhood of location. Second, houses fall in price with age because of improvements embodied in dwellings of more recent vintage. The more rapid the development of technical change in construction delivery, prefabrication and sewage disposal, the greater the rate of embodiment, and the more rapid the rate of obsolescence on old housing. Third, there is the effect of shifting preferences by age of housing. Some buyers prefer older housing to newer housing. Such taste change generates a demand for and the preservation of antiques. Prices of such houses increase with age. The first two effects imply $\partial\bar{g}(v)/\partial v < 0$, while the third suggests $\partial\bar{g}(v)/\partial v > 0$, with the result that no prior restriction can be imposed on the pattern of $\bar{g}$.

Finally, using (7) - (9) we obtain

$$(10) \qquad - k(t,v,z) = h(z)\, \bar{q}(t)\, \bar{g}(v)\, f(t,v,z)$$

which expresses capital losses as the product of a quality index, a hedonic price index, a depreciation index and an interaction term. This relation forms the basis of empirical examination of house prices in a metropolitan area.

2. Suburbanization and Market Prices

The relation (10) forms the basis of empirical tests for decomposing observed differentials in market prices in urban and suburban areas. Taking logarithms and adding subscripts for urban and suburban location

$$(11) \qquad \ell n\ m_U(t,v,z) = \ell n\ h_U(z) + \ell n\ \bar{q}_U(t) + \ell n\ \bar{g}_U(v) + \ell n\ f_U(t,v,z)$$

and

$$(12) \qquad \ell n\ m_S(t,v,z) = \ell n\ h_S(z) + \ell n\ \bar{q}_S(t) + \ell n\ \bar{g}_S(v) + \ell n\ f_S(t,v,z)$$

where $m_i(t,v,z) = -\ k_i(t,v,z),\ i = U,S$. The objective is to test price differentials between houses by location, and to determine sources of such differentials. Each market capital gain, the dependent variable, is expressed as the logarithmic sum of a characteristics index, a hedonic price index, a depreciation index and an interactive term.

The main focus of hypothesis testing is on the hedonic prices and depreciation forms. The first test is for equality of such indexes across locations, for each observed year in a data sample. If efficiency units of housing are homogeneous, and locations are also homogeneous, then the indexes will be equal. Alternatively, it can be hypothesized that zoning restrictions, capital constraints on purchasing and segregation imply economic rents for suburban householders. The null hypothesis of equality is, with time subscripts indicating discrete data

(13) $\ell n\ \bar{q}_{U,t} = \ell n\ \bar{q}_{S,t}$ each t

against the alternative of suburban economic rents, or

(14) $\ell n\ \bar{q}_{U,t} < \ell n\ \bar{q}_{S,t}$ each t

on the housing prices. It is also possible for $\ell n\ \bar{q}_U(t) > \ell n\ \bar{q}_S(t)$. Several arguments can be advanced for such a hypothesis. First, urban residential densities are higher, and land values and construction costs exceed those of the suburbs. Second, assume that the Kain (1968) hypothesis of job relocation to the suburbs is correct. In such a case, households would be willing to trade capital gains against job opportunities, and index values and rates of change for suburban homes would be less than those in the city.[10] Such a test of equality can be applied against a two-tailed alternative, to take account of these arguments. The test is applied for each year separately and all years simultaneously, as illustrated in Figure 1.

