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A Model of the Urban Housing and Residential Land Markets

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The work described in the following pages constitutes the first version of a non-spatial model of the urban housing and residential land markets. Although the analysis will continue to be refined in the future, publication of the results in this format reflects our view that the model is sufficiently developed to be a viable and useful took for the analysis of the effects of government policies on local housing and residential land markets. The results nevertheless have received little critical exposure and the details of the model should therefore be viewed as somewhat tentative. Comments and suggestions are solicited.

Various members of the Department of Economics have given useful advice and comments. The careful work of two research assistants is also appreciated--S. Margaret Grant and Nancy C. Jackson. Also, we wish to thank various staff members of the City of London administration for their cooperation and assistance in collecting data for this study, in particular, Veronica Brandt, John Campbell, Keith Cann, Larry Draho, Robert Gallagher, Gordon Jackson, Gary McInnis, and Campbell Miller. Mr. J. P. Delisle of Statistics Canada was particularly helpful in providing unpublished data on the housing markets in the City of London.

A no less important acknowledgement of a somewhat different type is due to Larry B. Smith for his extensive research findings on the housing and mortgage markets in Canada. Smith's work has attracted much attention in the literature--indeed, it constitutes a major portion of the literature on these markets in Canada. It has not been possible or feasible to pinpoint all of the ideas in this study which originate in his work but the sources are at least given in footnote 1 in the text. This study, as do many others, owes a considerable debt to Smith's work.

Jayne Dewar patiently and efficiently typed numerous drafts of this manuscript and made all the necessary corrections and changes.

The content of this study is the responsibility of the authors.

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way between Detroit, Michigan (120 miles)[3] and Toronto, Ontario (114 miles) but the hinterland of the municipality is almost entirely agricultural, with smaller municipalities dispersed more or less evenly through the area between Detroit and Toronto. The next largest urban area adjacent to the city is the City of St. Thomas which is located 18 roadway miles to the south of London and which had a population of 25,545 in 1971. The next closest municipality with a population greater than that of St. Thomas is the City of Woodstock with a population of 26,173 in 1971, at 29 miles from the City of London. The land mass surrounding London is bordered generally by Lake Huron to the north and Lake Erie to the south. The City of London therefore dominates the surrounding area economy. This is important insofar as the housing market in London will operate reasonably independently of the markets in other major subcentres and it is therefore legitimate to postulate and estimate separate economic relationships for the housing market in the city. In a city adjacent to other large urban centres, the model would have to be modified to take account of the market interactions between the two centres.

The next section contains a theoretical overview of the land and housing markets which forms a basis for the detailed specification of the model. The components of the model and their derivation are

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[3]The distance figures in this paragraph are roadway miles. They are taken from Ministry of Transportation and Communications, Ontario Canada Official Road Map, Government of Ontario, 1974.

described in detail in Sections III through VI. A section on model solution and policy analysis follows and the study ends with a summary section. Before proceeding to the details of the model, we first outline recent developments in the housing and land markets in the City of London and compare these developments with those in urban areas in Ontario and Canada.

A. HOUSING CAPACITY, PRICES AND RENTS

Figure 1 shows the stock of single-family detached dwellings per family household in the City of London and the median sale price of these units. The ratio of units to the number of family households shows some cyclical fluctuation around a value of about .783 over the period 1963 to 1967, declines secularly to about .726 in 1971, and fluctuates cyclically around a value of about .725 thereafter. Prices show a distinct secular increase which is more rapid in the years 1968-69 and, particularly, 1972-73.

These trends may be compared with those in urban Ontario and urban Canada. Table 1 shows the ratio of single-family detached units to the number of family households in each of the Census years 1961, 1966, and 1971 for the City of London, and for all urban areas in Ontario and in Canada.[4] The ratio for London (.80) stands above the ratio for Ontario (.75) and well above the ratio for Canada (.66) in 1961. This advantage has, however, decreased over time since the ratio for London fell between 1966 and 1971 whereas it decreased less rapidly in Ontario and much less rapidly in Canada between the same two dates.

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[4]Note that the figures calculated in Tables 1 and 3 below are for urban areas in Ontario and Canada. Here the definition of "urban" is the one used in the Census of Canada.

Figure 1

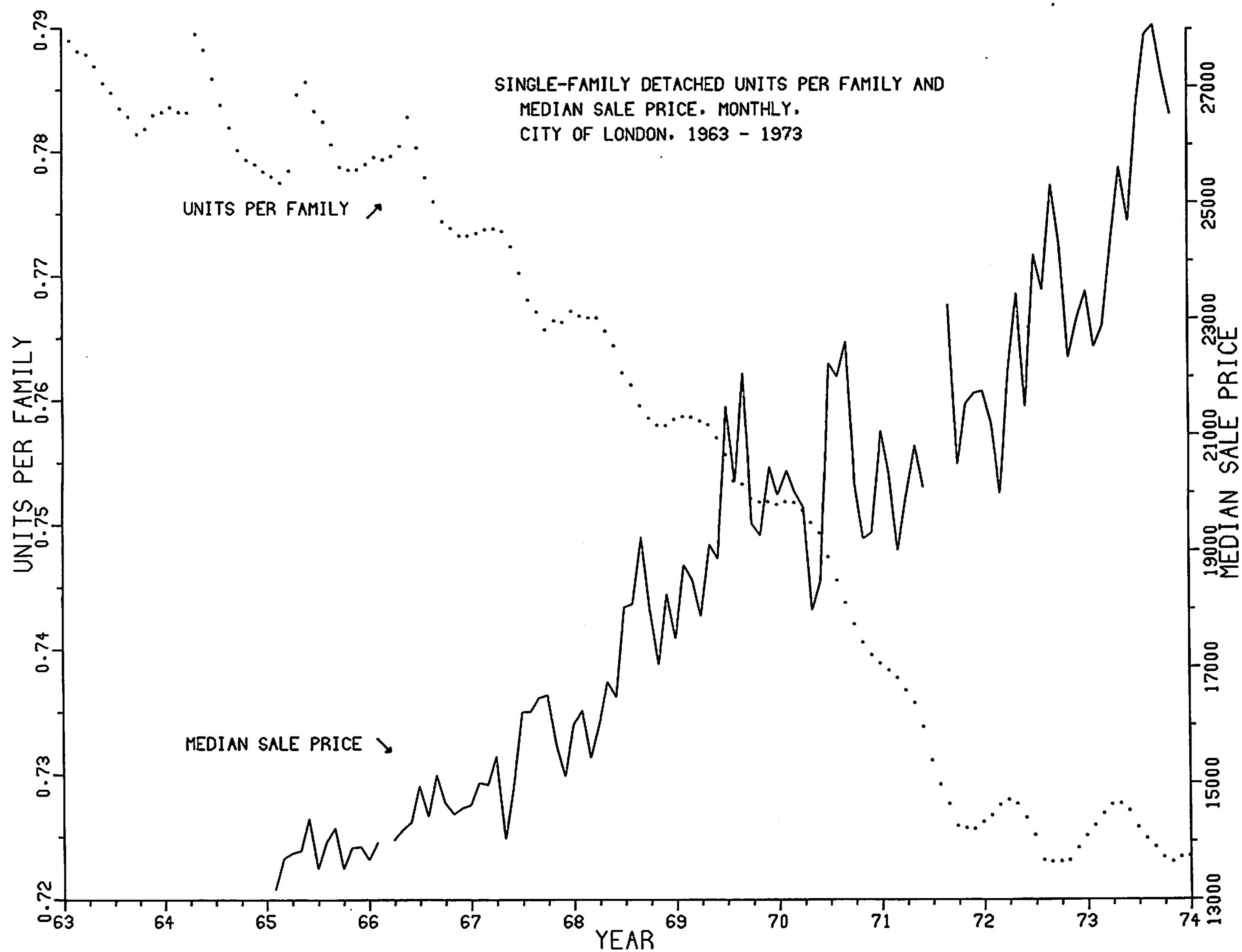
SINGLE-FAMILY DETACHED UNITS PER FAMILY AND
MEDIAN SALE PRICE, MONTHLY,
CITY OF LONDON, 1963 - 1973
UNITS PER FAMILY
MEDIAN SALE PRICE
UNITS PER FAMILY
MEDIAN SALE PRICE
YEAR
0.72
0.73
0.74
0.75
0.76
0.77
0.78
0.79
13000
15000
17000
19000
21000
23000
25000
27000
63
64
65
66
67
68
69
70
71
72
73
74

Table 1

Single-Family Detached Units Per Family Household,
London, Urban Ontario, and Urban Canada, 1961, 1966, and 1971

Year	Units per Family		
	London	Ontario	Canada
1961	.800	.752	.659
1966	.780	.731	.657
1971	.731	.701	.651

Sources:
a) Tables 5 and 7, Basic Dwelling Characteristics, Catalogue 93-523, Dominion Bureau of Statistics, Ottawa, 1961;
b) Tables 8 and 10, Households by Type, Catalogue 93-511, Dominion Bureau of Statistics, Ottawa, 1961;
c) Tables 3 and 5, Dwellings by Structural Type and Tenure, Catalogue 93-602, Dominion Bureau of Statistics, Ottawa, 1966;
d) Tables 29 and 31, Households by Type, Catalogue 93-605, Dominion Bureau of Statistics, Ottawa, 1966;
e) Tables 4 and 6, Dwellings by Tenure and Structural Type, Catalogue 93-727, Statistics Canada, Ottawa, 1971;
f) Tables 8 and 10, Households by Type, Catalogue 93-703, Statistics Canada, Ottawa, 1971.

Notes: The Census publishes occupied stocks only. The vacant stock for London was obtained from Statistics Canada (see Section III below) and the implicit vacancy rate was applied to the Ontario and Canada stocks from the Censuses to derive the total stock. The derivation of a time series for the number of family households for London is described in Section IV below.

Median sale prices are not available for other cities, but the average dollar value of Multiple Listing Service (M.L.S.) transactions follows this series quite closely (at least for the City of London) so we may compare London median and M.L.S. values with M.L.S. values in Ontario and Canada.[5] Table 2 shows these data for the years 1963 to 1973 for the City of London for the forty-four urban areas in Ontario for which M.L.S. data are collected, and for the seventy-eight urban areas in Canada for which M.L.S. data are collected. Comparing the M.L.S. series, London values range between 71.4 and 80.1 per cent of Ontario values with most of the observations in the lower part of this range being in the period 1966-71 and 1973. London values fall between 78.1 and 85.9 per cent of Canada values with no clear pattern over time. Although the purpose of this research is not to assess the determinants of house values as between urban areas, the comparative data on housing capacity and prices do suggest that the lower house prices in London are due to there being a larger stock per family household in that city.

The remainder of the stock of housing consists of single-family attached and semi-detached, duplex, row, townhouse, condominium, and multiple units which are mostly occupied on a rental basis, at least in the City of London. We compare the total of these units to the number of remaining

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[5] "These [M.L.S.] values are not average "house" prices, but are an average of all transactions (land, commercial, industrial, and residential), and tend to be somewhat higher than average house prices. We do feel however that these values can be useful as a comparison among cities." W. D. Strange, Director of Research, The Canadian Real Estate Association, letter of March 12, 1974. About 90 per cent of the transactions are suggested to be residential, which includes other dwelling types in addition to single-family detached. Also, only some fraction of all dwellings (or other real estate) are sold through the M.L.S. system.

Table 2

Median and M.L.S. Values, City of London,
and M.L.S. Values, Ontario and Canada, 1963-73

Year	London		Ontario	Canada
	Median	M.L.S.*	M.L.S.	M.L.S.
1963	N.A.	$11,862	$14,880	$14,420
1964	N.A.	11,761	15,605	15,061
1965	$13,888	13,511	16,877	15,951
1966	14,502	14,134	19,144	17,525
1967	15,786	16,029	21,395	19,168
1968	17,521	17,293	23,600	21,274
1969	19,716	19,042	25,840	23,260
1970	20,451	18,387	25,739	23,362
1971	21,024	20,347	27,249	24,584
1972	23,039	22,837	29,217	26,581
1973	25,925	26,458	36,877	32,328

Sources: a) Median sale prices for London are described in Section IV below.
b) M.L.S. data were obtained from the Canadian Real Estate Association, Don Mills, 1974.

Notes: *M.L.S. values for London include transactions for the City of St. Thomas from 1969-73. For other details on the M.L.S. series, see footnote 5 <u>supra</u>. N.A. indicates data not available.

households which is defined to be the number of non-family households plus the number of family households for whom single-family detached units do not exist.[6] This ratio and median rental rates are shown in Figure 2. The series on rents shows a distinct secular increase which is more pronounced during the years 1968, 1969, and 1971. Rental capacity defined in this way shows a rather marked cyclical pattern, rising and falling over periods totalling about four years; it increases over the whole period from about 1.11 at the beginning of 1963 to about 1.21 at the end of 1973.

We would expect that the secular increase in rents would be associated with a secular decline in the ratio of the number of other units to remaining households, ceteris paribus. Although this relationship is not evident over the entire period, decreases in rental capacity appear to be quite closely related to increases in rents over somewhat shorter periods. For example, capacity decreased markedly from 1966 to 1968 and rents rose very rapidly in the years 1968 and 1969. Similarly, the decrease in capacity through 1971 appears to have caused an increase in rents in the second half of 1971. The relationship between capacity and rents which is apparent from the secular trends will also be affected by changes in house prices and incomes over the entire period--given rental capacity, rents will be positively related to house prices and incomes. Both of these variables increased over the whole period, which may explain the anomalous relationship between capacity and rents revealed by the long term trends.

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[6]That is, the ratio $\frac{KO_t}{nfhh_t + (fhh_t - KS_t)} = \frac{KO_t}{hh_t - KS_t}$ where KO is the stock of other units, nfhh the number of non-family households, fhh the number of family households, hh the total number of households, and KS the stock of single-family detached units.

Figure 2

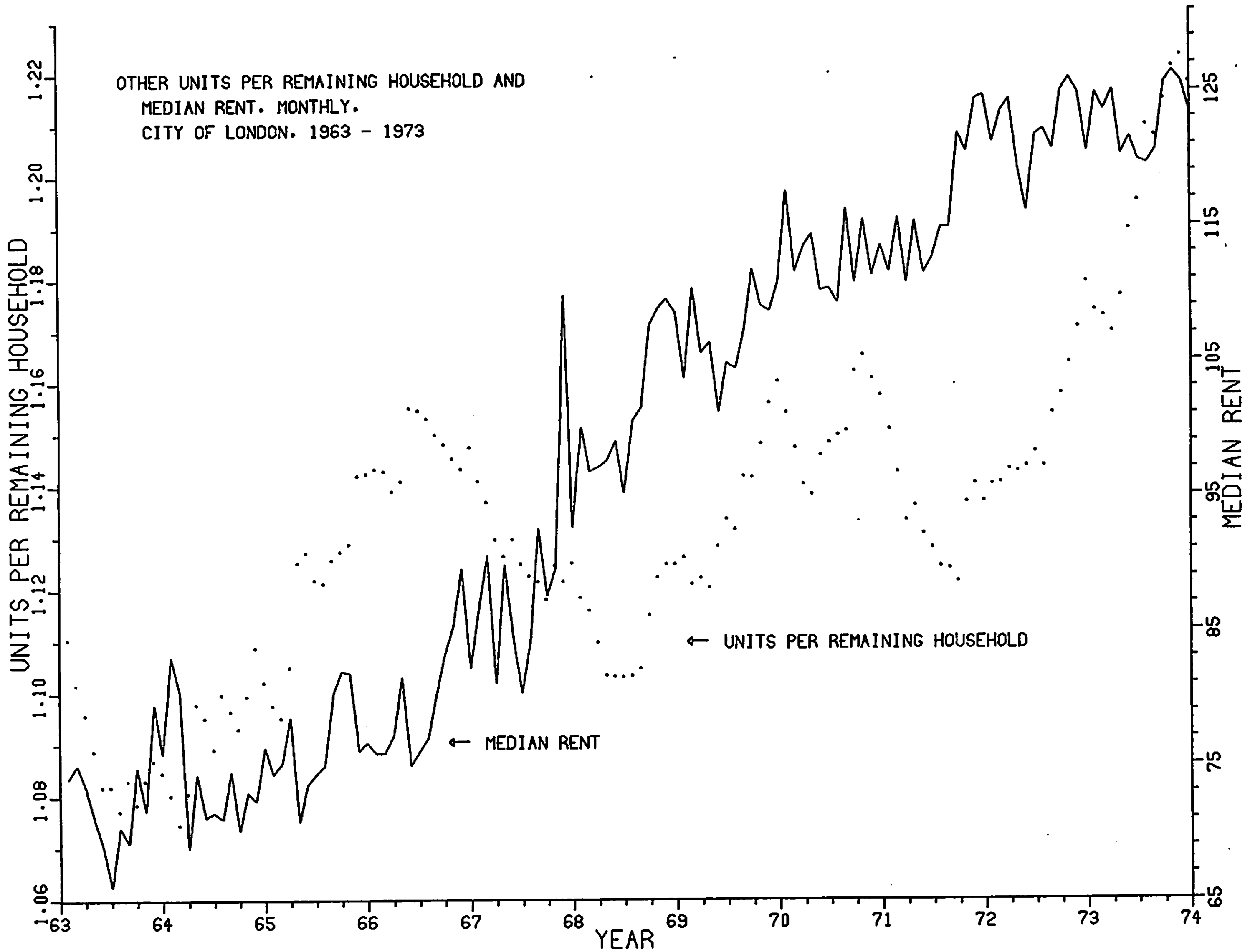
OTHER UNITS PER REMAINING HOUSEHOLD AND
MEDIAN RENT. MONTHLY.
CITY OF LONDON. 1963 - 1973
UNITS PER REMAINING HOUSEHOLD
1.06
1.08
1.10
1.12
1.14
1.16
1.18
1.20
1.22
MEDIAN RENT
65
75
85
95
105
115
125
YEAR
63
64
65
66
67
68
69
70
71
72
73
74
← UNITS PER REMAINING HOUSEHOLD
← MEDIAN RENT

Table 3 compares the ratio of other units to remaining households in London to the same ratio in Ontario and Canada. In 1961, the ratio for London stood at 1.11, above a value of 1.084 for Ontario and Canada. The ratio for London rose to 1.154 in 1966 and fell to 1.128 in 1971. The ranking of London, Ontario, and Canada is the same in all three Census years, except that the ratio for Ontario is marginally below the ratio for Canada in 1971. The advantage held by the City of London on this comparison is quite remarkable in that one would expect the advantage in single-family detached units to be accompanied by a disadvantage in other units. Moreover, London's advantage has not narrowed perceptibly over time, since the absolute difference between the ratios for London and Ontario was .026 in 1961, .041 in 1966, and .022 in 1971.

No series comparable to our rent variable is available for either Ontario or Canada. Table 4 shows, in both level and index form, median rents from 1961 to 1974 for London, rents from a C.M.H.C. survey for London from 1961 to 1965, C.M.H.C. survey rents for Ontario and Canada from 1961 to 1965, and the CANSIM index on rents from 1961 to 1974 for Canada. Comparing the C.M.H.C. survey rents for the three areas reveals that rents were highest in Ontario, with London and then Canada next highest over the period 1961 to 1965. The rate of increase in rents over the years 1961 to 1965 was about the same for London and Ontario (ten and eleven per cent, respectively) but somewhat higher for Canada (fifteen per cent). Comparison of our median rent series for London with the CANSIM series for Canada suggests that rents rose considerably more rapidly in London over the entire 1961 to 1974 period than in urban Canada.

Table 3

Other Units per Remaining Household,
London, Urban Ontario, and Urban Canada, 1961, 1966, and 1971

Year	Units per Remaining Household		
	London	Ontario	Canada
1961	1.110	1.084	1.084
1966	1.154	1.113	1.113
1971	1.128	1.106	1.107

Sources: See Table 1.

Notes: See Table 1.

Table 4

Rent and Rent Indexes for London, Ontario, and Canada, 1961-74

Year	London				Ontario		Canada		
	Median [a]		C.M.H.C. [b]		C.M.H.C. [b]		C.M.H.C. [b]		CANSIM [c]
	Level	Index 1961=100	Level	Index 1961=100	Level	Index 1961=100	Level	Index 1961=100	1961=100
1961	69.63	100.0	76.90	100.0	81.56	100.0	70.99	100.0	100.0
1962	70.37	101.1	76.91	100.0	81.50	99.9	71.01	100.0	100.2
1963	71.07	102.1	81.01	105.3	82.56	101.2	73.76	103.9	100.5
1964	74.76	107.4	78.62	102.2	83.95	102.9	77.50	109.2	100.9
1965	75.24	108.1	84.37	109.7	90.41	110.9	81.29	114.5	101.5
1966	78.25	112.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	103.2
1967	89.52	128.6	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	106.6
1968	100.13	143.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	111.2
1969	105.51	151.7	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	115.6
1970	111.75	160.5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	119.4
1971	115.42	165.8	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	121.3
1972	122.13	175.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	122.7
1973	123.89	177.9	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	124.5
1974	129.92	186.6	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	127.9

Sources: a) Median rents for London are described in Section III.B.6. below;
b) C.M.H.C. Survey: Table 101, Canadian Housing Statistics, 1966;
c) CANSIM Matrix No. 197.1.2.1.1.1.