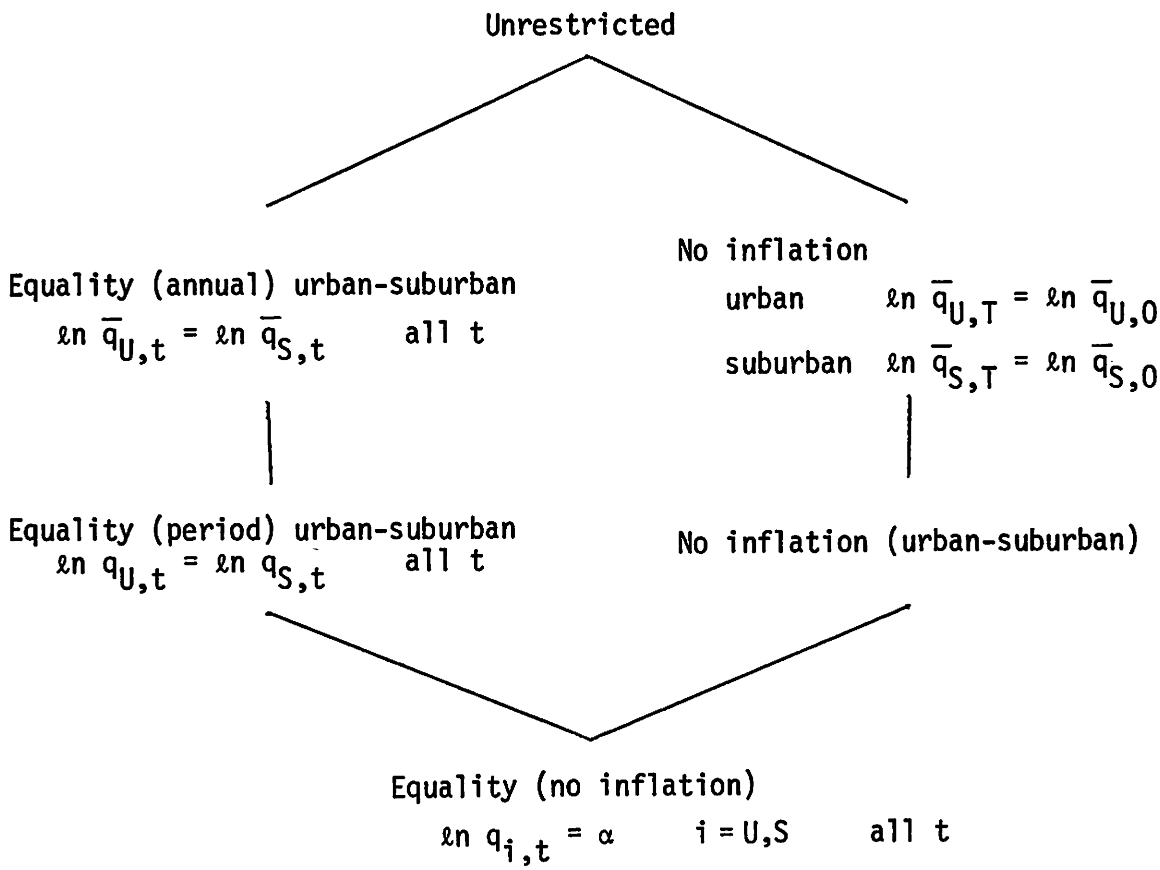
In addition, a test for inflation in hedonic prices can be applied, both in the city and suburbs. This requires in period form that the values at the initial and terminal years of the hedonic index be equal, or

(15) $\ell n\ \bar{q}_{U,T} = \ell n\ \bar{q}_{U,0}$

and

(16) $\ell n\ \bar{q}_{S,T} = \ell n\ \bar{q}_{S,0}$

FIGURE 1. Test Procedure, Hedonic House Prices



and, as in Figure 1, is followed by a simultaneous no inflation test for the metropolitan area.

Turning to depreciation, the first set of tests is for equality of rates across districts, or

$$(17) \qquad \ln \bar{g}_{U,v} = \ln \bar{g}_{S,v} \qquad \text{each } v$$

expressing the null hypothesis of equal house depreciation per period, and can also be tested for all v. The alternative hypotheses can be argued similarly to the case of hedonic prices. As the CBD decays through job relocation, housing demand falls relatively in the urban core. Owners have less incentive to maintain their property, and $\ln \bar{g}_{U,v} < \ln \bar{g}_{S,v}$, or the urban depreciation index falls more rapidly. Alternatively, owners may be willing to trade off additional maintenance and depreciation expenses for better job opportunities.

Finally, we test geometric depreciation forms, or

$$(18) \qquad \ln \bar{g}_{i,v} - \ln \bar{g}_{i,v+1} = \beta_i \qquad i = U,S$$

where β_i is a constant. The entire test structure is indicated in Figure 2. Geometric depreciation implies proportionality of such expenses to the existing capital stock.