Notes: C.M.H.C. figures for Ontario and Canada are an average of figures for large urban areas. N.A. indicates data not available.

B. PRICE AND QUANTITY OF LOTS

Figure 3 shows the stock of vacant lots zoned and approved for the construction of single-family detached units and the median sale price at which these lots transacted. The data reveal that the stock of lots decreased fairly rapidly over the period 1965 to 1967, rose thereafter to 1970, and fell quite rapidly through to the end of the period. Lot prices increased steadily over the period, except for a pronounced upward shift in 1969.

Lot values published by Central Mortgage and Housing Corporation (C.M.H.C.) for homes financed under the National Housing Act (N.H.A.) follow our median series fairly closely for London and therefore permit a comparison between prices in the City and in urban areas in Ontario and Canada. Table 5 shows median and N.H.A.-supported lot prices for London, for the periods 1965-73 and 1969-73 respectively, and N.H.A.-supported lot prices for Ontario and Canada, for the periods 1969-73 and 1965-73 respectively. Comparing the N.H.A. data for 1969-73 reveals a ranking from highest to lowest in lot prices in each year from 1969 to 1973 of Ontario, London, and Canada. London N.H.A. lot prices range between .924 and .840 of Ontario lot prices, with no clear pattern over time; London lot prices vary between 1.516 and 1.781 of Canada lot prices with a secular decline in the ratio evident from 1969 to 1972 and a marked increase (to 1.781) in the ratio in 1973. London lot values on this measure therefore fall between Ontario and Canada lot values and the differential between London and Canada lot values has narrowed, at least up to 1972.

To summarize the information in the above two subsections, housing

Figure 3

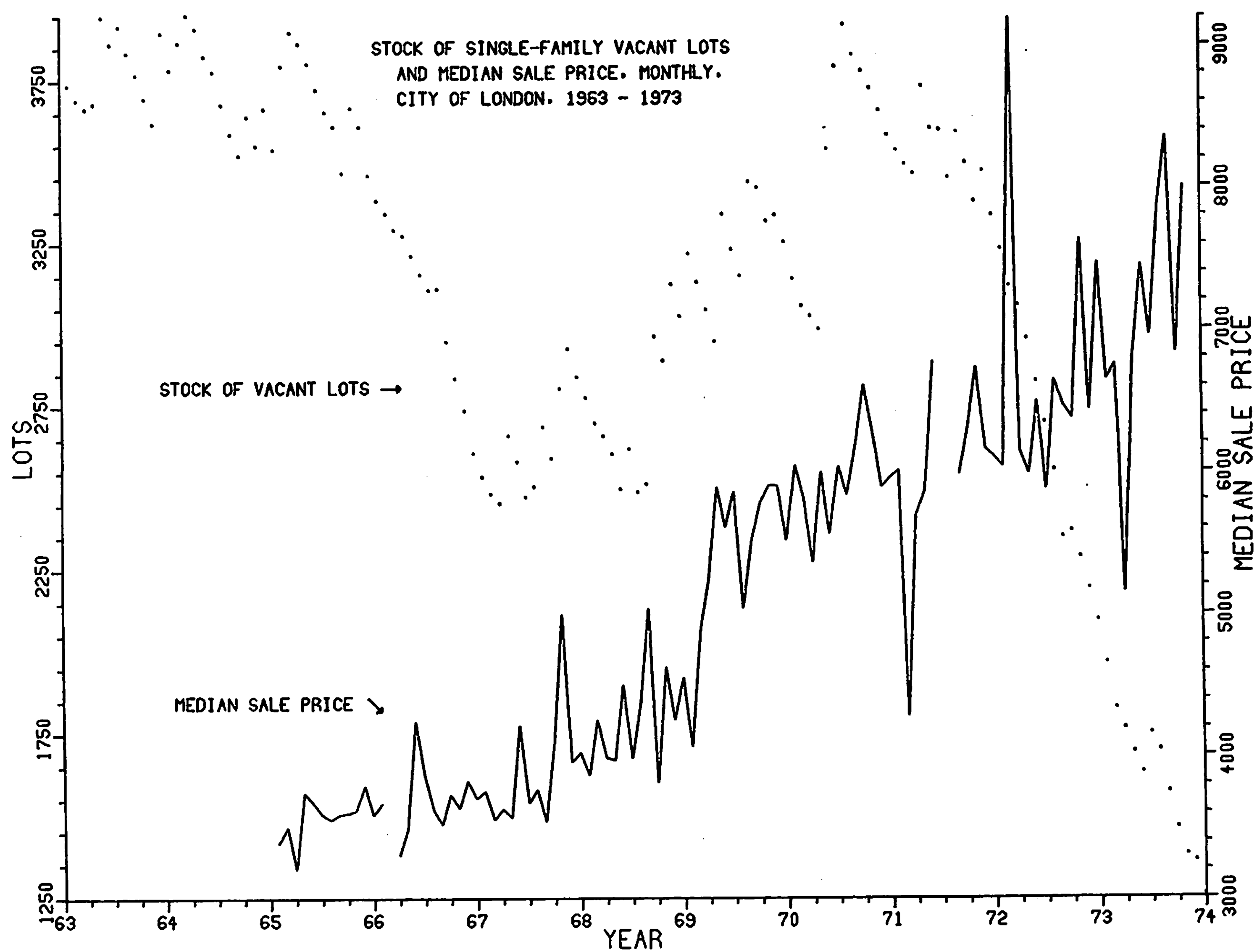
STOCK OF SINGLE-FAMILY VACANT LOTS
AND MEDIAN SALE PRICE, MONTHLY.
CITY OF LONDON, 1963 - 1973
STOCK OF VACANT LOTS →
MEDIAN SALE PRICE ↘
LOTS
3750
3250
2750
2250
1750
1250
MEDIAN SALE PRICE
9000
8000
7000
6000
5000
4000
3000
YEAR
63
64
65
66
67
68
69
70
71
72
73
74

Table 5

Lot Prices for London, Ontario,
and Canada, 1965-73

Year	London		Ontario	Canada
	Median	N.H.A.	N.H.A.	N.H.A.
1965	$ 3,584	N.A.	N.A.	$ 2,816
1966	3,637	N.A.	N.A.	3,006
1967	3,797	N.A.	N.A.	3,155
1968	4,149	N.A.	N.A.	3,350
1969	5,475	$ 5,941	$ 6,430	3,623
1970	5,988	5,771	6,873	3,666
1971	6,080	6,233	6,844	3,944
1972	6,441	6,568	7,425	4,333
1973	7,388	7,621	8,959	4,280

Sources: a) Median sale prices for London are described in Section VI.B.1. below.
b) Estimated Land Cost of New Single-Detached Dwellings Financed Under the National Housing Act, Canadian Housing Statistics, C.M.H.C., 1970-1974.

Notes: N.H.A. figures for Ontario are an average of figures for Ontario Metropolitan Areas and Urban Centres. N.A. indicates data not available.

capacity compared to the constituent elements of the population in the City of London is above that in urban Ontario and urban Canada. House prices in London are below those in urban Ontario and urban Canada whereas rents in London are below rents in Ontario but above those in Canada. Land prices in London are higher than in Canada, but lower than in Ontario. The general trends in the City are quite similar to those in other urban areas in Ontario and Canada, i.e., generally declining capacity, inflating house prices and rents, and inflating land prices. It is likely that the supply of undeveloped lots has dwindled in other urban areas in Ontario and Canada as it has in London, but we have no data to support this particular claim.

In the next section we outline a general theoretical structure of the land and housing markets which underlies the formulation of the model discussed in more detail in subsequent sections.

II. HOUSING AND LAND MARKETS

In this section we outline a comparative static model of the urban housing and residential land markets. This analysis forms a theoretical or conceptual basis for the specification of the equations of the empirical model of these markets which is the subject of subsequent sections of this report. The following conceptual model shows the relationships between the markets for rented multiple units, owner-occupied single-family detached units, and lots which are zoned and approved for single-family detached dwelling use. Beyond this, the model is partial equilibrium in that aggregate factor supplies are fixed and can only be induced to shift between the housing sector and other sectors through changes in relative factor prices.

Before proceeding to the comparative static model, some comments on the choice of sectoring are warranted. The basic objective of this research is to construct a model of inflation and capacity in the single-family detached housing market, because of the public concern generated over developments in this market in recent years. In all of the subsequent discussion, all single-family detached dwelling units in the municipality are implicitly assumed to be identical. This assumption is made for convenience. Although it is obviously not true that all houses are in fact identical in terms of size and quality, the use of this assumption does not invalidate the results, provided that one interprets them as applying to a typical or median-valued single-family detached unit. All single-family detached units in the area are assumed to be owner-occupied. This assumption approximates the actual situation quite closely.

A correct and meaningful specification of the single-family detached housing market requires that the market for lots which are subdivided and approved for the construction of these units also be examined. At any point in time, in a given municipality, there is normally a stock of vacant lots of this type and the lots in this stock comprise a reasonably homogeneous set. We therefore specify demand and supply functions for the market for these lots, assuming again that they are identical, in order to avoid unnecessary complexities.

Because there are substitutes for owning single-family detached dwellings, these alternative forms of housing cannot be ignored. Other dwelling types consist of single-family attached and semi-detached, duplex, row, townhouse, condominium, and multiple units. Multiples are the largest proportion of other types of units. To avoid adding a very large number of equations to the model and introducing unnecessary complexities, all of these types of units are assumed to constitute an entirely homogeneous set. In terms of the relative explanatory power of the price and starts equations for housing units of other types, this appears, at least for our purposes, to be a reasonable aggregation. Other dwelling types are assumed to all be rental units. This assumption approximates the actual situation quite closely since there are no multiple units in the city which may be individually purchased, most duplexes are rental units, there are very few 'for sale' condominiums and townhouses, and the number of owner-occupied semi-detached or attached units is very small, both on an absolute basis and relative to the total stock of housing units of other types.

Finally, we distinguish and define three time periods for the purposes of this exercise. The short run is defined to be a period within which the demand for, but not the supply of, the stock of housing units can change. In practical terms, the short run is, on the basis of empirical results discussed later, a period not less than five months since it takes this amount of time for information about house prices to affect single-family detached housing starts (three months) and for housing starts to result in housing completions (two to four months). The medium run is defined to be a period sufficiently long to permit adjustment in housing quantities, but not the stock of land. In practical terms, this time period ranges from five months to about three years. This latter period is the approximate time it takes to subdivide land, after it has been assembled. We first consider the market for owner-occupied, single-family detached dwelling units.

A. SINGLE-FAMILY DETACHED HOUSING MARKET

The medium term demand curve for the stock of owned single-family detached units, given some level of rents, RR_0, is shown as $DSM:RR_0$ in Figure 4. $DSM:RR_0$ is assumed to downward-sloping because, given the level of rents, a decrease in house prices induces a shift from renting (multiple units) to owning (single-family detached units), because families with lower incomes are able to afford a purchase at a lower price for single-family detached units.[7] Also, in Figure 4, SSS is the short term supply curve for single-family units and $SSM:PL_0$ the medium term supply curve for these units, given some price of single-family detached lots, PL_0. This supply curve is assumed to be upward-sloping because an increase in the stock of housing supplied requires the payment of increased factor prices in order that labour and material resources may be bid away

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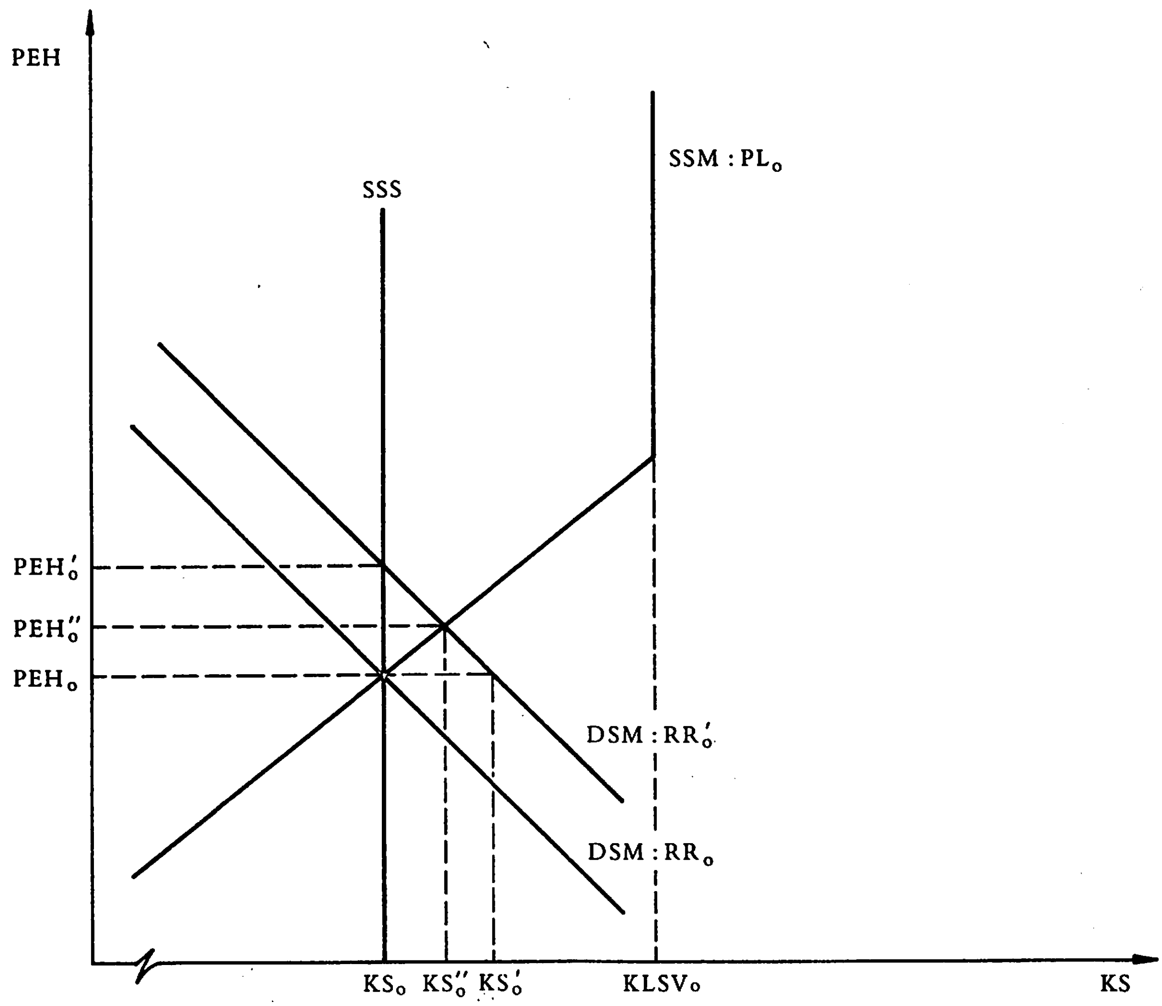
[7]The model is assumed to be closed in the sense that households do not enter the housing market in the area in response to changes in house price differentials between urban areas.

Figure 4

Single-Family Detached Housing Market



from other industries or sectors. The supply curve is vertical at $KLSV_0$, which is the total number of single-family lots in the area.[8] $KLSV_0$ consists of lots on which houses have already been constructed (KS_0) and of vacant lots which are zoned and approved for the construction of single-family detached units ($KLSV_0 - KS_0$). A stock of vacant lots can exist in medium term equilibrium if developers in some past period did not correctly anticipate the demand for houses in the current period.

Suppose that there is a one-time arbitrary increase in rents from RR_0 to RR_0'. This increases the relative attractiveness of owning versus renting and will induce some renters to enter the single-family detached housing market. This implies an outward shift in the demand curve $DSM{:}RR_0$ to $DSM{:}RR_0'$ in Figure 4. The shift in the demand curve results in excess demand equal to ($KS_0' - KS_0$) at the initial equilibrium price of PEH_0 and in a short term increase in price to PEH_0'. In the medium term, this increase in price induces a supply response and the quantity of housing offered increases from KS_0 to KS_0''. This supply response causes a movement downward along the demand curve $DSM{:}RR_0'$ until the market is in a new medium term equilibrium given by PEH_0'', KS_0''. Note that the increase in the stock of housing implies that the stock of vacant lots has been reduced from ($KLSV_0 - KS_0$) to ($KLSV_0 - KS_0''$). If the initial demand curve intersects $SSM{:}PL_0$ in the vertical range of the latter curve, an increase in demand would only serve to raise house prices--no supply response would be possible since at $KS \geq KLSV_0$ there is no land on which to construct single-family detached units.

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[8] If conversions or demolitions are assumed not to occur in the medium term, $SSM{:}PL_0$ would also be vertical below PEH_0 at KS_0.

The effect of changes in the market for lots on the single-family detached housing market may now be illustrated. In Figure 5, an arbitrary, one-time decrease in the price of lots from PL_0 to PL_0' shifts the supply curve for housing outward from $SSM:PL_0$ to $SSM:PL_0'$--with lower lot prices, builders require a lower return to supply each and every quantity of housing. The resulting price-quantity configuration is $PEH_0' < PEH_0$ and $KS_0' > KS_0$. If the initial equilibrium is given by PEH_0, KS_0, an increase in the supply of vacant lots from $KLSV_0$ to $KLSV_0'$ has no effect on the price and quantity of housing since the supply curve becomes $SSM':PL_0$ rather than $SSM:PL_0$, i.e., the constraint imposed on the quantity of housing supplied is moved from $KLSV_0$ to $KLSV_0'$. If the initial demand curve intersects $SSM:PL_0$ in the vertical range of the latter curve, an increase in the supply of vacant land lowers the equilibrium price of housing and raises the equilibrium stock.

B. MARKET FOR LOTS

The market for single-family detached lots is represented in Figure 6. Here the supply of land is shown by SLM and is assumed to be fixed at KLV_0 in the medium term. For each and every price of housing there is a derived demand curve for land: $DLM:PEH_0$ represents the demand curve for land corresponding to the price of housing PEH_0. The curve is assumed to be downward-sloping because, given the price of houses, PEH_0, and given residential labour and material costs, a higher quantity of land will be demanded for a lower price of land, as builders respond to higher profits by constructing more single-family detached units.

The effects of changes in the housing market on the market for vacant lots may now be illustrated. Here we assume, for the time being, that when

Figure 5

Effect of Land Market Changes on
Single-Family Detached Housing Market

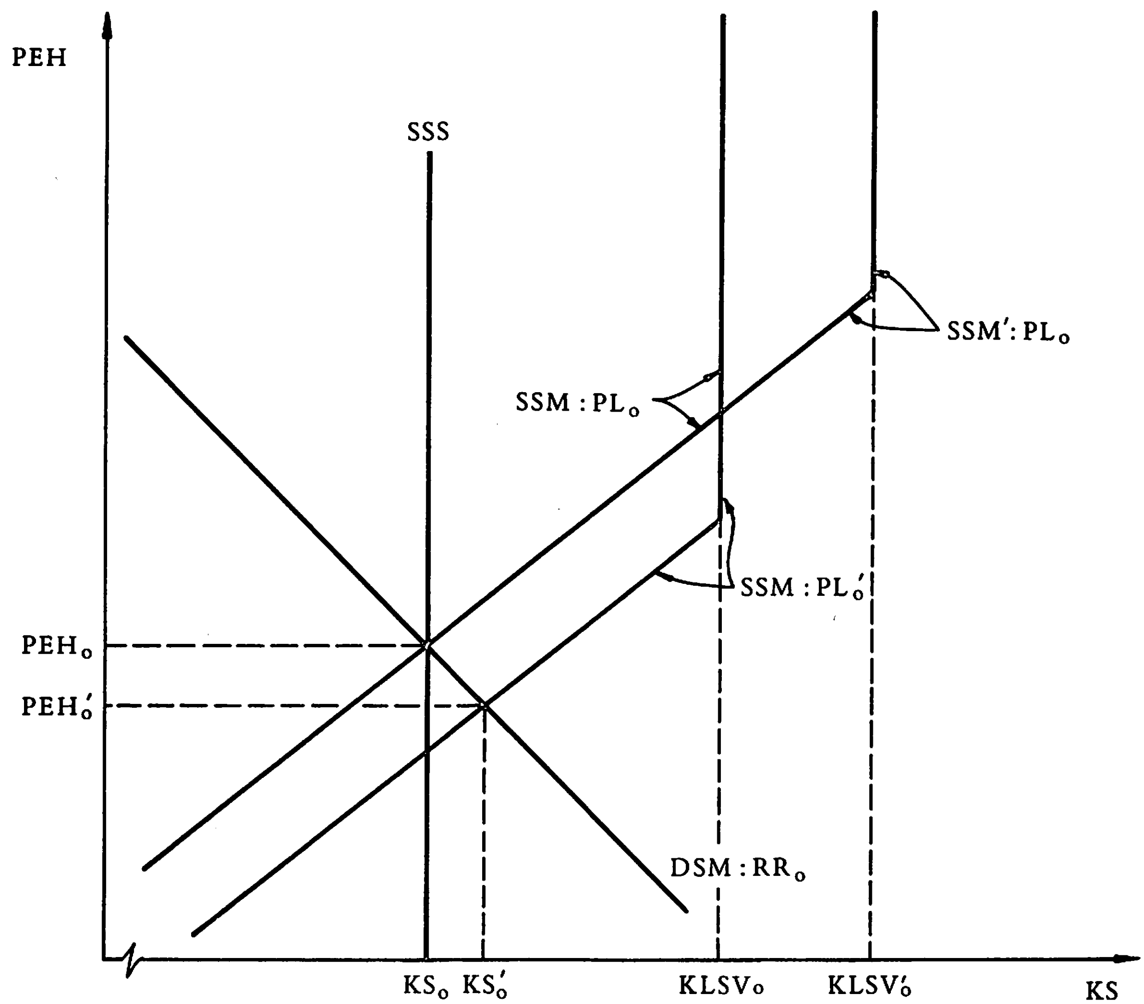
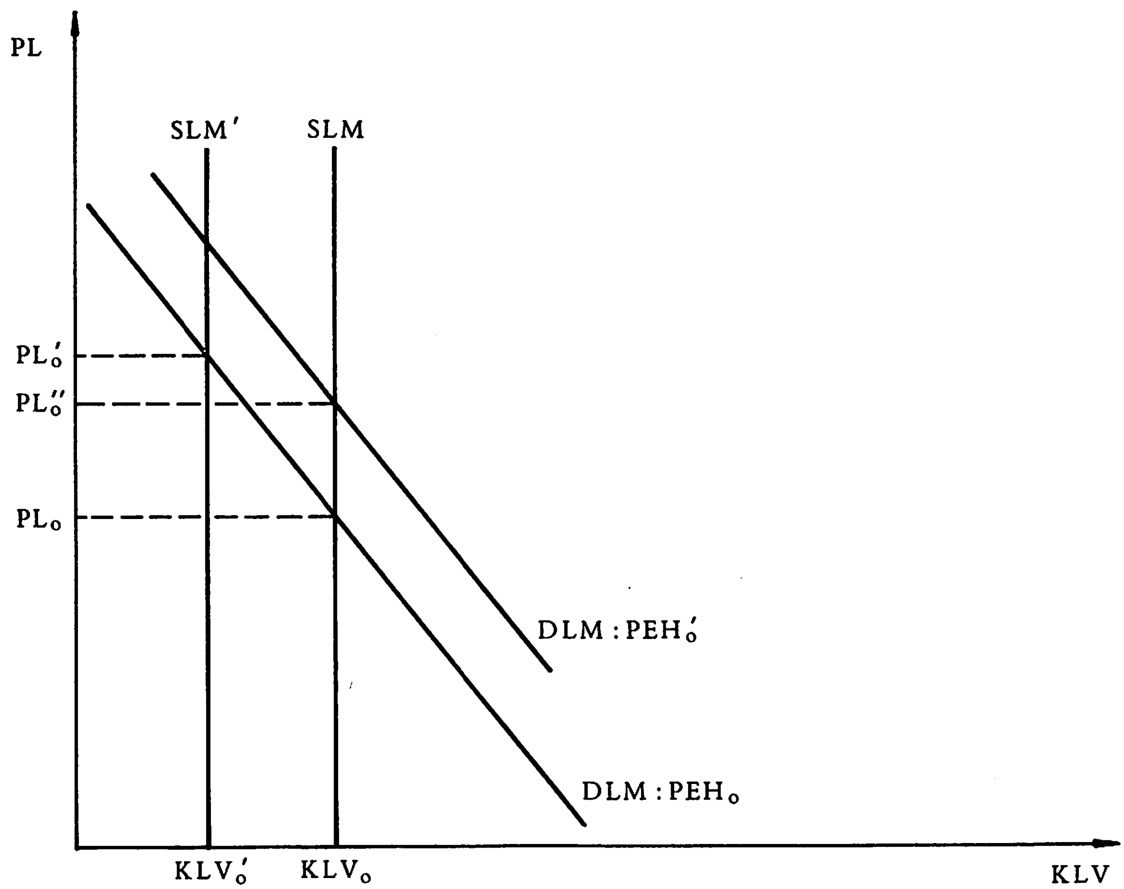


Figure 6

Single-Family Detached Lot Market



price or quantity change in the housing market there is no further response in that market to either that price or quantity change, or to any of the induced changes in the land market. Suppose that the stock of single-family units increases by $(KLV_0 - KLV_0')$ but that there is no price adjustment in the housing market.[9] In Figure 6, the quantity of vacant land is therefore reduced to KLV_0' and a movement upward along $DLM:PEH_0$ raises the price of lots to PL_0'. Given the initial supply curve SLM, if there is an arbitrary one-time increase in the price of houses from PEH_0 to PEH_0' builders will respond by bidding more for vacant land, because of the increased profitability of constructing single-family detached units, i.e., $DLM:PEH_0$ shifts outward to $DLM:PEH_0'$ and the price of lots rises from PL_0 to PL_0'' (in the assumed absence of any quantity response in the housing market).[10]

In the next subsection we combine the analysis of the single-family detached housing and land markets and show the response in both markets to exogenous changes in each of the other two markets.

C. SINGLE-FAMILY DETACHED HOUSE AND LOT MARKETS

In quadrant A of Figure 7, SSS is the short term supply curve for housing, $SSM:PL_0$ the medium term supply curve for housing, given the price of land, PL_0, and $DSM:RR_0$ the medium term demand curve for housing, given rental rate RR_0. In quadrant C, SLM_0 is the medium term supply curve of vacant land and $DLM:PEH_0$ the medium term demand curve for vacant lots for

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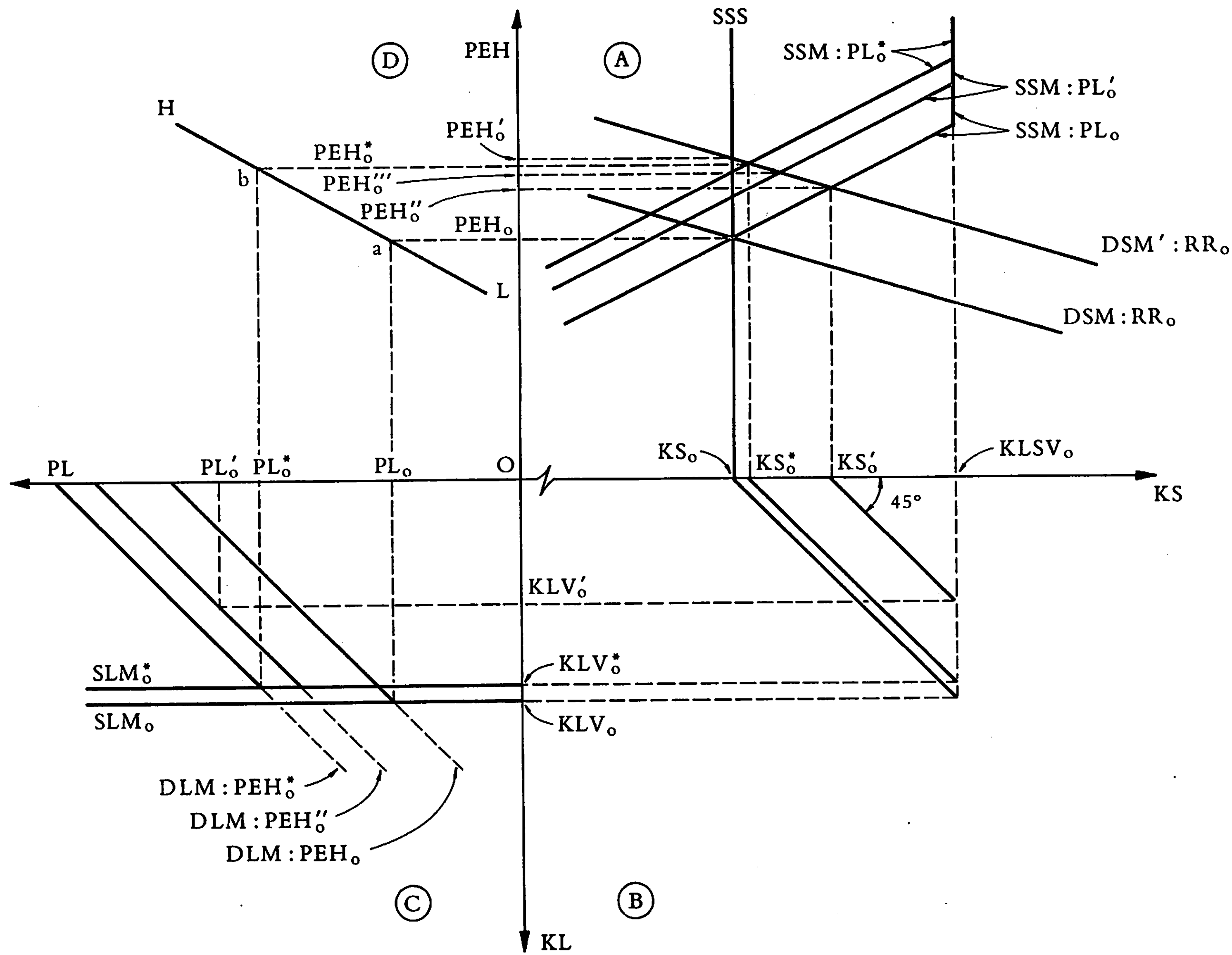
[9] This could occur if there were equal, instantaneous outward shifts in both $DSM:RR_0$ and $SSM:PL_0$.

[10] This could occur if there were a leftward shift in $SSM:PL_0$ equal to a rightward shift in $DSM:RR_0$.

Figure 7

Single-Family Detached House and Lot Markets



price of houses PEH_0. The 45° line in quadrant B ensures that the stock of vacant land is the same in quadrant A as in quadrant C, i.e., $(KLSV_0 - KS_0) = KLV_0$.

Assume that the demand curve for houses shifts rightward from $DSM:RR_0$ to $DSM':RR_0$ as a result of some purely exogenous change, e.g., an increase in incomes or a decrease in the mortgage rate.[11] The immediate outcome of this shift is for house prices to rise in the short run from PEH_0 to PEH_0'. This higher level of house prices elicits a supply response in the medium term from KS_0 toward KS_0' and a reduction in house prices from PEH_0' toward PEH_0''. Simultaneous with the price and quantity responses in the housing market, there are two responses in the land market. First, a higher price of housing shifts the demand curve for land, $DLM:PEH_0$, outward toward $DLM:PEH_0''$ because constructing dwellings has become more profitable as a result of the higher price of housing. Second, the increase in housing supplied reduces the supply of vacant land from KLV_0 toward KLV_0'. The two changes in the land market result in an upward movement of land prices from PL_0 to PL_0'.

The increase in land prices has a further induced effect on the housing market, which is to shift the supply curve for housing leftward from $SSM:PL_0$ toward $SSM:PL_0'$ in quadrant A which induces a movement in house prices from PEH_0'' toward PEH'''. This change in house prices induces an outward movement of $DLM:PEH_0''$ in quadrant C of Figure 7 toward $DLM:PEH_0'''$ (not shown) and an increase in KLV_0' toward KLV_0'' (also not shown).

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[11]We ignore, for the purposes of this subsection, any responses induced in the rental market.

We assume that the two markets reach a new equilibrium at $KS_0^* > KS_0$, $PEH_0^* > PEH_0$, $KLV_0^* < KLV_0$, and $PL_0^* > PL_0$, i.e., the increase in the demand for houses has resulted in a higher stock of houses, higher house prices, a lower stock of vacant land, and a higher price of vacant land. Note that the fixity of the total supply of land in the medium term at $KLSV_0$ has resulted in a lower stock of housing, higher price of housing, and higher price of land than would be the case if the supply of land was infinitely elastic, i.e., if its price were fixed at PL_0.

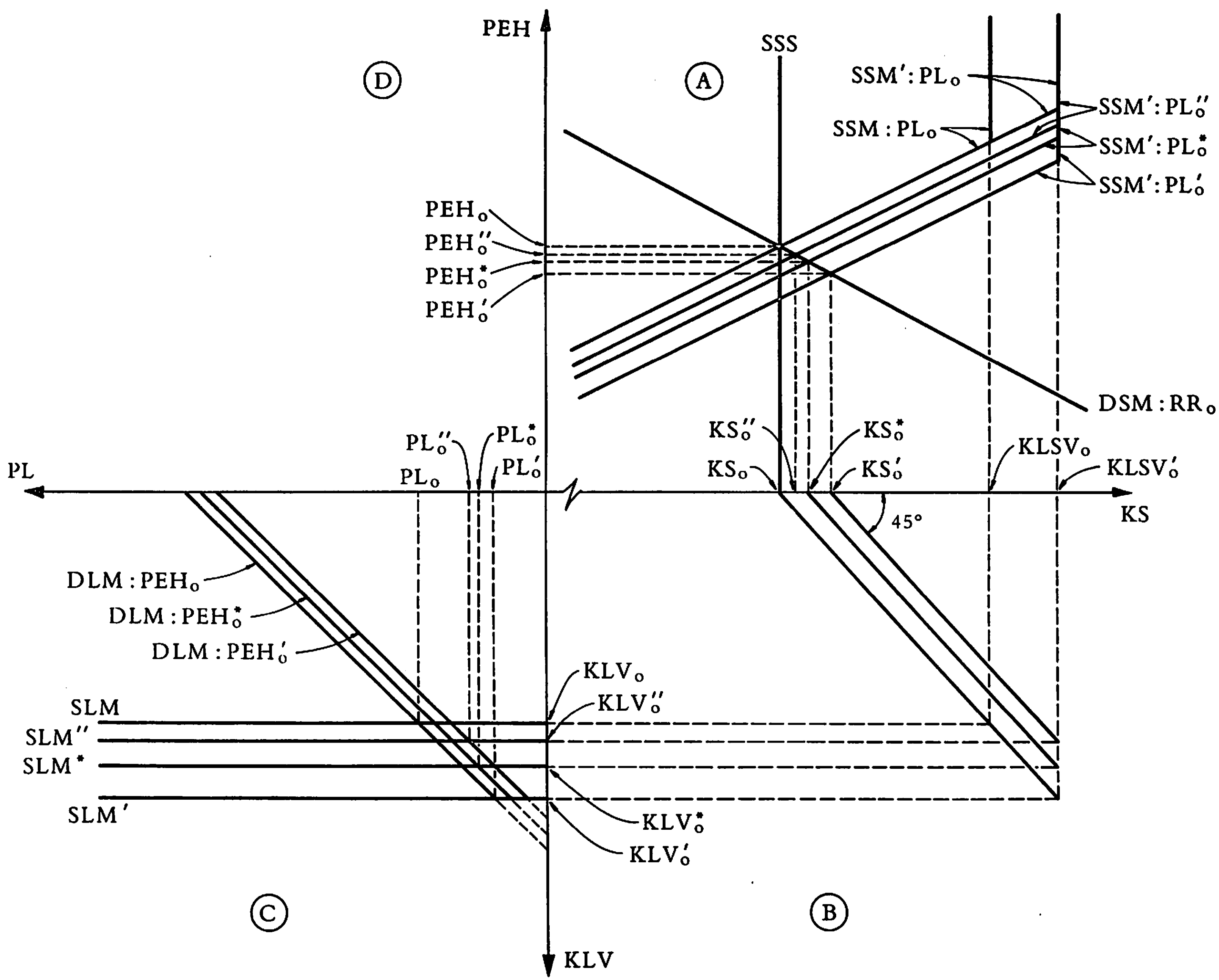
In quadrant D in Figure 7, HL is the locus of points for different equilibrium house and land prices in the two markets corresponding to different positions of the housing demand curve $DSM:RR_0$: point a corresponds to the initial equilibrium of PEH_0 and PL_0 and point b corresponds to the subsequent equilibrium of PEH_0^* and PL_0^*.

The effects on the two markets of an increase in the stock of vacant land may now be illustrated. Figure 8 reproduces the initial equilibrium of Figure 7. We assume that the stock of vacant land increases from KLV_0 to KLV_0' in quadrant C of Figure 8, i.e., the supply curve for vacant land shifts outward from SLM to SLM'. Corresponding to this shift in the supply curve for land is a shift in the medium term supply curve for owner-occupied units, from $SSM:PL_0$ to $SSM':PL_0$. This shift itself does not affect price or quantity in the housing market because the supply curve is in the same position as $SSM:PL_0$ at the point where it is intersected by $DSM:RR_0$.

However, the shift in SLM to SLM' in quadrant C brings about a reduction in the derived price of land, from PL_0 toward PL_0'. This lower price of land results in a shift in $SSM':PL_0$ outward toward $SSM':PL_0'$ in quadrant A, a movement in house prices downward from PEH_0 to PEH_0',

Figure 8

Effect of Increase in Lot Supply on Single-Family Detached House and Lot Markets



and an increase in the stock of housing from KS_0 to KS_0'. The reduction in house prices and increase in housing stock have two induced effects on the land market: the demand curve for land $DLM{:}PEH_0$ moves inward toward $DLM{:}PEH_0'$ and the supply of vacant land decreases from SLM_0' to SLM_0''. Both of these changes increase vacant lot prices from PL_0' toward PL_0''. This higher price of land causes a further shift in $SSM'{:}PL_0'$ leftward toward $SSM'{:}PL_0''$, a new higher price of housing $PEH_0'' > PEH_0'$, and a new lower stock of housing $KS_0'' < KS_0'$. These effects are transmitted to the land market via a shift in SLM_0'' outward to SLM_0''' (not shown) and in $DLM{:}PEH_0'$ outward to $DLM{:}PEH_0''$ (also not shown), etc.

This analysis shows that an arbitrary one-time increase in the quantity of vacant lots increases the stock of housing ($KS_0^* > KS_0$) yet increases, on a net basis, the stock of vacant land ($KLV_0^* > KLV_0$). Also, the price of housing is reduced ($PEH_0^* < PEH_0$), as well as the price of vacant land ($PL_0^* < PL_0$).

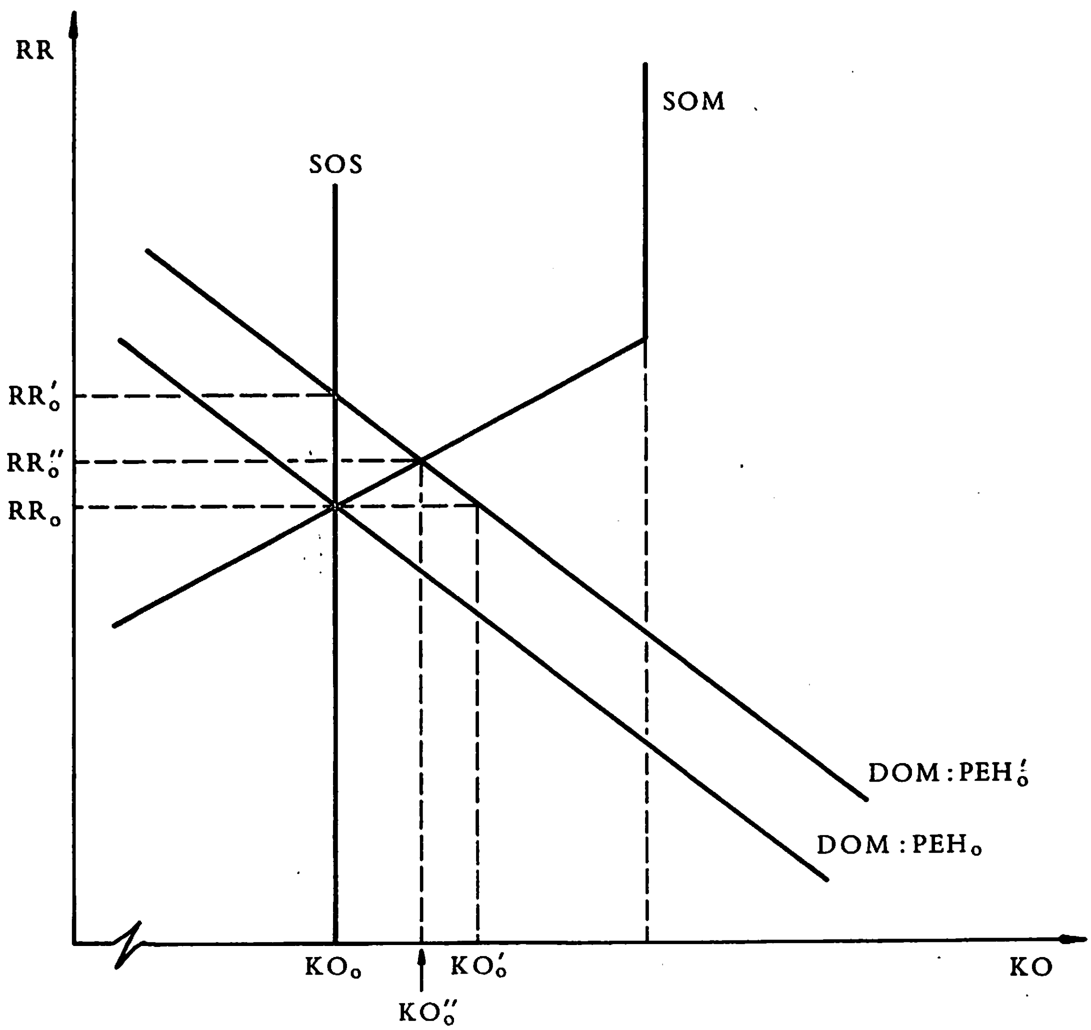
We now turn to a brief description of the rental housing market.