3. Specification and Empirical Results

Specification of the model is performed by introducing additive errors, not necessarily contemporaneously uncorrelated, in (11) and (12), and viewing the right-hand side elements as coefficients of dummy matrices of characteristics. The data comprise capital gains calculations

FIGURE 2. Test Procedure, Depreciation Forms

Unrestricted

Equal rates (annual) urban-suburban

$\ln \bar{g}_{U,v} = \ln \bar{q}_{S,v}$ each v

Equal rates (period) urban-suburban

$\ln \bar{g}_{U,v} = \ln \bar{g}_{S,v}$ all v

Geometric depreciation

urban $\ln \bar{g}_{U,v} - \ln \bar{g}_{U,v+1} = \beta_U$

suburban $\ln \bar{g}_{S,v} - \ln \bar{g}_{S,v+1} = \beta_S$

Geometric (urban-suburban)

on all housing transactions in a medium-sized metropolitan area 1967-1972.[11] Dummy variables are used to indicate year of sale, age at sale and location within separate urban and suburban groupings. Location is viewed as the characteristic in h(z). In addition, interactive effects are specified, but restrictions are imposed to reduce the magnitude of the regressor matrix.[12]

The system is estimated by maximum likelihood procedures, iterating on the seemingly unrelated regression (SUR) technique of Zellner (1962). Restrictions on the system are imposed across equations, and the value of the likelihood function for each restricted system retrieved. Test statistics for the parametric equality restrictions are constructed by computing twice the reduction in the maximized value of the logarithm of the likelihood function. These likelihood ratios are asymptotically distributed as χ^2 with degrees of freedom equal to the number of restrictions tested. The assignment of critical values to the test procedure is indicated in Table 1, with the overall level maintained at a maximum of .05.

The first set of tests performed is that for homothetic separability, or zero interactions. Separate tests are utilized for urban and suburban housing, and the joint test is subsequently applied. The χ^2 test statistics are 0.10 for the urban case alone, and 1.60 for the suburban case alone. Since the critical value of χ^2 with two degrees of fredom for the assigned .005 significance level is 5.30, the hypothesis is not rejected in each case. For the joint imposition, at the .01 level with a critical value of 3.32 the hypothesis is not rejected, given a test statistic of 0.84.

The tests for hedonic prices in the urban and suburban markets are summarized in Table 2. Equality tests of hedonic prices within the

TABLE 1. Test Structure and Allocated Significance

	Form		Allocated Significance		Total
1.	Unrestricted				
2.	Homothetic separability				
	i)	Urban		.005	
	ii)	Suburban		.005	
	iii)	Urban-Suburban		.01	.01
3.	Hedonic prices				
	i)	Annual (1967-1972) Urban-Suburban	5 tests		
	ii)	No inflation	3 tests		
	iii)	Identical prices	1 test		
4.	Depreciation				
	i)	Annual (1 year tenancy, 2 years, 3 years, 4)	3 tests[b]		
	ii)	Identical depreciation	3 tests		
	iii)	Geometric depreciation (conditional on 4(ii))			.04[a]
5.	Hedonic Prices and Depreciation				
		Equal annual prices and depreciation rates			.04

Notes: [a]Allocated at discretion between the tests, with the maximum being .04. Items 3 and 4 are tested in parallel.

[b]There is one normalization, eliminating one test in the dummy regressor matrix.

TABLE 2. Test Statistics, Urban-Suburban Hedonic Prices

1. Hedonic Price Equality

Year	χ^2/D.F.	D.F.
1967	0.88	1
1968[a]	-	-
1969	5.15	1
1970	6.41	1
1971	5.18	1
1972	1.33	1
1967-1972	1.91	5

2. No Inflation

Urban	2.46	1
Suburban	6.98	1
Urban-Suburban	4.57	2

Note: [a]No test is performed because indexes are normalized in 1968.

metropolitan area are performed in the first block, and subsequently performed for each year. A maximum significance level of .04 is assigned to these tests. At a level of .01, all separate tests of equality are accepted. However, these conclusions are in no sense decisive, since at a level of .025, equality of prices for urban and suburban houses must be rejected for 1969-1971. The results suggest some tendency for quality corrected house prices to be equalized in a metropolitan area, but no decisive evidence in favor of such a hypothesis.

Turning to tests of inflation, the hypothesis of no inflation in the urban market is not rejected, while that for the suburban market is rejected at the .01 level. As before, a metropolitan area test of no inflation passes at a level of .01, but fails at a level of .025.

The test statistics for the depreciation pattern are reported in Table 3. Equal "depreciation" rates on housing in the metropolitan area are not rejected. However, declining house prices with age are not observed, and in fact a monotone increasing pattern occurs. Fitting a geometric pattern of house price appreciation, the hypothesis is accepted for each case. For the full system, parametric estimates are reported in Table 4, for the more important restrictive forms. The subscripts on the q elements indicate year, and those on the g elements represent house age. The f terms are interactions, and h(z) is the locational quality index. The parameter estimates suggest that there is little change in the hedonic price index, where $\ell n\ q_{68} = 0$ by normalization, between 1968 and 1972. At the same time, house prices increase monotonically with age, and these coefficients are all significant, with $\ell n\ g_1 = 0$.

There are several potential causal factors for the observation of increasing age effects, or house appreciation. First, the houses

TABLE 3. Test Statistics, Depreciation in Housing

1. Equal rates, urban-suburban

House Age	χ^2/D.F.	D.F.
2 years	4.42	1
3 years	4.39	1
4 years	4.26	1
2 years or more	2.33	3

2. Geometric Appreciation

Urban	1.81	1
Suburban	0.79	1
Urban-Suburban	1.30	2

TABLE 4. Maximum Likelihood Parameter Estimates, Urban and Suburban Housing Prices (standard errors in parentheses)

	Unrestricted	Hom. Sep.	Hed. Price Equality	No Inflation	Equal Dep.	Geo. Dep.	All Years and Ages Equal
URBAN							
Constant	6.99 (.25)	6.98 (.24)	7.26 (.23)	7.02 (.24)	6.93 (.24)	6.95 (.24)	7.14 (.21)
$\ell n\ q_{67}$	0.86 (.38)	0.89 (.37)	0.54 (.25)	0.60 (.34)	0.98 (.38)	0.93 (.37)	0.52 (.25)
$\ell n\ q_{69}$	0.63 (.50)	0.69 (.40)	0.08 (.24)	0.84 (.40)	0.48 (.39)	0.72 (.40)	0.10 (.24)
$\ell n\ q_{70}$	0.27 (.47)	0.34 (.44)	-0.53 (.27)	0.45 (.43)	-0.07 (.43)	0.33 (.44)	-0.49 (.27)
$\ell n\ q_{71}$	0.46 (.50)	0.55 (.49)	-0.33 (.32)	0.60 (.47)	0.11 (.47)	0.52 (.49)	-0.27 (.31)
$\ell n\ q_{72}$	-0.11 (.62)	-0.09 (.60)	-0.61 (.35)	0.60 (.34)	-0.64 (.54)	-0.01 (.60)	-0.58 (.35)
$\ell n\ g_2$	0.36 (.37)	0.37 (.32)	0.54 (.32)	0.26 (.32)	0.81 (.21)	0.64 (.23)	0.78 (.21)
$\ell n\ g_3$	0.53 (.63)	0.59 (.52)	0.91 (.48)	0.26 (.49)	1.29 (.32)	-	1.19 (.21)
$\ell n\ g_4$	0.97 (.52)	0.91 (.51)	1.34 (.45)	0.56 (.43)	1.63 (.34)	0.93 (.51)	1.61 (.34)
h(z)	0.37 (.28)	0.37 (.27)	0.42 (.27)	0.33 (.27)	0.31 (.27)	0.32 (.27)	0.35 (.27)
f_1	0.17 (.74)	-	-	-	-	-	-
f_2	0.31 (1.10)	-	-	-	-	-	-
SUBURBAN							
Constant	7.37 (.17)	7.42 (.16)	7.45 (.16)	7.47 (.16)	7.51 (.16)	7.43 (.16)	7.50 (.15)
$\ell n\ q_{67}$	0.48 (.32)	0.46 (.32)	0.54 (.25)	-0.04 (.27)	0.30 (.32)	0.48 (.32)	0.52 (.25)
$\ell n\ q_{69}$	-0.16 (.37)	-0.38 (.30)	0.08 (.24)	-0.24 (.31)	-0.18 (.30)	-0.41 (.30)	0.10 (.24)
$\ell n\ q_{70}$	-1.32 (.38)	-1.06 (.34)	-0.53 (.27)	-0.80 (.34)	-0.74 (.34)	-1.08 (.34)	-0.49 (.27)
$\ell n\ q_{71}$	-0.89 (.40)	-0.93 (.40)	-0.33 (.32)	-0.55 (.40)	-0.51 (.37)	-0.95 (.40)	-0.27 (.31)
$\ell n\ q_{72}$	-0.81 (.43)	-0.90 (.43)	-0.61 (.35)	-0.04 (.27)	-0.53 (.41)	-0.87 (.43)	-0.58 (.35)
$\ell n\ g_2$	1.31 (.33)	1.23 (.28)	0.97 (.27)	0.91 (.27)	0.81 (.21)	1.40 (.19)	0.78 (.21)
$\ell n\ g_3$	1.52 (.44)	1.89 (.39)	1.37 (.36)	1.35 (.37)	1.29 (.32)	-	1.19 (.31)
$\ell n\ g_4$	2.32 (.46)	2.27 (.45)	1.87 (.41)	1.60 (.40)	1.63 (.34)	2.28 (.45)	1.61 (.34)
h(z)	-0.07 (.22)	-0.08 (.22)	-0.21 (.20)	0.05 (.22)	0.00 (.21)	-0.12 (.21)	-0.14 (.20)
f_1	-0.33 (.57)	-	-	-	-	-	-
f_2	1.15 (.69)	-	-	-	-	-	-