D. RENTAL HOUSING MARKET

Figure 9 illustrates the market for rental housing units. In this figure, $DOM{:}PEH_0$ is the demand curve for these units, given the price of housing PEH_0; SOS is the vertical short run supply curve; and SOM is the medium run supply curve for these units, vertical at the constraint imposed by the total quantity of land available for the construction of rental housing units. The demand curve for rental units given the price of houses is downward-sloping because a lower level of rents encourages household undoubling and a substitution by some owners from owning to renting.

Figure 9

Rental Housing Market



The rental housing market works in the same fashion as the owner-occupied market. If the price of houses increases from PEH_0 to PEH_0', the relative attractiveness of owning versus renting changes in favour of renting, and some owners enter the rental housing market. In Figure 9, this implies an outward movement in DOM:PEH_0 to DOM:PEH_0'. At the original equilibrium rent of RR_0, this shift results in excess demand of $(KO_0' - KO_0)$ and an increase in rents to RR_0'. In the medium term, the stock of other units increases from KO_0 to KO_0'' and this increase in stock causes a movement along the demand curve DOM:PEH_0', implying a decrease in rents from RR_0' to RR_0''.

In the following subsection we show the interrelationships between the owner-occupied and rental housing markets.

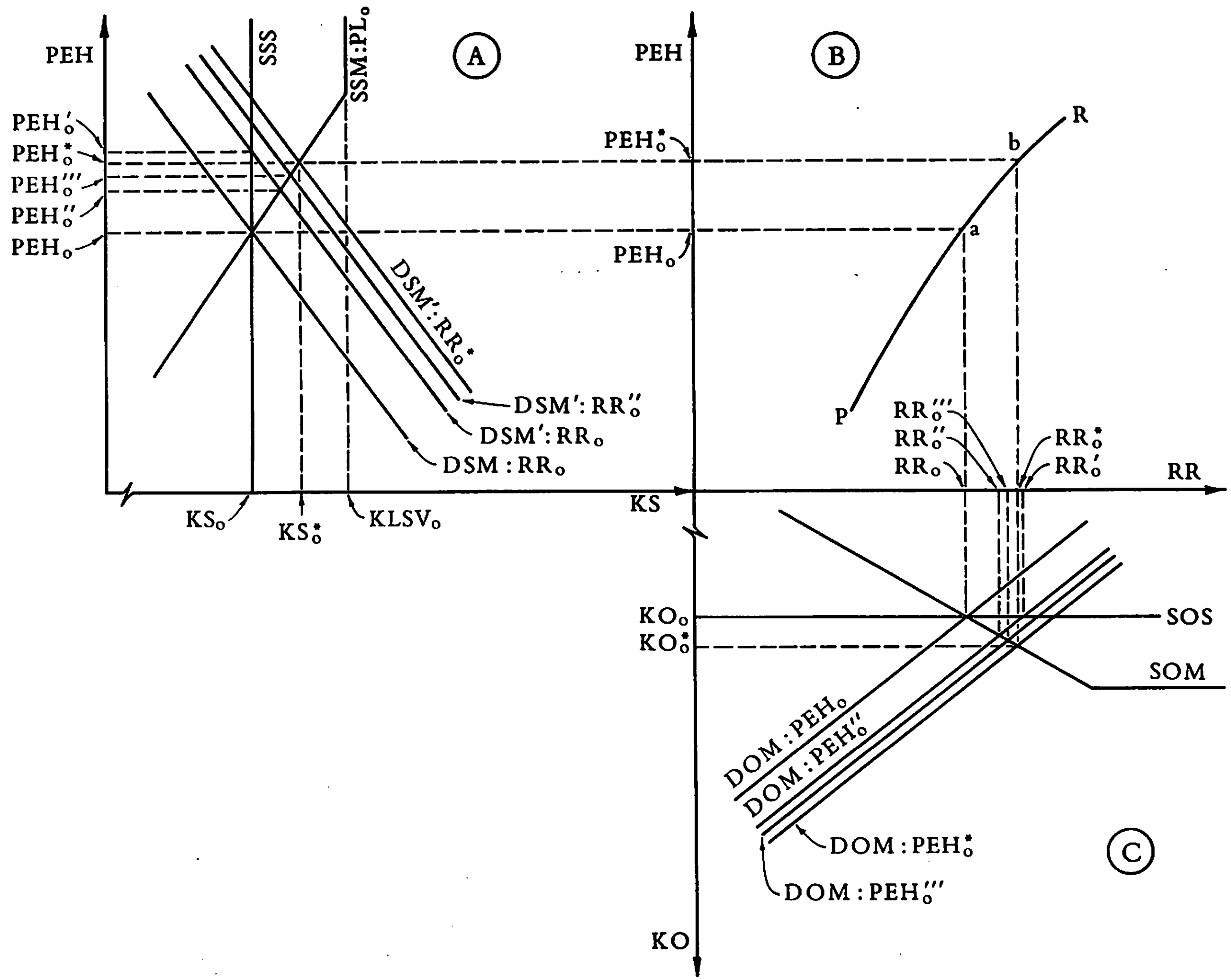
E. OWNER-OCCUPIED AND RENTAL MARKETS

Figure 10 depicts the two markets: quadrant A shows the single-family detached market and quadrant C the rental market. All of the curves illustrated here have been encountered in subsections A. and D. above, except the curve in quadrant B. The two markets are shown to be in an initial equilibrium given by PEH_0, KS_0, RR_0, and KO_0.

Suppose that the demand curve for owner-occupied units shifts rightward due to some purely exogenous change in this market, e.g., a property tax reduction on owner-occupied dwellings only. This shift implies excess demand at the original price PEH_0 and an increase in price toward PEH_0'. The increase in price in the medium term induces an increase in the quantity of single-family detached units from KS_0 and a reduction in price from PEH_0' to PEH_0''. Given the initial level of rents, RR_0, and the increased price of housing, PEH_0'', some owners of single-family

Figure 10

Owner-Occupied and Rental Housing Markets



detached dwellings find renting other types of units more attractive, i.e., the demand curve for renting shifts outward from DOM:PEH_0 to DOM:PEH_0''. This induces an increase in rents in the short run from RR_0 to RR_0'. The increase in rents elicits an increase in the stock of rental units supplied from KO_0 and a subsequent decrease in rents from RR_0' to RR_0''.

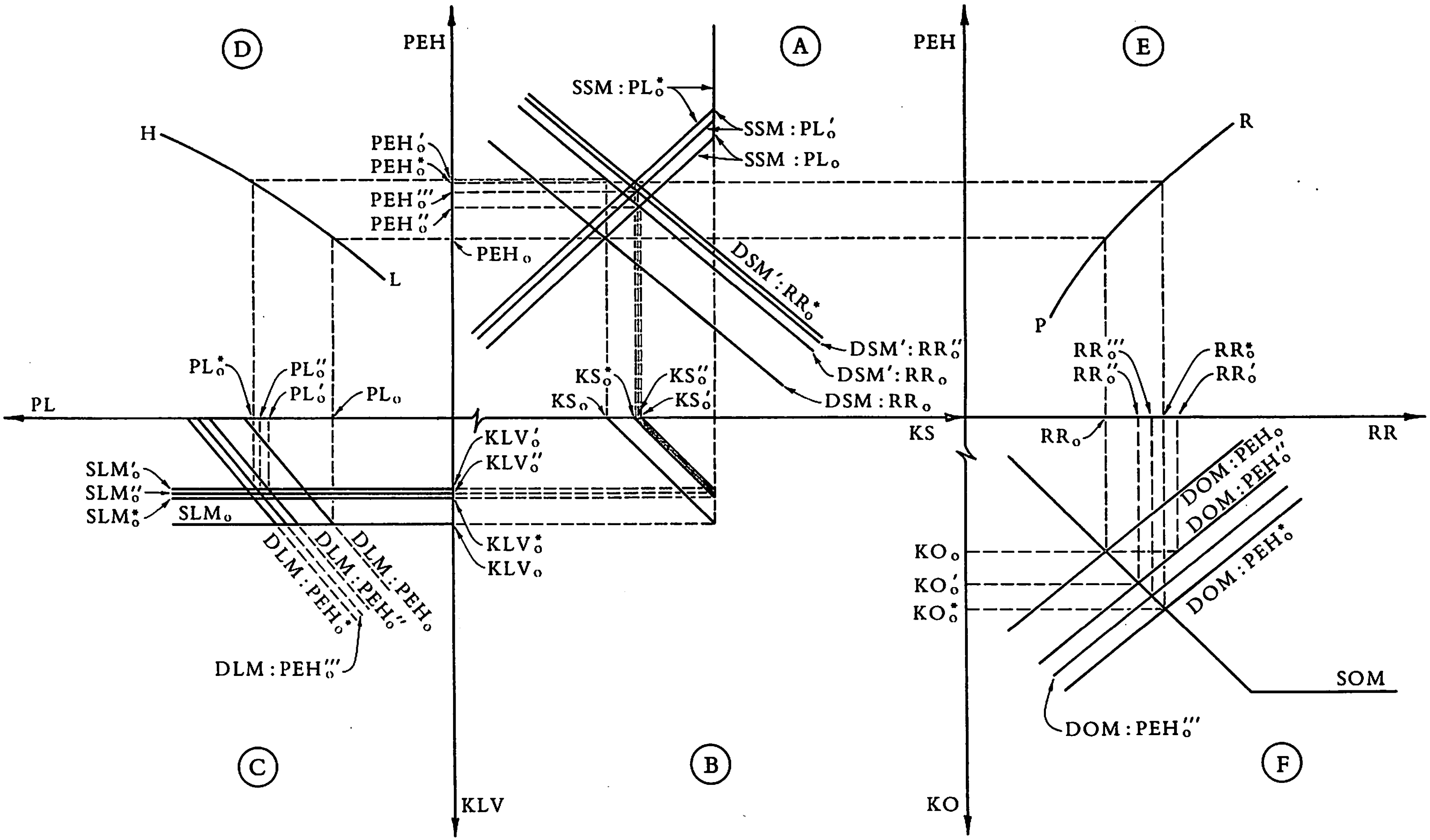
The increased level of rents from RR_0 to RR_0'' in turn shifts the demand curve for owner-occupied units outward from DSM':RR_0 to DSM':RR_0'' which implies an increase in house prices from PEH_0'' to PEH_0'''. This higher level of house prices further shifts DOM:PEH_0'' outward to DOM:PEH_0''' which causes an increase in rents from RR_0'' to RR_0'''. These related effects continue until the two markets reach a new equilibrium with $PEH_0^* > PEH_0$, $KS_0^* > KS_0$, $RR_0^* > RR_0$, and $KO_0^* > KO_0$, i.e., with higher prices, rents, and stocks. In quadrant B of Figure 10, the coordinates of point a are the initial rent/price configuration and those of point b are the new rent/price configuration. The curve PR is therefore a locus of equilibrium house prices and rents. If SSM:PL_0 and SOM have the same elasticity, we can assume that the slope of PR declines because, as both house prices and rents increase, housing becomes a larger proportion of household budgets and more homeowners are forced to economize by renting rather than owning. We may now show the interrelationships between all three markets.

F. RENTAL AND OWNER-OCCUPIED HOUSING MARKET AND LAND MARKET

In Figure 11, the single-family detached or owner-occupied housing market is represented in quadrant A, the market for single-family detached lots in quadrant C, and the market for rented other types of housing units in quadrant F. The markets are assumed to be in an initial equilibrium given by PEH_0, KS_0, PL_0, RR_0, and KO_0.

Figure 10

Rental and Owner-Occupied Housing Market and Lot Market



The interrelationships may be illustrated by assuming an exogenous outward shift in the demand curve for single-family detached housing units, $DSM{:}RR_0$ in quadrant A of Figure 11, to $DSM'{:}RR_0$, as a result of some factor such as a decrease in single-family detached property taxes or in owner-occupied mortgage rates. In the short run, this shift causes excess demand in the market and an increase in price to PEH_0' which induces an increase in supply from KS_0 to KS_0' in the medium term and a consequent decrease in price from PEH_0' to PEH_0''. The price and quantity adjustment in the owner-occupied housing market affect both the market for land and the market for rental units. First, in the land market in quadrant C of Figure 11, the stock of vacant lots is reduced from KLV_0 to KLV_0' as a result of the increase in the stock of housing from KS_0 to KS_0'. The demand curve for land, $DLM{:}PEH_0$ in quadrant C, shifts outward to $DLM{:}PEH_0''$ as a result of the higher price of single-family detached housing units, PEH_0''. These two induced effects in the land market raise the price of land from PL_0 to PL_0'. Second, in the rental market in quadrant F, the demand curve for rental units shifts outward from $DOM{:}PEH_0$ to $DOM{:}PEH_0''$ which raises rents, in the short term, from RR_0 to RR_0'. Excess demand at RR_0 elicits a quantity increase in the rental market from KO_0 to KO_0' and a corresponding decrease in rents from RR_0' to RR_0''.

The effects in both the land and rental housing markets feed back on the owner-occupied housing market. First, the higher level of rents, RR_0'', shifts the demand curve for single-family detached units outward from $DSM'{:}RR_0$ to $DSM'{:}RR_0''$. Second, the increase in the price of land from PL_0 to PL_0' shifts the medium term supply curve for single-family detached units inward from $SSM{:}PL_0$ to $SSM{:}PL_0'$. $DSM'{:}RR_0''$ and $SSM{:}PL_0'$ intersect at a new price of housing, $PEH_0''' > PEH_0''$, and quantity of housing, $KS_0'' < KS_0'$.

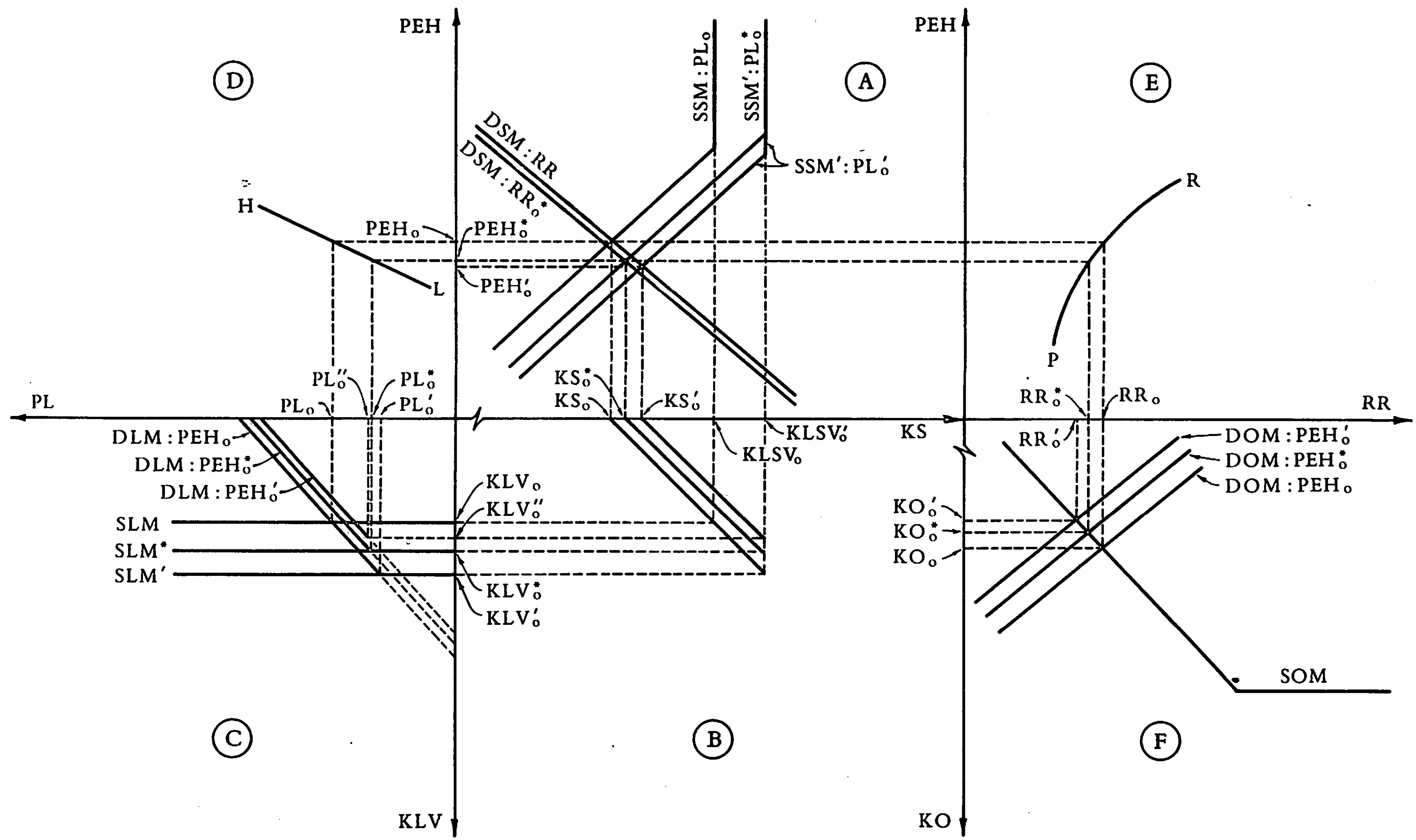
These secondary effects in the owner-occupied housing market have further induced effects on the other two markets. In the land market, the stock of vacant lots increases from KLV_0' to KLV_0'' and the demand curve for lots shifts outward from $DLM:PEH_0''$ to $DLM:PEH_0'''$: the resulting intersection gives a new price to vacant lots equal to $PL_0'' > PL_0'$. In the rental market, the higher price of houses PEH_0''' causes a shift in $DOM:PEH_0''$ outward to $DOM:PEH_0'''$ and a higher level of rents, $RR_0''' > RR_0''$. The price effect in the land market shifts the supply curve of housing $SSM:PL_0'$ inward to $SSM:PL_0''$ (not shown in quadrant A); the price effect in the rental market shifts the demand curve for housing outward from $DSM':RR_0''$ to $DSM:RR_0'''$ (also not shown in quadrant A). The net response to an increase in demand in the owner-occupied housing market is $PEH_0^* > PEH_0$, $KS_0^* > KS_0$, $PL_0^* > PL_0$, $KLV_0^* < KLV_0$, $RR_0^* > RR_0$, and $KO_0^* > KO_0$.

The effects on the three markets of an increase in vacant single-family detached lots may now be illustrated. Figure 12 reproduces the initial equilibrium of Figure 11. The supply of vacant lots is assumed to increase from KLV_0 to KLV_0'. The immediate effect of this increase is to lower the price of lots from PL_0 to PL_0'. The quantity increase and price decrease in the land market shift the supply curve in the single-family detached housing market outward from $SSM:PL_0$ to $SSM':PL_0'$ which causes the price of single units to fall from PEH_0 to PEH_0' and the stock of single units to increase from KS_0 to KS_0'.