considered were first sold at the beginning of the period, and neighborhood effects which enhance prices develop only with age. Specific examples are the growth of green areas such as parks and trees, the installation of recreational facilities, generally completed after revenue generating items by developers, and the development of the school system. A younger house is less likely to be associated with such externalities than an older house, leading to the observed pattern.

Second, there may be changing preferences towards older houses. Houses less than a year old contain unfinished areas and require a break-in period, while after a few years such defects have been remedied. Third, lot sizes of land can affect house prices by age. Houses are sold in structure-land packages, but vary in sizes. The price of land has generally increased relative to that of structures[13] and the technology of housing production is land saving, exemplified by lower lot requirements for sewage treatment. Hence older houses have higher average lot sizes, and given low depreciation rates on structures, older house packages will increase in price.[14]

4. Conclusions and Implications

To summarize the main conclusions, hedonic prices, corrected for quality, are equal across the metropolitan area. Depreciation functions for houses are not observed, but rather price increases with age. Consequently, in the construction of cost of living indexes for housing, it is not necessary to isolate suburban from urban locations within a metropolitan area, at least for single-family dwelling. However, given that the relevant hypotheses are accepted only at a relatively low Type I error, further research on the construction of such indexes is needed.

Such tests can be applied to other cities to determine whether an urban-suburban distinction is necessary in housing planning. If hedonic prices are relatively constant throughout the region this has implications for the location of public housing. A relatively even distribution of such housing may not have an adverse effect on neighboring house prices, *ceteris paribus*. At the same time, the conclusion of hedonic price equality may not obtain universally.

Inflation is found to be present in suburban house prices. Policies of tax increases on suburban structures and land as opposed to urban houses can be used to control inflation, if policy makers are interested in preserving accessibility and preventing windfall gains to suburban homeowners. From the point of view of metropolitan municipal revenue, taxes should be shifted relatively heavily on suburban property, but this clearly may not be possible in unincorporated city areas.

Rapid house price increases appear to be associated more with age than time or pure inflation. This suggests an increased focus on lot and land size as the tax base for the levy of municipal taxes, given the larger lot sizes of older houses. This would encourage more efficient use of land, and shift the tax burden from structures to land. Such measures would tend to reduce the effective subsidy to homeowners with low valuations on large lots.