The adjustments in the owner-occupied housing market feed back on both the land and rental housing markets. The lower price of houses PEH_0' shifts the demand curve for land inward from $DLM:PEH_0$ to $DLM:PEH_0'$ and the higher stock of housing KS_0' implies an inward shift in SLM' from KLV' to KLV_0'': the result is an increase in the price of land from PL_0' to PL_0''. In the rental

Figure 12

Effects of Increase in Vacant Lots on Rental and Owner-Occupied Housing Markets and Lot Market



market, the decrease in house prices causes an inward shift in the demand curve for rental units, from $DOM{:}PEH_0$ to $DOM{:}PEH_0'$. Rents decrease from RR_0 to RR_0' and the stock of these other types of units decreases from KO_0 to KO_0'.

The induced effects in the land and rental markets feed back on the single-family detached housing market. First, the increase in the price of land from PL_0' to PL_0'' shifts the supply curve for single units inward from $SSM'{:}PL_0'$ to $SSM'{:}PL_0''$ (not shown in quadrant A of Figure 12). Second, the lower level of rents RR_0' shifts the demand curve for single units inward from $DSM{:}RR_0$ to $DSM{:}RR_0'$ (also not shown in quadrant A). The three markets are assumed to reach a new equilibrium at $PEH_0^* < PEH_0$, $KS_0^* > KS_0$, $RR_0^* < RR_0$, $KO_0^* < KO_0$, $PL_0^* < PL_0$, and $KLV_0^* > KLV_0$, i.e., the exogenous increase in the stock of vacant lots has decreased rents and house and land prices, increased the stock of owner-occupied units, increased the stock of vacant lots on a net basis, but decreased the stock of other types of units.

G. RELATIONSHIP OF THEORETICAL MODEL TO EMPIRICAL MODEL

The objective of this exercise has been to establish a theoretical framework for the empirical model of the land and housing markets. The actual specification of the various relationships in each of the markets is somewhat more detailed than the abstract formulations given in this section. In particular, any real world model of these markets must first of all be a dynamic model because responses to exogenous changes do not in practice occur instantaneously. Second, the empirical model is implicitly a disequilibrium model because the exogenous variables which affect these markets constantly change and because responses to these changes do not occur instantaneously.

Apart from these differences between the theoretical and empirical models, there are two other important respects in which the empirical model deviates from the theoretical model presented in this section. In the theoretical analysis, we assumed the total population to be fixed which permitted meaningful discussion about the total stocks of owner-occupied and rental units. However, the population and number of households of the study area have been constantly increasing over the period analyzed and the composition of the total number of households as between family and non-family has likewise been changing. There are two separate stocks of housing in the model--owner-occupied and rental. Because it is mostly family households which occupy owned single-family detached dwelling units, we use the ratio of the stock of these types of dwellings to the number of family households as the stock variable in the equation for the price of single-family units. Because there are more family households than there are single-family detached units, some family households occupy rental units. We define the number of remaining households to be the number of family households for whom single-family detached units do not exist, plus the number of non-family households; the stock variable in the rental rate equation is accordingly defined as the ratio of the stock of other types of housing units to the number of remaining households.

The other respect in which the theoretical and empirical models differ is that housing stocks in the latter model are assumed to be irreversible downward, at least in a behavioral sense. In the two housing markets in the theoretical model, housing stock decisions were assumed to be reversible (but conversions between single-family detached units and other types of units were assumed not to occur). In the empirical model, the assumption about the irreversibility of housing stock decisions and the existence of conversions are reflected in the use of a net rate of demolition and conversion for each of the two stocks. The net rate of demolition and conversion is assumed fixed between Census dates, i.e., demolitions and conversions occur, but they are a fixed per cent of the total stock of housing units of each type.

The specification and statistical quantification of each of the relationships in the three markets are discussed in some detail in Sections III through VI below. Section VII, Model Solution and Policy Analysis, shows the dynamic solution of the model and the disequilibrium effects of increases in land supply on the objective variables. In all of the following, variables which are endogenous in the model are represented by upper case characters and variables exogenous to the model by lower case characters. Only equations which are part of the model are numbered (in square brackets), not necessarily in the order in which they appear in the text. The equations of the complete model are summarized in Appendix I which also includes a glossary of variables.

III. HOUSING STOCKS

This section shows the determination of the stocks of single-family detached units and of other types of units. Housing starts are behavioral functions, completions are distributed lag functions of starts, and the stocks are determined definitionally.

A. SPECIFICATION OF STARTS EQUATIONS

Single-family detached housing starts are taken to depend simply on a measure of the expected profitability of constructing and selling single-family detached units and on the cost and availability of mortgage credit.[12] We have

$$SS_t = f(\overline{ds}_t, PEH_t - SDC_t, rm_t, rm_t - rb_t)$$

in which $\overline{ds}$ is a set of monthly, seasonal and winter works dummies, PEH the market selling price of a typical existing house, SDC a measure of single-family detached land and construction costs, rm the mortgage rate, and rb the bond rate. The term rm measures simply the cost of mortgage borrowing. The term (rm - rb) measures credit availability: as the bond rate rises relative to the mortgage rate, financial institutions will attempt to shift their lending away from mortgages by introducing more

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[12]The vacancy rate is not included here as an explanatory variable to avoid multicollinearity with the price variable. The price variable reflects both the return from selling a house and the probability of selling it, in that price will vary inversely with excess demand or the vacancy rate.

restrictive mortgage terms. A narrowing of the differential therefore reduces housing starts. Our hypotheses related to this equation are therefore

- $\frac{\partial SS_t}{\partial(PEH_t - SDC_t)} > 0$;

- $\frac{\partial SS_t}{\partial rm_t} < 0$; and

- $\frac{\partial SS_t}{\partial(rm_t - rb_t)} > 0$.

Analogous to single starts, other starts are taken to be a function of a measure of the profitability of constructing and renting multiple units and of the cost and availability of mortgage credit. Since we are comparing monthly rental rates per unit to a measure of construction costs, the profitability term is formulated as a ratio in this equation. We have

$$SO_t = g(\overline{do}_t, RR_t/RC_t, rm_t, rm_t - rb_t)$$

where SO is starts of other units, $\overline{do}$ is a set of monthly, seasonal, and winter works dummies, RR is monthly rental rates, and RC is a measure of residential construction costs. Our hypotheses concerning signs are

- $\frac{\partial SO_t}{\partial(RR_t/RC_t)} > 0$;

- $\frac{\partial SO_t}{rm_t} < 0$; and

- $\frac{\partial SO_t}{\partial(rm_t - rb_t)} > 0$.

B. SOURCES OF DATA FOR STARTS EQUATIONS

1. Starts of Single and Other Units

Monthly series for starts of single units, SS, and for other units, SO, were obtained for the years 1963 to 1974 from Mr. J. P. Delisle, Chief, Housing and Building Permits Section, Construction Division, Statistics Canada.

2. Price of Single-Family Detached Units

To derive a series for the price of existing single-family detached units, PEH, we first created a complete inventory of single-family detached dwellings in the city (as of mid-summer, 1974). Teela Digest publishes a Monthly Realty Sales Review which gives details on all transactions in real estate for the City. The price and closing date of each transaction in single-family detached dwellings from 1964 were coded from the publication and this information was merged with the inventory. Existing computer programs were used to sort these transactions by month and to calculate the monthly median sale price. The median, rather than the mean, sale price was used in order to avoid the effects of unusually large or small transactions in any month.

3. Single-Family Detached Land and Construction Costs

The method for deriving a measure of single-family detached land and construction costs, SDC, is reasonably involved. We begin by defining residential construction costs, RC, to be a weighted sum of labour and material costs, i.e.,

$$RC_t = w_1 \cdot \ell c_t + w_2 \cdot mc_t$$

where ℓc is labour cost in residential construction, mc is material costs in residential construction, and w_1 and w_2 are the weights to be determined.

These weights were set to make the construction cost variable comparable to the Ontario total index of residential building construction input prices, rco, from CANSIM (Matrix No. 3778.1). This Ontario total index is very nearly a weighted sum of the Ontario residential building materials price index, mco, from CANSIM (Matrix No. 3778.1.1.1), and Ontario average hourly earnings in construction, ℓco from CANSIM (Matrix No. 1470.1.4.1), i.e.,

$$rco_t = \hat{w}_1 \cdot \ell co_t + \hat{w}_2 \cdot mco_t + \varepsilon_t ,$$

so the weights w_1 and w_2 were estimated from the monthly Ontärio data for the period January 1971 to December 1973 with the following results:[13]

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[13]The value in parentheses beneath each coefficient is the corresponding t-statistic. All coefficients in each regression presented in this paper are significant at, at least, the 10% level of confidence (one-tailed test).

O.L.S. below the regression indicates that the method of estimation was Ordinary Least Squares. C.O.R.C. indicates that the Cochrane-Orcutt iterative technique was used. In the case of C.O.R.C. the value for ρ and the corresponding t-statistic are also presented.

P.D. represents the period of data, i.e., the sample period used in estimation. Dates are printed in the format YEAR·MONTH (for example, 63·1 is January 1963). Dates separated by a dash represent a continuous period. Dates separated by a comma indicate missing observations.

The number of observations is given by N. This number will be one less than the number of months in the sample period if the Cochrane-Orcutt technique has been used (one degree of freedom is lost in estimating ρ).

The R^2-statistic has little meaning if the regression does not contain a constant term and it is omitted in such cases.

The Durbin-Watson statistic is indicated by D.W.

The F-statistic is calculated to test the null hypothesis that all coefficients except the constant are jointly zero. If the regression contains a constant term, the F-statistic is calculated using the R^2-statistic. Otherwise, the following formula [Henri Theil, Principles of Econometrics (John Wiley and Sons, New York, 1971), pp. 138-139] is used:

$$rco_t = \underset{(4.11552)}{3.34965} \ \ell co_t + \underset{(19.5980)}{.829686} \ mco_t$$

C.O.R.C.: $\rho = .5289988$ $(t = 3.6878572)$

P.D. = 71·1 - 73·12

N = 35

D.W. = 2.0118

$F_{2,33} = 886{,}015.$

$Pr(F_{2,30} > 6.355) = .005$

In creating the construction cost variable, RC, the series of average hourly earnings in construction for London from CANSIM (Matrix No. 1675.1.4) was used for the labour cost variable ℓc. It was necessary to use a proxy material cost variable because Statistics Canada does not publish a building materials index for London. Unfortunately, the closest substitute, the Ontario index of residential building material prices, mco, is not available for the months prior to January 1971. In its place, the building materials index for Canada, mcc, from CANSIM (Matrix No. 185.1) was used for the months January 1965 to December 1970. For the sake of continuity the materials index for Canada (1961=100) was multiplied by a

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$$F_{K,n-K} = \frac{y'y - (n-K)s^2}{K \cdot s^2}$$

where y = dependent variable vector

n = number of observations

K = number of regressors

s^2 = residual variance .

Finally, to indicate the success of the F-test in rejecting the null hypothesis, we present the probability that a variable having an F-distribution with the same or similar degrees of freedom is greater than some critical value taken from a table [Donald B. Owen, Handbook of Statistical Tables (Addison Wesley, Massachusetts, 1962), Table 4.1, pp. 63-87]. The critical value is selected to be less than the calculated F-statistic.

constant factor so that it would equal 100.0 in June 1971, the base month for the Ontario materials index. Thus,

$$[3] \quad RC_t = \begin{cases} 3.34965\ \ell c_t + .829686\ mcc_t\ , & t = \text{January 1965 to December 1970} \\ 3.34965\ \ell c_t + .829686\ mco_t\ , & t = \text{January 1971 to December 1973}\ . \end{cases}$$

The cost of a representative single-family detached dwelling, SDC, is defined as the sum of the price of a single-family detached lot, PL (endogenous in the model), and the cost of construction. The cost of construction of a single-family detached dwelling is taken to be the residential construction cost variable, RC, multiplied by an adjustment factor, i.e.,

$$SDC_t = PL_t + w_3 \cdot RC_t\ .$$

To estimate w_3, it is assumed that the average rate of return on building single-family detached houses is equal to the average rate of return on bonds, i.e.,

$$\frac{\overline{PEH} - \overline{SDC}}{\overline{PEH}} = \overline{rb}$$

where $\overline{rb}$ represents the average bond rate, $\overline{SDC}$ the average dwelling cost and $\overline{PEH}$ the average selling price. Substituting for SDC and rewriting yields an expression for the adjustment factor:

$$w_3 = \frac{(1 - \overline{rb})\ \overline{PEH} - \overline{PL}}{\overline{RC}}\ .$$

Using data[14] for the period 1965-1973, w_3 was found to be 130.858. Thus,

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[14] PL, the median sale price of single-family detached lots, is described in Section VI.B.1. below.

[4] $$SDC_t = PL_t + 130.858\ RC_t$$

4. Mortgage Rate

A monthly series for the mortgage rate, rm, was obtained from CANSIM (Matrix No. 2560.24).

5. Bond Rate

A monthly series for the bond rate, rb, was obtained from CANSIM (Matrix No. 2560.31).

6. Rental Rates

No published or unpublished series on rental rates was available. To derive a series we made use of the classified advertisement section of The London Free Press. We first tabulated the asking rental rate on all unfurnished, one-bedroom apartments (for which the rate was quoted) which were advertised on the middle Saturday of each month. In contrast to asking house prices, quoted rental rates are quite close to contracted rents since there is little or no negotiation over price in this particular market. The use of rents for one-bedroom apartments assures that the derived series will not change in response to changes in the mix of apartment types which are advertised. The rental variable used is simply the monthly median advertised rental rate on one-bedroom unfurnished apartments. The derived series may be viewed as quite reliable: it covers a homogeneous commodity, the number of observations tabulated in each month was fairly large (ranging from 20 to 123), the standard deviation of observations in each month was not large (it ranged from 10.7 to 26.0), and use of the median rather than the mean or average rental rate avoids distortions caused by unusual outlying observations on the high or low side.

7. Residential Construction Costs

The derivation for a monthly series on residential construction costs, RC, is given in subsection B.3. above.

C. ESTIMATION OF STARTS EQUATIONS

For both single and other starts, expected profitability will depend on profitability in some past month. Moreover, the lag on the gross return (price or rents) may be different from the lag on the cost measure. Finally, we would expect the lag on the profitability measure to be longer for other starts than for single starts, since the acquisition of land suitable for multiples and the planning time required will be longer for multiples than for singles. The same considerations apply to the lag structure on the mortgage cost and availability terms.

A variety of equations for SS and SO were estimated using different lags on the variables. The (rm - rb) term was not statistically significant with the hypothesized sign in any of the formulations attempted. The only monthly or seasonal pattern evident was a lower level of single starts in the months of February and March.

The introduction of a dummy variable, dp_t, in the single starts equation for the period after January 1969 was suggested by an examination of the data. The same dummy variable was found to be significant with the same sign in the regression for the price of single-family lots. The explanation given in both cases is that anticipation of the Official Plan tended to increase building activity. Further elaboration of this point is made in Section VI.C below. The best formulation (in terms of t- and F-statistics) for single starts is the following:

$$[1] \quad SS_t = \underset{(4.00285)}{206.447} + \underset{(2.57722)}{32.9854}\, dp_t - \underset{(-5.30659)}{40.0574}\, w_t$$

$$+ \underset{(2.52151)}{.00572349}\,(PEH_{t-3} - SDC_{t-3}) - \underset{(-2.36909)}{15.0707}\, rm_{t-1}$$

where

$$dp_t = \begin{cases} 1\,, & t > \text{January 1969} \\ 0\,, & \text{otherwise} \end{cases}$$

$$w_t = \begin{cases} 1\,, & t = \text{February, March} \\ 0\,, & \text{otherwise} \end{cases}$$

C.O.R.C.: $\rho = .3710402$ ($t = 3.9755940$)
P.D. = 65·4 - 66·4, 66·6 - 71·8, 71·11 - 73·12
N = 99
$R^2 = .4492$
D.W. = 2.0863
$F_{4,94} = 19.17$
$Pr(F_{4,80} > 4.030) = .005$

From this equation it appears that it takes three months for information on housing prices and costs to be incorporated into builders' expectations and for construction on the unit to be started.

The data for other starts and construction costs clearly suggest a non-linear specification. A variety of regressions were therefore attempted with the profitability measure squared and with different lags applying to all of the variables in the equation. The mortgage rate was statistically significant when lagged three months, but the credit availability term was not significant with the hypothesized sign in any of the formulations. The following regression represents the best of the various results obtained:

$$[2] \qquad SO_t = \underset{(4.75297)}{545.831} (RR_{t-8}/RC_{t-9})^2 - \underset{(-3.37507)}{54.4473}\, rm_{t-3}$$

O.L.S.
P.D. = 65·10 - 73·12
N = 99
D.W. = 1.8815
$F_{2,97} = 98.07$
$Pr(F_{2,80} > 5.667) = .005$

As expected, the lag on the profitability measure is somewhat longer in this equation. On the basis of these results, information about rents takes eight months to affect the level of other starts, and information about costs takes nine months to affect these starts.

D. SPECIFICATION OF COMPLETIONS EQUATIONS

Completions of single units, CS, and other units, CO, are postulated to be a lagged function of the respective housing starts, i.e.,

$$CS_t = \sum_{i=0}^{n} \hat{\alpha}_{-i}\, SS_{t-i} + \varepsilon_t$$

and

$$CO_t = \sum_{j=0}^{m} \hat{\beta}_{-j}\, SO_{t-j} + \varepsilon_t$$

where $\hat{\alpha}_{-i}$ and $\hat{\beta}_{-j}$ are empirically-determined weights, and n and m are the empirically-determined lag periods. Because virtually all housing starts result in housing completions in the City of London, the appropriate criterion in selecting a lag structure from the many possible structures which the data may support is the proximity of the sum of lag coefficients to unity; i.e., we require that

$$\sum_{i=0}^{n} \hat{\alpha}_{-i} = 1$$

and

$$\sum_{j=0}^{m} \hat{\beta}_{-j} = 1 \ .$$

Once the lag structures have been selected, the housing completions equations can be re-estimated constraining the coefficients to sum exactly to unity.

E. SOURCES OF DATA FOR COMPLETIONS EQUATIONS

1. Single and Other Housing Completions

The actual numbers of single and other dwelling completions, CS and CO, respectively, by month for the City of London were obtained for the years 1963 to 1974 from Mr. J. P. Delisle, Chief, Housing and Building Permits Section, Construction Division, Statistics Canada. The monthly series for starts of both types were obtained from the same source.

F. ESTIMATION OF COMPLETIONS EQUATIONS

For each completion equation a large number of regressions were run. Those which resulted in negative or insignificant coefficients were immediately discarded.

In the case of completions of single units there is strong evidence which indicates seasonal variation in the lag structure, especially with regard to fall and early winter starts. Accordingly, the completion equation for single units is respecified as a lagged function of housing starts by quarter,[15] i.e.,

$$CS_t = \sum_{i=0}^{n1} \hat{\alpha}1_{-i}\ SSQ1_{t-i} + \sum_{i=0}^{n2} \hat{\alpha}2_{-i}\ SSQ2_{t-i} + \sum_{i=0}^{n3} \hat{\alpha}3_{-i}\ SSQ3_{t-i} + \sum_{i=0}^{n4} \hat{\alpha}4_{-i}\ SSQ4_{t-i} + \varepsilon_t$$

where

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[15] An alternative formulation which is also satisfactory consists in specifying completions as a lagged function of winter starts, SSW, and non-winter starts, SSN. The regression results for this formulation are

$$CS_t = \underset{(11.1521)}{1.04300}\ SSW_{t-3} + \underset{(3.66175)}{.273699}\ SSN_{t-2} + \underset{(4.25440)}{.445448}\ SSN_{t-3} + \underset{(2.98205)}{.254697}\ SSN_{t-4}$$

O.L.S.

P.D. = 63·5 - 74·12

N = 140

D.W. = 1.727

$F_{4,136} = 201.75$

$Pr(F_{4,120} > 3.921) = .005$

where

$$SSW_t = \begin{cases} SS_t & \text{if } t = \text{December, January, March} \\ 0 & \text{otherwise} \end{cases}$$

$$SSN_t = \begin{cases} 0 & \text{if } t = \text{December, January, March} \\ SS_t & \text{otherwise .} \end{cases}$$

$$SSQ1_t = \begin{cases} SS_t & \text{if } t = \text{January, February, March} \\ 0 & \text{otherwise} \end{cases}$$

$$SSQ2_t = \begin{cases} SS_t & \text{if } t = \text{April, May, June} \\ 0 & \text{otherwise} \end{cases}$$

$$SSQ3_t = \begin{cases} SS_t & \text{if } t = \text{July, August, September} \\ 0 & \text{otherwise} \end{cases}$$

and $$SSQ4_t = \begin{cases} SS_t & \text{if } t = \text{October, November, December} \\ 0 & \text{otherwise .} \end{cases}$$

We require that

$$\sum_{i=0}^{n1} \hat{\alpha}1_{-i} = 1, \quad \sum_{i=0}^{n2} \hat{\alpha}2_{-i} = 1, \quad \sum_{i=0}^{n3} \hat{\alpha}3_{-i} = 1, \text{ and } \sum_{i=0}^{n4} \hat{\alpha}4_{-i} = 1.$$

The regression which best satisfies this restriction is the following:

$$\begin{aligned} CS_t = \; & \underset{(1.91227)}{.314486}\, SSQ1_{t-2} + \underset{(2.13992)}{.391330}\, SSQ1_{t-3} + \underset{(1.90571)}{.348256}\, SSQ1_{t-4} \\ & + \underset{(2.06870)}{.252692}\, SSQ2_{t-2} + \underset{(2.98130)}{.473898}\, SSQ2_{t-3} + \underset{(1.95679)}{.309304}\, SSQ2_{t-4} \\ & + \underset{(1.60834)}{.197346}\, SSQ3_{t-2} + \underset{(3.41788)}{.483136}\, SSQ3_{t-3} + \underset{(2.91809)}{.374212}\, SSQ3_{t-4} \\ & + \underset{(3.11811)}{.423165}\, SSQ4_{t-3} + \underset{(2.66037)}{.431857}\, SSQ4_{t-4} \end{aligned}$$

O.L.S.

P.D. = 63·5 - 74·12

N = 140

D.W. = 1.8902

$F_{11,129} = 67.09$

$Pr(F_{11,120} > 2.617) = .005$

All the coefficients are significant at the ten per cent level of confidence. Note that the lag coefficients for each quarter form an inverted-V pattern and that their sums are close to unity:

$$\sum_{i=0}^{4} \hat{\alpha}1_{-i} = 1.054, \quad \sum_{i=0}^{4} \hat{\alpha}2_{-i} = 1.036, \quad \sum_{i=0}^{4} \hat{\alpha}3_{-i} = 1.055, \text{ and } \sum_{i=0}^{4} \hat{\alpha}4_{-i} = .855 .$$

Also, unlike the other quarters, the largest proportion of fourth quarter starts are not completed until four months after the start. That is, the lag is longest for fourth quarter starts.

In the case of completions of other units there is insufficient evidence of seasonal variation in the lag structure so a quarterly version of the equation is not used. Of the lag structures that were tried the following regression represents the best:

$$CO_t = \underset{(1.56726)}{.106279}\, SO_{t-10} + \underset{(2.48024)}{.172503}\, SO_{t-11} + \underset{(2.48527)}{.178482}\, SO_{t-12}$$

$$+ \underset{(1.65244)}{.118051}\, SO_{t-13} + \underset{(1.92860)}{.136676}\, SO_{t-15} + \underset{(2.75592)}{.191154}\, SO_{t-16}$$

O.L.S.

P.D. = 64·5 - 74·12

N = 128

D.W. = 2.0593

$F_{6,122} = 45.66$

$Pr(F_{6,120} > 3.285) = .005$

All the coefficients are significant at the ten per cent level of confidence and their sum is close to unity:

$$\sum_{j=10}^{13} \hat{\beta}_{-j} + \sum_{j=15}^{16} \hat{\beta}_{-j} = .903$$

Note that the lag coefficients form an inverted-W pattern with peaks occurring in the twelfth and sixteenth lagged months and with coefficients implicitly zero in the ninth, fourteenth and seventeenth lagged months. This unusual pattern would not be expected if the other units formed a homogeneous group but since the classification includes single attached and semi-detached, duplex, row, townhouse, condominium, and apartment dwellings, each type requiring a different period of construction, it is not surprising to encounter a combination of inverted-V patterns.

It remains to enforce the restriction that all housing starts result in housing completions. With the appropriate coefficients constrained to sum to unity[16] the re-estimated single unit completions equation is

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[16] For an example of this procedure, consider the regression

$$Y_t = \alpha_1 X_t + \alpha_2 Z_t + \varepsilon_t$$

with the restriction

$$\alpha_1 + \alpha_2 = 1 .$$

Employing the restriction, the regression is rewritten as

$$Y_t = (1 - \alpha_2)X_t + \alpha_2 Z_t + \varepsilon_t$$

and again as

$$(Y_t - X_t) = \alpha_2(Z_t - X_t) + \varepsilon_t .$$

O.L.S., applied to this last form of the regression, yields an estimate for α_2 and this, in turn, is substituted into the restriction equation to obtain an estimate for α_1, i.e.,

$$\hat{\alpha}_1 = 1 - \hat{\alpha}_2 .$$

[5] $$CS_t = .158247\ SSQ1_{t-2} + \underset{(2.30913)}{.372628}\ SSQ1_{t-3} + \underset{(2.89513)}{.469125}\ SSQ1_{t-4}$$

$$+ .197850\ SSQ2_{t-2} + \underset{(2.95962)}{.455534}\ SSQ2_{t-3} + \underset{(2.74898)}{.346617}\ SSQ2_{t-4}$$

$$+ .171159\ SSQ3_{t-2} + \underset{(3.48627)}{.466766}\ SSQ3_{t-3} + \underset{(3.02424)}{.362075}\ SSQ3_{t-4}$$

$$+ .452249\ SSQ4_{t-3} + \underset{(4.37557)}{.547751}\ SSQ4_{t-4}$$

O.L.S.

P.D. = 63·5 - 74·12

N = 140

D.W. = 1.9381

$F_{7,133} = 18.48$

$Pr(F_{7,120} > 3.087) = .005$

and the re-estimated other unit completions equation is

[6] $$CO_t = .124392\ SO_{t-10} + \underset{(2.71229)}{.188629}\ SO_{t-11} + \underset{(2.64533)}{.190724}\ SO_{t-12}$$

$$+ \underset{(1.79497)}{.128865}\ SO_{t-13} + \underset{(2.19610)}{.155245}\ SO_{t-15} + \underset{(3.07774)}{.212145}\ SO_{t-16}$$

O.L.S.

P.D. = 64·5 - 74·12

N = 128

D.W. = 2.0247

$F_{5,123} = 35.10$

$Pr(F_{5,120} > 3.548) = .005$

The coefficients which appear without a t-value beneath them have been calculated by subtracting the appropriate sum of estimated coefficients from unity.

The mean lag time for completions of single units implied by the relevant equation above is 3.31, 3.15, 3.19, and 3.55 months for starts in the first, second, third, and fourth quarters respectively. In other words, starts in the months January, February, or March take about (3.55 - 3.31)(30) = 7.2 days or one week longer to complete than starts in October, November, or December which in turn take about (3.31 - 3.17)(30) = 4.2 days longer to complete than starts in the months April through September. The relative lags here are reasonable since they conform to the relative severity of weather conditions in the different periods. The overall average completion time for single units, regardless of the quarter in which the start is made, is 3.30 months. This may be compared with the only other related information available for the City which shows an actual median completion time for single-family detached units for starts in 1972 of 6.12 months.[17] The discrepancy between the figure implied by our equation and the observed number of months to completion for dwellings started in 1972 may result from the latter figure being a median rather than an average value, from 1972 being an atypical year, or both.

For other units, the completion time indicated by the above equation is 13.01 months. The corresponding direct information which we have for 1972 shows a median completion time for multiple units of 13.80 months, but this figure applies to multiple units only so that any comparison here is not very meaningful since other units in our specification includes semi-detached, semi-attached, duplex, row, townhouse, and condominiums in addition to multiple units.

G. SPECIFICATION OF STOCK EQUATIONS

We define the stock of single units, KS, and the stock of other units, KO, respectively, as

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[17] This information was obtained in unpublished form from J. P. Delisle, Housing and Building Permits Section, Construction Division, Statistics Canada.

$$KS_t = KS_{t-1}(1 - \delta_s) + CS_{t-1}$$

and

$$KO_t = KO_{t-1}(1 - \delta_o) + CO_{t-1}$$

where δ_s and δ_o are the net rates of demolition and conversion of the single and other stocks, respectively.[18] KS and KO refer to the total (occupied plus vacant) stock of each type.

H. SOURCES OF DATA FOR STOCK EQUATIONS

1. Stocks of Single and Other Units

Both stocks, KS and KO, are known (from the Census) for June of 1961, 1966 and 1971. In addition, the stock of single-family dwellings is known for June of 1974.[19] These figures are presented in Table 6. As mentioned previously, completions are known monthly only for the years 1963 to 1974 so the stock series are also limited to this period.

2. Completions of Single and Other Units

The source for completions of single units, CS, and other units, CO, is given in subsection E.1. above.

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[18]Conversions and demolitions, which are the two sources of depletion of either stock, are very low even on an annual basis in the City of London, both in absolute terms and relative to the total stocks.

[19]In the course of collecting data on house prices we constructed a list of all single-family detached dwellings in London. This was done by eliminating the addresses of dwellings other than single-family detached from a list of all addresses in the City. These other dwellings were identified by reference to the City land use maps. The number of addresses remaining on the list constituted the total stock (vacant and occupied) of single-detached dwellings. The list was current as of June 1974.

Table 6

Stocks of Housing, Single-Family Detached and Other, City of London

Year*	Vacant Dwellings					Occupied Stock		Total Stock		Vacancy Rate	
	Type[a]			Revised							
	Single	Other	Not Stated	Single**	Other**	Single	Other	Single (KS)	Other (KO)	Single %	Other %
1961	575	1,279	123	613	1,364	31,133[b]	16,124[b]	31,746	17,488	1.9	7.8
1966	965	2,288	194	1,023	2,424	34,715[c]	21,402[c]	35,738	23,826	2.9	10.2
1971	800	3,165	165	833	3,297	38,795[d]	30,075[d]	39,628	33,372	2.1	9.9
1974	-	-	-	-	-	-	-	43,601[e]	-	-	-

Sources: a) J. P. Delisle, Statistics Canada.

b) Basic Dwelling Characteristics (Catalogue No. 93-523), Table 5, Statistics Canada.

c) Dwellings by Structural Type and Tenure (Catalogue No. 93-602), Table 5, Statistics Canada.

d) Dwellings by Tenure and Structural Type (Catalogue No. 93-727), Table 4, Statistics Canada.

e) Private enumeration; see footnote 19 supra.

Notes: *Figures in table refer to June 1st.

**Includes "not stated" type in the proportion of vacancies by type to total vacancies.

I. ESTIMATION OF STOCK EQUATIONS

Since the stocks are definitional statements, no empirical estimation is required, but the initial stocks and net rates of demolition/conversion must be calculated.

The following procedure was used to estimate the net rate of demolition/conversion for each of the stocks. Beginning with the stock in June 1966 and using a trial rate of demolition/conversion and housing completions from that month on, the stock was projected forward to June 1971 by applying the stock equation recursively. The terminal stock value was then compared to the actual (Census) stock value and the trial rate of demolition/conversion was corrected to minimize this terminal difference. The procedure was repeated until a rate of demolition/conversion had been found which resulted in a terminal difference of less than three housing units. Because of the repetitive nature of these calculations a computer was used for the operation. In the case of single units, the stock is also known for June 1974, so two rates were calculated, δ_{s1} and δ_{s2}, the former based on the years 1966 to 1971 and the latter on the years 1971 to 1974.

The estimated rates of demolition/conversion are

$$\delta_{s1} = .0002434$$

$$\delta_{s2} = .0000365$$

$$\delta_{o} = -.0001387$$

The negative sign on δ_o indicates that conversions to other types of units, which are, typically, single-family detached dwellings being split into duplexes or apartments, exceed the demolition of other units. Also, the evidence from the estimation of δ_s is that this rate of conversion is declining.

By rewriting the stock equations in the following form

$$KS_{t-1} = (1 - \delta_s)(KS_t - CS_{t-1})$$

and

$$KO_{t-1} = (1 - \delta_o)(KO_t - CO_{t-1})$$

it is possible to project the stocks back using actual completions from June 1966 to January 1963, the first month for which completion data are available. The stocks calculated for this month become the base figures for the two stock series. Thus, the two stock equations used in the model are

$$[7] \quad KS_t = \begin{cases} 32{,}818 \, , & t = \text{January 1963} \\ KS_{t-1}(1 - .0002434) + CS_{t-1} \, , & t = \text{February 1963 to June 1971} \\ KS_{t-1}(1 - .0000365) + CS_{t-1} \, , & t > \text{June 1971} \end{cases}$$

and

$$[8] \quad KO_t = \begin{cases} 19{,}207 \, , & t = \text{January 1963} \\ KO_{t-1}(1 + .0001387) + CO_{t-1} \, , & t > \text{January 1963} \, . \end{cases}$$

IV. HOUSE PRICES AND RENTS ON MULTIPLES

This section contains a description of the development and estimation of equations for the price of single-family detached dwelling units and for rents on the stock of housing units of other types. The house price equation includes a speculative or investment term, in recognition of the fact that a house may be purchased as an asset for the potential capital gain which it may yield. Both the price and rent equations include the cost of the alternative type of housing as an independent variable.

A. SPECIFICATION OF HOUSE PRICE EQUATION

To derive an equation for the price of the existing stock of houses, PEH, we recognize that there are two motives for purchasing a house. Housing provides a stream of services for the owner. We refer to this motive for purchasing a house as the consumption demand. The other motive for purchasing a house is a speculative or investment one--housing is an asset which is similar in many respects to other assets which are held for the potential capital gains they may yield. Recognizing that families and individuals can and do purchase houses to satisfy both motives, we begin by conceptualizing that the two demands can be distinguished. We consider first the asset or investment demand for single-family detached houses.

The offer or bid price for housing to hold as an asset will depend partly on the expected nominal rate of return from holding housing relative to the expected rate of return from holding the next best asset. Neglecting transactions costs and carrying costs, we may define the expected equilibrium nominal rate of return from holding housing as an asset by

$$\dot{PEH}^e_t = \frac{PEH^e_{t+i+1} - PEH^e_{t+i}}{PEH^e_{t+i}}$$

where PEH^e_{t+i} is the expected price of existing housing in period t+i. For the rate of return on the next best asset, we use the nominal savings deposit rate, rs. This rate is chosen because it is the yield on the alternative asset which prospective homeowners are most likely to invest in. Also, using this rate avoids the problem of determining the expected yield of a financial asset which does not have a fixed face value. The expected relative rate of return from holding housing is therefore $\dot{PEH}^e_t/rs_t$.

The offer price for housing to hold as an asset will also depend on the number of dwellings per family household in the area, on permanent disposable income per household, and on the cost and availability of mortgage credit. We can write

$$P^a_t = s(\dot{PEH}^e_t/rs_t,\ yp_t,\ KS_t/fhh_t,\ rm_t - rb_t,\ rm_t)$$

where P^a is the offer price for housing to hold as an asset, yp permanent disposable income, and fhh the number of family households. We hypothesize the following:

$$\frac{\partial P^a_t}{\partial(\dot{PEH}^e_t/rs_t)} > 0$$

because an increase in the relative rate of return from holding housing induces a portfolio adjustment from other assets to housing;

- $\frac{\partial P_t^a}{\partial yp_t} > 0$ because an increase in permanent disposable income increases the potential number of bidders for a given house;

- $\frac{\partial P_t^a}{\partial (KS_t/fhh_t)} < 0$ because an increase in the number of units per family household, given incomes and mortgage rates, reduces the number of bidders for a given house;

- $\frac{\partial P_t^a}{\partial (rm_t - rb_t)} > 0$ because an increase in the yield differential will result in a portfolio shift by lenders into mortgages, with more favourable credit terms; and

- $\frac{\partial P_t^a}{\partial rm_t} < 0$ because an increase in the mortgage rate reduces the potential number of bidders for a given house.

Considering now the consumption motive for purchasing housing, we hypothesize that the bid price for housing to hold as a consumption item is related to the cost and availability of mortgage credit, household permanent disposable income, the stock of single housing per family household, and the rental rate on other housing, which gives

$$P_t^c = c(rm_t - rb_t, rm_t, yp_t, KS_t/fhh_t, RR_t)$$

where P^c is the offer price for housing to hold as a consumption item.
We hypothesize that

- $\frac{\partial P^c}{\partial(rm_t - rb_t)} > 0$ because, as the spread widens, mortgage financing will be more readily available on more generous terms;

- $\frac{\partial P_t^c}{\partial rm_t} < 0$ because an increase in the mortgage rate will reduce the number of households which can afford to purchase single-family detached housing;

- $\frac{\partial P^c}{\partial yp_t} > 0$ because an increase in permanent disposable incomes will increase the number of households which can afford a purchase;

- $\frac{\partial P^c}{\partial(KS_t/fhh_t)} < 0$ because the higher the per household stock of housing the less competition in bidding there will be for a given house; and

- $\frac{\partial P^c}{\partial RR_t} > 0$ because an increase in the rental rate on other housing will induce substitution from other to single housing.

The actual market price for single houses will be a function of a bidding process in which the bids reflect the consumption and investment motives. We can therefore write the observed market price for the existing housing stock as some function of the demands to hold housing for consumption and for investment purposes, giving

$$PEH_t = d(P^c_t, P^a_t)$$

$$= d(c(rm_t - rb_t, rm_t, yp_t, KS_t/fhh_t, RR_t),$$

$$s(\dot{PEH}^e_t/rs_t, yp_t, KS_t/fhh_t, rm_t - rb_t, rm_t))$$

or $$PEH_t = z(KS_t/fhh_t, yp_t, \dot{PEH}^e/rs_t, rm_t, rm_t - rb_t, RR_t) .$$

B. SOURCES OF DATA FOR HOUSE PRICE EQUATION

1. Price of Existing Single-Family Detached Units

The derivation of the house price series, PEH, is given in Section III.B.2.

2. Single-Family Detached Units per Family Household

A derivation for the stock of single-family detached units, KS, is given in Sections III.G., III.H., and III.I.

To derive a monthly series for the number of family households, fhh, we begin with a monthly series for marriages. The number of marriage licences issued in the city for each month since January 1972 is presented in Table 7 along with the percentage breakdown, by month, of total marriages. Prior to 1972, the figures are available only on an annual basis. These annual figures, presented in Table 8, were converted into a monthly series by applying the percentage breakdown from Table 7.

Family formation, or the change in the number of family households, is assumed to be directly proportional to the number of marriages, i.e.,

Table 7

Number of Marriage Licences Issued,
City of London, Monthly, 1972-1974

Month	1972	1973	1974	Total	Percentage of Total Marriages, 1972-74
January	109	110	127	346	4.94
February	125	93	117	335	4.78
March	176	163	144	483	6.90
April	215	203	208	626	8.93
May	272	249	255	776	11.07
June	291	258	254	803	11.45
July	214	263	312	789	11.25
August	256	304	287	847	12.08
September	232	213	230	675	9.63
October	175	183	160	518	7.39
November	147	153	132	432	6.16
December	123	110	148	381	5.43
Total	2335	2302	2374	7011	100.01*

Source: City Clerk's Office, City of London.

Note: *Total does not sum to 100.00 because of rounding.

Table 8

Number of Marriage Licenses Issued,
City of London, Annually, 1961-1971

Year	Marriages
1961	1,285
1962	1,332
1963	1,292
1964	1,435
1965	1,365
1966	1,565
1967	1,660
1968	1,875
1969	1,973
1970	2,058
1971	2,311

Source: Municipal Year Book, City of London, 1974.

$$fhh_t - fhh_{t-1} = \alpha \cdot m_{t-1}$$

where m is the number of marriages and α the average number of family households formed per marriage, assumed stable between Census dates. Rewriting this equation yields a recursive relation for generating the monthly series for family households:

$$fhh_t = fhh_{t-1} + \alpha \cdot m_{t-1} \ .$$

The numbers of family households in each of the Census years 1961, 1966 and 1971 are presented in Table 9 (column 3). For the period between any two Censuses, the average number of family households formed per marriage, α, can be calculated as the ratio of the change in the total number of family households to the total number of marriages during the period, i.e.,

$$\alpha = \frac{fhh_{t2} - fhh_{t1}}{\sum_{t=t1}^{t2} m_t}$$

where t1 and t2 represent two consecutive Census dates. Using this formula, the values of α were found to be .903 for the period June 1961 to June 1966, and .893 for the period June 1966 to June 1971. In other words, for every ten marriages in London approximately nine family households were formed. The monthly series for family households was generated using the following set of recursive relations:

Table 9

Population and Number of Households, City of London, 1961-1971

Year*	Population (pop)	No. of people in families (popf)	No. of family households (fhh)	Av. no. of people in family households (γ)	No. of people in non-family households (pop - popf)	No. of non-family households (nfhh)	Av. no. of people in non-family households (β)	No. of households (hh)
1961	169,569[a]	143,959[b]	39,668[c]	3.629	25,610	7,830[c]	3.271	47,498[a]
1966	194,416[a]	167,911[b]	45,809[d]	3.665	26,505	10,559[d]	2.510	56,368[a]
1971	223,222[a]	190,944[b]	54,210[e]	3.522	32,278	15,005[e]	2.151	69,213[a]

Sources: a) Households by Size (Catalogue no. 93-702), Table 1, Statistics Canada.
b) Families by Size and Type (Catalogue no. 93-714), Table 1, Statistics Canada.
c) Households by Type (Catalogue no. 93-511), Table 11, Statistics Canada.
d) Households by Type (Catalogue no. 93-605), Table 31, Statistics Canada.
e) Households by Type (Catalogue no. 93-703), Table 10, Statistics Canada.