APPENDIX

Data Description

The data comprise observations on sales of the same house in a medium-sized urban market over the period 1967-1972. The city selected is London, Ontario, with a Canadian Census population of 223,222 in 1971. All sales for which transactions on single-family homes were registered are included. Houses were classified into two groups, namely within the urban core, and external to the core or suburban.

Since the data require capital gains measures, all houses for which only one sale took place during the period were removed from the sample. Data were initially on a monthly basis, but all multiply-traded houses in the same year were excluded, because in many cases the houses were not fair-traded.

Variables in the data bank include:

1) Day, month and year of sale as recorded in Teela Realty Sales Review;

2) Final transaction price, and financing mix (down payment, first and second mortgages); and

3) Locality by municipal planning district (twenty-one districts).

Given that individual records are available, purchase and sale prices can be matched to the same house.

Originally, the data base contained about 30,000 transactions on 18,000 houses. By excluding single sale houses and multiple trades in the same year, the number of houses was reduced to 1,500. These were divided into two groups, urban and suburban, and a random number generator used to select a sample of 75 for each district, given loading constraints in the maximum likelihood estimation procedure. Finally, some houses exhibited negative capital gains. In such cases the observations on the dummy variables were multiplied by negative unity.

The interactive grid used in each equation is as follows, where location interactions are constrained to be zero, with normalizations excluded:

Year/Age (years)	2	3	4 or more
1967	0	0	0
1969	1	0	0
1970	0	1	0
1971	0	0	0
1972	0	0	0

FOOTNOTES

[*] I am grateful to Gordon W. Davies for helpful comments and discussions. The data base on housing prices was constructed by Nancy C. Jackson and Peter L. Jackson, and the computations performed by John M. Gartenburg. This research is part of a larger study of equilibrium in housing markets which is currently funded through this research program by the Academic Development Fund of the University of Western Ontario.

[1] On the former, see Solow (1973) and Mills (1972). For the latter argument, see Kain (1968) where it is further argued that the pattern of housing by race and income has additional effects in inducing industrial relocation and job displacement.

[2] Examples are Bailey, Muth and Nourse (1963) and Bhatia (1971).

[3] Such a period is defined as a time unit sufficiently short such that intraperiod price variation can be ignored.

[4] For a discussion of geometric depreciation see Feldstein and Rothschild (1974).

[5] The equilibrium conditions in markets for characteristics are derived in Rosen (1974). For a discussion of characteristics equilibrium in the housing market see Rothenburg (1975).

[6]This underlying model follows Hotelling (1925) and Hall (1971) except that capital gains are the dependent variable, preferences are not homothetically separable and resale of housing is permissible at any time.

[7]The condition under which such a factorization can be performed is essentially that required for the existence of a housing capital aggregate. Efficiency units of capital are perfectly substitutable. Such a rule is derived by Fisher (1965).

[8]This justifies the use of regressions of prices on a group of non-multiplicative characteristics, as in Lapham (1971) and Daniels (1975) for housing markets. However, there is alternative evidence that such interactive effects are significant statistically, and exclusion can lead to biased estimates of the effects of given characteristics in explaining house prices. In particular, Weston (1971) derived significant interactions between several characteristics, including time and length of ownership in a house price regression.

[9]See Ohta (1975).

[10]This argument has two cutting edges. It is also consistent with the Kain hypothesis that hedonic prices would be lower in the city. As jobs are relocated away from the central business district (CBD), demand for housing will fall in the city and increase in the suburbs, raising at least the relative hedonic price of suburban homes.

[11]Data construction is described in the Appendix.

[12]The actual interactive grid used is illustrated in the Appendix.

[13]See for example Christensen and Jorgenson (1969).

[14]A potential method of solution of this problem is to derive separate explanations of the demand for structures and land. However, in the housing market, consumers are confronted with tied sales of structures and land, and separate purchase is not generally possible. Moreover, a problem is posed in the allocation of the purchase price between the house and lot. One potential data source, namely insured value, is not necessarily the economic value of the house.

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