Note: *Figures in table refer to June 1st.

$$fhh_t = \begin{cases} 39{,}244 \, , & t = \text{January } 1961^{20} \\ fhh_{t-1} + .902 \, m_{t-1} \, , & t = \text{February 1961 to June 1966} \\ fhh_{t-1} + .893 \, m_{t-1} \, , & t > \text{July 1966} \end{cases}$$

3. Household Permanent Disposable Income

There is no published or unpublished monthly source for disposable income per household for the City or, obviously, for permanent income, yp. Instead, we use, as a proxy for income, average monthly wages and salaries for the City of London from CANSIM (Matrix No. 1673.1).

4. Rate on Savings Deposits

The rate on savings deposits, rs, which we used was obtained from CANSIM (Matrix No. 2560.35).

5. Mortgage Rate

The source for the series on the mortgage rate, rm, is given in Section III.B.4.

6. Bond Rate

The source for the bond rate, rb, is given in Section III.B.5.

C. ESTIMATION OF HOUSE PRICE EQUATION

The equation in general functional form given in subsection A. above was estimated with a variety of lag structures. Several different

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[20] The figure for January was obtained by projecting back the Census stock for June 1961 using the following relation:

$$fhh_{t-1} = fhh_t - .902 \, m_{t-1} \, .$$

multi-period lags on income were attempted in order to better approximate the effect of <u>permanent</u> income on the price of housing. Any formulation of lag structures on income (and the other variables) resulted in insignificant coefficients on most of the other variables, which suggests that there is multicollinearity between income and some of the other variables. The income variable was therefore not retained in the equation.

The credit availability term, rm - rb, also failed to work in this equation. This is anomalous because a correct specification would appear to require the variable, for which we have a reasonable measure. Also, the variable was significant with the hypothesized sign in the rental rate equation. We have no convincing explanation for this result.[21]

Of the various lag structures attempted, without the income and credit availability variables, the most successful regression equation (in terms of t-statistics and R^2) was the following:

$$[9] \quad PEH_t = \underset{(2.79535)}{80{,}231.1} - \underset{(-2.78901)}{92{,}759.8}\,(KS_t/fhh_t) + \underset{(2.96245)}{78.0726}\,RR_{t-4}$$

$$+ \underset{(2.68937)}{69.9236}\,RR_{t-5} + \underset{(1.60308)}{7{,}599.99}\left(\frac{PEH_{t-5} - PEH_{t-6}}{PEH_{t-6}} \Big/ rs_{t-3}\right)$$

$$- \underset{(-1.7555)}{721.565}\,rm_{t-4}$$

---

[21]Also, we attempted to take account of the fact that the house price series is not adjusted for quality changes over time, by introducing a trend term into the equation. The stock of housing will change (improve) gradually over time and it will most likely do so at a constant rate: a trend term would therefore capture the expected quality changes. The formulations with the trend term included were unsatisfactory in that the term was never significant and it appeared to interfere with the effects of the other variables.

C.O.R.C.: ρ = .6306 (t = 7.5794)

P.D. = 65·7 - 66·1, 66·3 - 66·6, 66·9 - 71·5, 71·8 - 71·10, 72·2 - 73·10

N = 87

R^2 = .929

D.W. = 2.15

$F_{5,81}$ = 211.01

$Pr(F_{5,80} > 3{\cdot}65) = .005$

Note that rental rates enter the equation with both a four- and five-period lag, with a higher weight on the four-period lag. We suggest that this lag is due to an information lag on house prices, required search times for house buyers, and the role of leases in preventing renters from purchasing immediately. The results also suggest that prospective investors are influenced by the rate of change in house prices five periods back and the rate on savings deposits three periods back. The shorter lag on the savings deposit rate is reasonable since the information lag for this variable is not as long as for house prices. Finally, the mortgage rate acts with a four-period lag. This is reasonable since a prospective buyer must obtain a commitment for a mortgage at the time he signs an Offer to Purchase, which may be well in advance of the actual closing date. The actual rate he pays at the time of closing may be higher or lower than the initial rate quoted.

D. SPECIFICATION OF RENTAL RATE EQUATION

In formulating a decision on owning versus renting, households will consider both the cost of renting and the cost of purchasing and holding a single-family detached dwelling unit. The rental decision will also be affected by the availability of mortgage credit for the purchase of a single unit. The stock of other housing units per remaining household will also affect the level of rents with a higher (lower) stock per remaining household resulting in lower (higher) rents. Finally, income may be expected to influence the level of rents with higher incomes giving rise to a higher level of rents.

We may therefore write an equation for rental rates in general functional form as

$$RR_t = r(KO_t/RHH_t, yp_t, PEH_t, rm_t, rm_t - rb_t)$$

with the following hypotheses about signs:

- $\frac{\partial RR_t}{\partial (KO_t/RHH_t)} < 0$ since an increase in the stock per remaining household will reduce the demand for a typical unit;

- $\frac{\partial RR_t}{\partial yp_t} > 0$ since an increase in income will increase the demand for the existing stock of rental units;

- $\frac{\partial RR_t}{\partial PEH_t} > 0$ since higher house prices will induce a greater demand for rental units;

- $\frac{\partial RR_t}{\partial rm_t} > 0$ since higher mortgage rates will reduce the demand for owned single-family detached dwelling units and increase the demand for rental units; and

$$\frac{\partial RR_t}{\partial(rm_t - rb_t)} < 0$$

since a widening in the spread between the mortgage rate and the bond rate will induce greater mortgage availability, a higher demand for owned housing, and a reduced demand for rental housing.

Except for the stock variable, the independent variables in this equation may be expected to act with a lag because renters must form a decision about renting versus owning some time in advance of the rental or owning transaction and because they are further restricted from acting immediately because they are generally locked into leases on the properties they rent.

E. SOURCES OF DATA FOR RENTAL EQUATION

1. Rental Rates

The derivation for a series on rental rates, RR, is given in Section III.B.6.

2. Stock per Remaining Household

The derivation for the total stock of other housing units is given in Sections III.G., III.H., and III.I.

The number of remaining households, RHH, is defined to be the total number of households (family plus non-family) minus the number of single-family detached units, i.e.,

[11] $$RHH_t = hh_t - KS_t$$

$$= nfhh_t + (fhh_t - KS_t)$$

where $nfhh_t$ is the number of non-family households. To generate a series for the total number of households we first write a definition for the total population, as follows:

$$pop_t = \gamma_t \cdot fhh_t + \beta_t \cdot nfhh_t$$

where γ is the average number of people in a family household and β is the average number of people in a non-family household. Population, numbers of households and values of γ and β are presented in Table 9 for the Census years 1961, 1966 and 1971. Note that the values of γ and β change significantly over time. Rewriting this equation yields a formula for calculating the number of non-family households:

$$nfhh_t = \frac{pop_t - \gamma_t \cdot fhh_t}{\beta_t} .$$

Before applying this formula, we first generate monthly series for population and the average numbers of people in family and non-family households.

Population is assumed to grow geometrically, i.e.,

$$pop_{t+i} = (1 + r)^i \, pop_t$$

where r is the monthly rate of growth, assumed stable between Census dates, and i is the number of months for which the growth occurs. By manipulating this equation we derive a formula for calculating the monthly rate of population growth for the period between any two Censuses:

$$r = (pop_{t2}/pop_{t1})^{\frac{1}{t2 - t1}} - 1$$

where t1 and t2 represent two consecutive Census dates and t2 - t1 represents the number of months between the two dates. The values of r were found to be .00228 for the period June 1961 to June 1966, and .00231 for the period June 1966 to June 1971. In other words, the London population has been growing at a rate of approximately 0.2 per cent per month, or 2.8 per cent per year. The monthly population series is given by:

$$pop_t = \begin{cases} 167{,}648 \ , & t = \text{January } 1961^{22} \\ 1.00228 \ pop_{t-1} \ , & t = \text{February 1961 to June 1966} \\ 1.00231 \ pop_{t-1} \ , & t > \text{June 1966} \end{cases}$$

The monthly series for γ and β, the average number of people in family and non-family households, respectively, were determined in the same manner as described for the population series. That is, both γ and β are assumed to grow (decline) geometrically and two monthly rates of growth (decline) were calculated for each, one for the period before June 1966 and one for the period after. Thus,

$$\gamma_t = \begin{cases} 3.626 \ , & t = \text{January } 1961^{23} \\ 1.000165 \ \gamma_{t-1} \ , & t = \text{February 1961 to June 1966} \\ .999337 \ \gamma_{t-1} \ , & t > \text{June 1966} \end{cases}$$

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[22] The figure for January was obtained by projecting back the Census figure for June 1961 using the following relation:

$$pop_{t-1} = (1/1.00228) pop_t \ .$$

[23] The figure for January was obtained by projecting back the Census figure for June 1961 using the following relation:

$$\gamma_{t-1} = (1/1.000165) \gamma_t \ .$$

and

$$\beta_t = \begin{cases} 3.344\ , & t = \text{January } 1961^{24} \\ .995596\ \beta_{t-1}\ , & t = \text{February 1961 to June 1966} \\ .997431\ \beta_{t-1}\ , & t > \text{June 1966}\ . \end{cases}$$

The series for the number of non-family households may now be calculated. Given this series and the series for the number of family households, the series for the total number of households is simply their sum, i.e.,

$$hh_t = fhh_t + nfhh_t\ .$$

3. Household Permanent Disposable Income

For a discussion of this variable, yp, see subsection B.3. above.

4. Price of Existing Single-Family Detached Units

The derivation of the price of existing house variable, PEH, is described in Section III.B.2.

5. Mortgage Rate

The source for the series on the mortgage rate, rm, is given in Section III.B.4.

6. Bond Rate

The source for the bond rate, rb, is given in Section III.B.5.

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[24]The figure for January was obtained by projecting back the Census figure for June 1961 using the following relation:

$$\beta_{t-1} = (1/.995596)\beta_t\ .$$

F. ESTIMATION OF RENTAL RATE EQUATION

A variety of lag structures were attempted for the rental rate equation. The regression results given below exclude the (rm - rb) term. A regression with the (rm - rb) included gave very similar results, with the correct sign for the variable and a t-value of -2.72. The term was excluded from our final formulation because it was not significant in the house price and starts equations and because the coefficient on the (rm - rb) term in the rental rate equation was negative and higher in absolute value than the positive coefficient on the rm term in the same equation. This would mean that rental rates would decrease in policy experiments which consisted of increasing rm but letting the other exogenous variables take on their actual values. In the following equation, all of the variables are significant at the five per cent confidence level, with the hypothesized signs on the coefficients:

[10]

$$RR_t = \underset{(5.11747)}{188.508} - \underset{(-5.17242)}{172.689}\,(KO_t/RHH_t)$$

$$+ \underset{(2.50908)}{.00109550}\,PEH_{t-2} + \underset{(1.89809)}{.000843641}\,PEH_{t-3}$$

$$+ \underset{(1.73533)}{.142165}\,yp_{t-1} + \underset{(2.48184)}{.211103}\,yp_{t-2}$$

$$+ \underset{(4.95234)}{3.96992}\,rm_{t-3}$$

C.O.R.C.: $\rho = .2917567\ (t = 3.0041741)$

P.D. = 65·4 - 66·3, 66·6 - 71·7, 71·11 - 73·12

N = 97

$R^2 = .9484$

D.W. = 2.1636

$F_{6,90} = 275.70$

$Pr(F_{6,80} > 3.388) = .005$

The lags on the variables relating to the alternative form of housing (PEH and rm) are between two and three months. Income affects rents with both a one-period and two-period lag: a multi-period lag is expected since yp actually measures current wages and salaries (rather than permanent disposable income).

In the next section we outline a method for determining the stock of lots for single-family detached units.

V. STOCK OF LAND

The stock of land in the model is endogenous but predetermined. The following subsections outline the determination of the stock equation and show some related information on the variable.

A. SPECIFICATION

We are concerned with specifying an equation for the number of lots zoned and approved, by the subdivision process, for the construction of single-family detached dwelling units. The stock is augmented by subdivision approvals and depleted, by definition, by construction starts of single-family detached units. The equation may therefore be written as

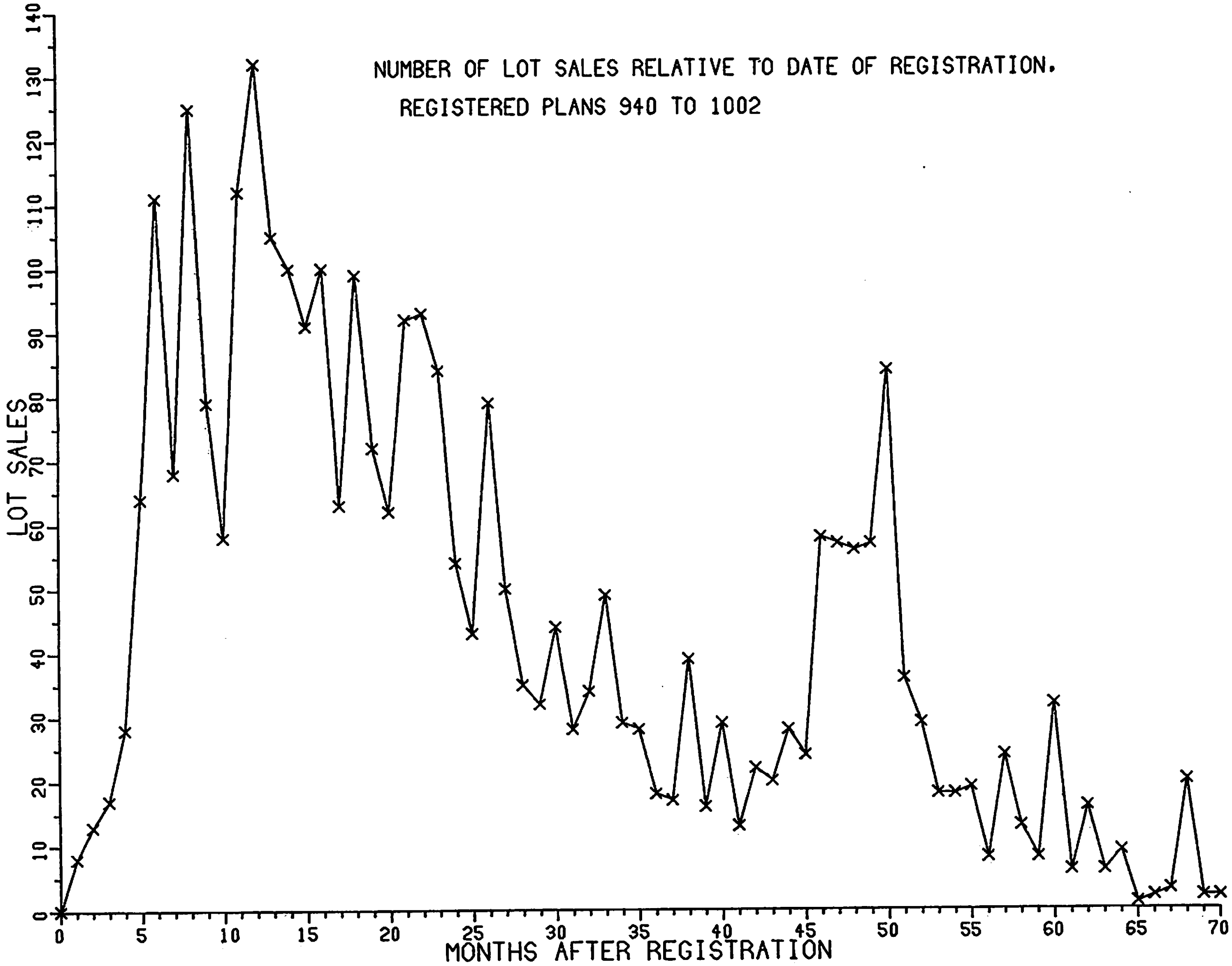
[12] $$KL_t = KL_{t-1} - SS_{t-1} + n\ell_{t-1}$$

where KL is the number of single-family detached lots and $n\ell$ the number of new lots created by the registration of subdivision plans and their accompanying agreements.

Analysis of the stock of land defined in this way implies that lots, once their subdivision plans and agreements are registered, are assumed to be reasonably homogeneous, although in fact they may carry varying amounts of servicing between the time that they are registered and have a housing start constructed on them. Our approach is based on the fact that lots do not legally exist as such until the registration of the agreement occurs but that, when it does, the lots in the subdivision must normally have services provided for them within a specified minimum time period.

Some data which bear on this issue are available from our file of land transactions. Figure 13 shows a frequency distribution of the number

Figure 13


NUMBER OF LOT SALES RELATIVE TO DATE OF REGISTRATION.
REGISTERED PLANS 940 TO 1002
LOT SALES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
MONTHS AFTER REGISTRATION
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

of transactions in single-family detached lots relative to the date of registration of the subdivision plan and agreement.[25] The overall distribution of sales peaks at twelve months from the date of registration. There are no transactions in lots prior to the date of registration of the subdivision plan and agreement. Based on this information, our assumption about homogeneity appears reasonable since many transactions occur shortly after the registration date of the subdivision; for example, the third highest peak in the frequency distribution occurs at only seven months from the date of registration.

B. SOURCES OF DATA

1. Single-Family Detached Housing Starts

The source for our series on single-family detached housing starts, SS, is given in Section III.B.1.

2. Number of New Lots Created

The number of new lots created by the registration of subdivision plans and their accompanying agreements was obtained by referring to all subdivision plans and agreements which were registered over the entire period. The approved use for each plot of land in each subdivision registered over the period was determined by referring to the actual subdivision plan and agreement and, when there was some doubt, by referring to City land use maps which show the type of dwelling constructed on each parcel of land in the City. In cases where registered plans

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[25] Some of these transactions may involve the same properties changing hands more than once. The possible extent of an "intermediate" market in lots is discussed in Section VI.

modified parts of earlier plans, the lots affected were considered part of the newer plan and were excluded from our count of lots in the previous plan. There is therefore no rate of 'depreciation' of the stock of lots: if a lot was approved for the construction of a single-family detached dwelling it eventually must have received this use. If not, it was not added to the stock at the point of registration of the subdivision plan. Therefore, the only depletion of the stock occurs through single-family detached housing starts--once a lot has a housing start on it, it is no longer a 'vacant' lot for sale as such.

3. Stock of Land

The stock of vacant lots on February 1, 1974 was obtained from Inventory of Applications for Residential Development, City of London Planning Department. Application of the above equation for the stock therefore permitted solution of the KL series from 1963 to 1973 for use in estimating subsequent equations in the model.

C. ESTIMATION

Since the supply of land is assumed to be predetermined, no estimation is involved for this equation. Some further comments on the $n\ell$ series are warranted, however.

For the purposes of the model, we let $n\ell$ be exogenous. In fact, the number of lots brought onto the market in any month will depend in part on the expected profitability of subdivision in some previous time period. However, the lag between initiating development and the date of subdivision approval may be, and normally is, as long as three years, so that no problems arise in policy experiments with the model as a result of assuming that $n\ell$ is exogenous, since the time period for subdivision development is longer than the time period to be used in experiments with the model. The variable $n\ell$ is taken to be a policy variable in the model in that the City and Province can influence, within limits, the rate at which subdivision development occurs. As is well known, the subdivision process is extremely long and costly, involving a number of municipal and provincial agencies. Our assumption that $n\ell$ is exogenous recognizes that the rate of subdivision approval can be altered by the bureaucracies involved[26] or by a policy of land banking, which is practiced in some cities in Canada and being actively discussed and encouraged in other cities by higher levels of government.

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[26]Some simple explanatory equations for the $n\ell$ series may be attempted in future work with this model. New lots approved might depend on a distributed lag function of past changes in lot prices relative to some measure of land development costs. (In such a specification the policy analysis would involve arbitrarily changing the lag structure.) No very detailed specification will be attempted, however, since the land development process is very complex and such an analysis is beyond the scope of this study.

VI. LAND PRICES

In this section we describe the development and estimation of an equation for the price of lots which are zoned and approved for the construction of single-family detached dwelling units. Since the supply of lots is exogenous in the current period, the price of lots is demand-determined. The formulation of the price equation includes an expected profitability term but, in this equation, it is the expected rate of change of profitability from constructing and selling houses which affects the current price of lots. An equation in general functional form is developed in the next subsection.

A. SPECIFICATION

We first postulate that the price of lots is related to the stock of lots per household--a higher (lower) stock per household decreases (increases) competition in bidding for lots and hence decreases (increases) the observed market price for lots.

Some speculative or asset demand term may be appropriate in this equation, analogous to the asset or investment demand for houses. Individuals or builders may purchase lots and resell them without constructing dwellings on them, with the intention of realizing a capital gain. Our examination of lot transactions suggests that there is no such important 'intermediate' market in lots. Table 10 shows the number of dual transactions in lots, the interval between the two transactions (in months), and the average absolute increase in sale price. There are a total of 106 dual transactions over the period 1967-73. These dual transactions are 106 ÷ 3964 = 2.7 per cent of all transactions in lots

Table 10

Dual Transactions in Lots, City of London, 1967-73

Number of Dual Transactions	Interval Between Transactions (months)	Average Absolute Increase in Sale Price
28	0	$2,652
10	1	3,986
10	2	4,240
2	3	1,200
2	4	3,450
2	5	-200
5	6	950
5	7	1,419
3	8	1,333
8	9	738
1	11	1,000
6	12	1,936
2	14	975
2	15	1,200
2	16	1,250
1	17	0
7	18	1,696
1	21	8,000
2	25	2,225
1	28	2,400
1	30	4,250
1	32	1,000
1	44	3,500
1	45	4,250
1	48	-2,840
1	50	4,750

Notes: A few of the dual transactions shown in column 1 involve the same lot transacting <u>three</u> or more times.

over the same period. Inspection of these transactions reveals that they are mostly from developer to builder to private individual. Because these dual transactions are such a small proportion of all transactions and because they may be motivated by considerations other than the expectation of a capital gain (e.g., a builder simply reducing an excess inventory of lots), our specification of this equation does not include a term reflecting speculation in undeveloped lots.

Although builders do not appear to speculate in undeveloped lots, they may be motivated by an expected capital gain applying to developed properties. Our specification of a lot price equation therefore recognizes that builders buy lots from developers, construct houses on these lots and then sell these lots and finished houses with the intention of realizing a profit which may have a capital gain component applying to the land or house, or both. The expected profitability of building and selling houses therefore affects the builders' offer price for land. The expected rate of change of profitability is defined as

$$\dot{PEH}_t^e - \dot{RC}_t^e$$

where $\dot{RC}_t^e$ is the expected nominal rate of change in the construction cost index. $\dot{RC}_t^e$ is defined as

$$\dot{RC}_t^e = \frac{RC_{t+i+1}^e - RC_{t+i}^e}{RC_{t+i}^e}$$

where RC^e is the expected value of the residential construction cost index. Since a builder has alternative investments open to him, we use the expected <u>relative</u> change in profitability from building and selling houses, which is the nominal rate divided by rd, the rate on chartered bank 90-day deposit receipts; i.e., the relevant independent variable is

$$(\dot{PEH}^e - \dot{RC}^e_t)/rd_t \ .$$

A builder's bid price will also be related to the financial cost of holding the land until he begins construction and can obtain mortgage financing. We therefore postulate that the price for land will be negatively related to the prime rate of interest, rp. Whether a builder may borrow at this rate will depend on the size of his operation and his credit worthiness, but at least some builders will be considered prime borrowers by financial institutions and, for those who are not, the rate at which they may borrow will be related to the prime rate.

The formulation written in general functional form is therefore

$$PL_t = \ell\left(\frac{KL_t}{hh_t} \ , \ (\dot{PEH}^e_t - \dot{RC}^e_t)/rd_t \ , \ rp_t \right)$$

and our hypotheses concerning signs are:

- $\dfrac{\partial PL_t}{\partial (KL_t/hh_t)} < 0$ since an increase in the number of lots per household will reduce competition in bidding for lots;

- $\dfrac{\partial PL_t}{\partial (\dot{PEH}^e_t - \dot{RC}^e_t)/rd_t} > 0$ since an increase in the expected relative rate of change in profitability from building and selling houses, ceteris paribus, will increase the bid and observed price of lots; and

- $\frac{\partial PL_t}{\partial rp_t} < 0$ since an increase in land carrying costs (interest charges) will reduce bidding for lots.

Two factors which may affect the price of lots are excluded from this specification: changes in average lot sizes and changes in the extent of servicing of land over time. At this stage, we have no measure of lot size for those properties which transacted but a measure of average lot size by subdivision plan for a sample of lots in each subdivision by date of registration of the subdivision plan and agreement has been derived and is shown in Table 11. The sample consists only of those lots in the subdivision for which the areas are given on the assessment rolls. It is apparent from Table 11 that there is wide variation in average lot size between subdivision plans. Table 12 summarizes this information on an annual basis, showing a weighted average of the last column in Table 11 for all samples in plans registered in each year. The weights are the number of lots in each sample divided by the total number of lots in all samples for the year. A trend toward smaller average lot sizes is apparent from Table 12. Average lot sizes decreased from about .20 acres at the beginning of the period to about .12 acres at the end of the period, except for the one sample in 1973.

Although we have no data on the amount of servicing carried by lots, because of the problem of measuring the level of servicing, new lots did carry increased levels of servicing over this period. The level of servicing of land represents a change in quality which would be expected to influence lot prices positively. The changes in lot size and level of servicing therefore work in opposite

Table 11

Average Lot Size for a Sample of Lots by Subdivision Plan, City of London

Subdivision Plan Number	Date of Registration Mo/Day/Yr	Number of Lots in Plan	Number of Lots in Sample	Average Lot Size (acres)
903	4/20/61	91	35	.278
904	4/26/61	168	37	.170
910	6/23/62	430	132	.178
912	8/29/62	140	56	.162
916	12/ 3 /62	332	161	.175
921	4/ 2 /63	319	175	.128
922	6/ 4 /63	131	59	.158
924	11/13/63	373	91	.141
928	1/ 4 /64	138	83	.140
930	2/ 6 /64	114	24	.147
934	9/24/64	126	69	.105
936	11/ 4 /64	109	41	.170
937	11/23/64	69	23	.156
940	1/20/65	337	108	.148
941	2/11/65	136	71	.158
944	9/20/65	278	166	.124
956	3/14/67	96	23	.132
959	6/ 8 /67	138	63	.170
961	7/26/67	269	162	.101
962	9/28/67	285	121	.152
963	10/11/67	186	66	.136
966	5/24/68	239	98	.122
971	8/16/68	259	103	.118
972	10/28/68	348	109	.139
973	12/ 3 /68	280	128	.123
976	4/11/69	245	79	.147
977	4/29/69	231	116	.128
979	7/10/69	413	162	.183
980	8/14/69	76	31	.301
987	5/27/70	331	56	.108
988	6/ 4 /70	203	116	.110
990	5/ 6 /71	120	58	.140
991	3/ 1 /71	356	181	.103
1002	8/24/72	101	32	.119
1012	10/30/73	74	37	.539

Notes: The lots included in each sample are those for which lot sizes are given on the assessment rolls. The samples included in this table are only those which have more than 21 lots in them and which have a number of lots in them greater than ten per cent of all lots in the subdivision plan.

Table 12

Average Lot Size for Sample of Lots, for Subdivision Plans Registered Yearly, City of London, 1961-73

Year of Registration of Plan(s)	Average Lot Size for Sample(s) of Lots in Plan(s) (acres)
1961	.223
1962	.174
1963	.137
1964	.137
1965	.139
1967	.132
1968	.126
1969	.169
1970	.109
1971	.112
1972	.119
1973	.539

directions: we simply assume here that they offset each other in terms of their effects on lot prices. Although this assumption is motivated by the lack of a proper lot size variable and by the impossibility of formulating a reasonable measure of lot servicing, it is not an unreasonable assumption since the two variables will in any case change slowly over time and, as noted, their effects work in opposite directions. In fact, the decrease in average lot sizes will be caused in part by, or at least facilitated by, an increase in the level of servicing because lots which do not connect with the municipal sewerage system must, by law, be larger in order to accommodate waste flow into septic tanks, i.e., larger lot size is, in this sense, a simple substitute for a lower level of servicing.

B. SOURCES OF DATA

1. Price of Lots

The Teela Digest Monthly Realty Sales Review gives data on transactions in lots for the city. It was possible to determine whether each lot was approved for single-family detached use by referring to city land use maps which show the type of dwelling constructed on each parcel of land in the city and by referring to the subdivision plan which created the property in question. The property description (usually subdivision plan and lot number), the sale price, and the date of closing were coded for each transaction in single-family detached lots in the city. The variable PL is simply the monthly median sale price of these lots. The median was calculated using existing computer programs. It is used in order to avoid the effects of unusually large or small observations in any month.

2. Stock of Lots

The series on the stock of lots, KL, is described in Sections V.A. and V.B.

3. Price of Houses

The variable, price of existing single-family detached housing units, PEH, is discussed in Section III.B.2.

4. Residential Construction Cost Index

The estimation of a series for residential construction costs, RC, is covered in Section III.B.3.

5. Rate on Chartered Bank 90-Day Deposits

The rate on 90-day deposits, rd, was taken from CANSIM (Matrix No. 2560.18).

6. Prime Rate of Interest

A monthly series for the prime interest rate was obtained from CANSIM (Matrix No. 2560.2).

C. ESTIMATION

Concerning the specific functional form for this regression equation, there is no reason to expect the relationship between price and stock to be strictly linear. An examination of the data suggests, in fact, that the price of land is a non-linear function of the number of lots per household, KL/hh. For this reason, the stock variable appears in the regression equation as a quadratic, i.e., as

$$\hat{\beta} \cdot \frac{KL_t}{hh_t} + \hat{\gamma} \cdot \left(\frac{KL_t}{hh_t}\right)^2$$

where $\hat{\beta}$ and $\hat{\gamma}$ are the empirically-determined coefficients. The hypotheses are that $\hat{\beta} < 0$ and $\hat{\gamma} > 0$.

Our earlier discussion of the stock of land series and the frequency distribution of lot sales relative to date of registration of the subdivision plan given in Figure 13 suggests that the stock variable enter the land price equation with a lag. Of the various lags attempted, the best results (in terms of t-statistics and R^2) were obtained when the stock variables were lagged four periods. The expression for this part of the equation therefore becomes

$$\hat{\beta} \cdot \frac{KL_{t-4}}{hh_{t-4}} + \hat{\gamma} \cdot \left(\frac{KL_{t-4}}{hh_{t-4}}\right)^2 .$$

The data further suggest that a structural shift in this relationship occurred early in 1969. After January 1969, lots traded for consistently higher prices, regardless of the number of lots per household, than before this month. This shift is apparent in the plot of lot prices shown in Figure 3. This result holds even when the price variable, PL, is deflated by the consumer price index for Canada.[27] There is no other relevant variable which explains this jump in price. It is reasonable to suppose that the explanation lies in the more restricted land use policies adopted by the City as part of its Official Plan. One important component of the Official Plan involved the introduction of staging, whereby large blocks of land were to be held off the market to control the city's growth. Although the Official Plan was not introduced until 1971, the staging and other policies were known and vigorously discussed well in advance of their introduction. The expectation that the stock of single-family lots would become restricted could have triggered a sustained speculative increase in price or the increased costs in terms of restrictive controls and

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[27]From CANSIM (Matrix No. 193.1).

uncertainty may have led to a once-and-for-all shift in price.[28] In our expression for the equation this phenomenon is represented as a change in the value of the constant, i.e., our expression for the first part of the equation now reads

$$\hat{c} + \hat{\alpha} \cdot dp_t + \hat{\beta} \cdot \frac{KL_{t-4}}{hh_{t-4}} + \hat{\gamma} \cdot \left(\frac{KL_{t-4}}{hh_{t-4}}\right)^2$$

where $dp_t = \begin{cases} 1 & t \geq \text{January 1969} \\ 0 & \text{otherwise.} \end{cases}$

Concerning the expected change in profitability, we hypothesize that builders form their expectations about future rates of change based on the rate of change in some past periods (or periods). Likewise, the term for the rate on 90-day deposit receipts may enter the ratio with a lag and this lag may be different from the lag on the rate of change in profitability. Although a builder must invest at the current 90-day rate, a lagged formulation is appropriate because of an information delay and because a builder must decide on a purchase some time in advance of the actual closing date of the transaction. We attempted a variety of lag structures on both the rate of change of relative profitability measure and the 90-day deposit rate and found the best results (in terms of the t-statistic and R^2) for a four-period lag on the profitability measure and a three-period lag on the 90-day deposit rate, as reported below.

The same general considerations concerning lags apply to the prime

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[28]The implication is that there is a social cost, in terms of the price of housing, associated with controlling growth by planning techniques such as Official Plans. Further investigation of these effects of planning, although warranted, is beyond the scope of this paper.

rate as for the 90-day deposit rate but the best results were obtained when the current value of this rate was included.

Of the various equations estimated, the regression which best fits our specification is as follows:

$$[13] \quad PL_t = \underset{(9.70982)}{8,232.80} + \underset{(15.0515)}{2,164.56} \cdot dp_t$$

$$- \underset{(-3.82611)}{118,618.} (KL_{t-4}/hh_{t-4}) + \underset{(2.62258)}{857,320.} (KL_{t-4}/hh_{t-4})^2$$

$$+ \underset{(2.50040)}{15,215.0} \left(\frac{PEH_{t-4} - PEH_{t-5}}{PEH_{t-5}} - \frac{RC_{t-4} - RC_{t-5}}{RC_{t-5}} \right) / rd_{t-3}$$

$$- \underset{(-1.30752)}{91.0710} rp_t$$

O.L.S.

P.D. = 65·6 - 66·1, 66·3 - 66·5, 66·8 - 71·5, 71·8 - 71·9, 72·1 - 73·10

N = 93

R^2 = .8383

D.W. = 1.8615

$F_{5,87}$ = 90.21

$Pr(F_{5,80} > 3.654) = .005$

Based on these results, builders appear to form their expectations about future prices and costs primarily on the basis of the rate of change in the profitability of building and selling houses four months prior to the current period. The corresponding lag on the rate of return on an alternative investment, rd, is three months. On the other hand, the cost of borrowing, rp, acts without a lag. All the coefficients are of the hypothesized signs and are significant at, at least, the 10 per cent level of confidence.

VII. MODEL SOLUTION AND POLICY ANALYSIS

In this section we show the solution of the model from 1965 to 1973 and demonstrate its use in evaluating the effects of changes in the supply of single-family detached lots. The latter exercise illustrates the dynamic behavior of the model and the interrelationships between the land and housing markets and it permits an assessment of the effects of changes in land supply on lot prices, housing capacity, and housing prices and rents. Two subsections follow: the first of these shows the solution of the model when all exogenous variables take on their actual values and the next shows the results of an experiment in which the number of new lots created, $n\ell$, is increased in February 1967.

A. MODEL SOLUTION

In this subsection we show simulations with the model in which all exogenous variables take on their actual values. The simulated values of the endogenous variables are then compared to actual values over the time period. This experiment therefore tests the "tracking" ability of the model, i.e., its ability to generate time paths for the endogenous variables, based on exogenous information only, which follow the actual time paths for the endogenous variables. This exercise is important because, if the model does not track especially well, we can have little confidence in the policy experiments, because failure of the model to track properly indicates that some or all of the functions in the model, either independently or together, do not properly describe the behavior which they are intended to.

The experiment starts in October 1965 because it is necessary to supply lagged values of endogenous variables up to sixteen months prior to the first solution month and October 1965 is the earliest month for which all of the necessary lagged values are available. The model is simultaneous but recursive, i.e., the endogenous variables which appear unlagged as independent variables in some equations may be solved with reference only to other lagged endogenous or current and lagged exogenous variables. An iterative technique is therefore not required in order to solve the model and the solution of the model is unique, given an appropriate ordering of equations. The experiment runs until December 1973 and includes a total of ninety-nine solution periods.

There are no widely-accepted criteria for testing the tracking behavior of a model such as this one. We formulate and employ three related measures of tracking ability: (1) an average of the absolute deviations in the simulated values of the variable from the actual values, as a per cent of the average actual value of the variable; (2) the per cent of changes in the level of the variable which are simulated correctly; and (3) the difference between the average actual and solution values of the variable in the last six months of the simulation period as a per cent of the average actual value of the variable in the last six months. The first measure is defined as

$$\sum_{t=65\cdot 10}^{73\cdot 12} \left(\frac{|Y_t^s - Y_t^a|}{Y_t^a} \right) * \frac{100}{n}$$

in which Y_t^s is the simulated value of the endogenous variable, Y_t^a the actual value of the variable, and n is the number of observations.[29] It is

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[29]Data for some months on a few of the endogenous variables are missing: these months are simply excluded from the calculation. Also, in a few cases, Y_t^a takes on a value of zero. These cases are likewise omitted from the calculation, to avoid division by zero.

necessary to use the absolute value of the difference because positive and negative differences would otherwise cancel out and the sum would give misleading results. The differences are taken as per cents of the actual values to give some indication of the importance of the error relative to the level of the variable, e.g., a ten-dollar average absolute difference in monthly rents is more important than the same average difference in monthly house prices. This measure is shown in Table 13 for single housing starts (SS), housing starts of other types of units (SO), the stock of single-family detached housing units per family household (KS/fhh), the stock of other units per remaining household (KO/RHH), median house prices (PEH), median rents (RR), the stock of land (KL), and the price of lots (PL).

The second measure is defined as the per cent of times the simulated value of the variable moved in the same direction as the actual value of the variable. The first measure gives some indication of how closely the model tracks in terms of generating levels for variables which are close to their actual levels; the second measure is intended to describe the ability of the model to generate changes in levels which correspond to actual changes in levels. This latter measure therefore attempts to describe the degree to which the model accurately characterizes the dynamic behavior of the system. This calculation for each of the above eight variables is also shown in Table 13.

The third and final measure is defined as the difference between the average simulated and actual values over the last six months of the simulation period as a per cent of the average actual value of the variable over the same period, i.e., as

Table 13

Measures of Tracking Ability of Model, 1965·10 - 1973·12

Variable	Measure		
	Average Absolute Per Cent Error	Per Cent of Changes Simulated Correctly	Per Cent Difference Between Last Six Values
SS	27.47	50.51	26.11
SO	215.6	52.53	86.13
KS/fhh	.5821	73.74	.9301
KO/RHH	3.236	50.51	7.233
PEH	7.996	53.19	19.46
RR	8.243	52.53	18.14
KL	3.384	96.97	2.933
PL	11.36	60.64	3.669

$$\frac{\sum_{73\cdot 7}^{73\cdot 12} Y_t^s - \sum_{73\cdot 7}^{73\cdot 12} Y_t^a}{\sum_{73\cdot 7}^{73\cdot 12} Y_t^a} * 100 .$$

The reason that this measure is used, in addition to the other two, is that the previous two measures may appear to indicate that the solution value is not diverging from the actual value, whereas in fact it may. For example, if a variable is increasing monotonically over time the model may capture all, or most, of the positive changes and the average solution value may not differ greatly from the average actual value, but the simulated values at the end of the period may diverge significantly from the actual values. The last six values are compared in order to avoid misleading results which may arise from an unusually accurate (or inaccurate) simulated value in the single terminal month. This measure for the same eight variables is also shown in Table 13.

Of the eight variables shown, the model tracks starts of other units relatively poorly. Just over half the turning points in other starts are simulated correctly, the average absolute error in the variable is 216 per cent, and the average terminal difference is about 86 per cent. In terms of a goodness of fit criterion, this equation in the model is inferior to the others. This arises because of the very wide monthly fluctuation in multiple starts, which is to be expected in a city the size of London. In fact, starts of other units in many months are zero whereas in other months they are quite large, as construction is started on large apartment buildings. The relatively poor performance of the model here is not critical to the other simulation results because the model tracks the stock of other units very well: the average absolute deviation in the total stock of other units is 2.97 per cent, 100 per cent of the turning points are simulated correctly, and the average simulated terminal values differ from the average actual terminal values by 5.95 per cent. The ability of the model to track the other variables is somewhat better than for starts of other units.

B. INCREASE IN NEW LOTS IN 1967

In the experiment described in this subsection the policy change consists of an increase in February 1967 of 250 in $n\ell$, the number of single-family detached lots added to the total stock of lots. This number of lots corresponds to the registration of a medium-sized subdivision plan. February 1967 was chosen as the month for this policy change for two reasons. First, as evident from Figure 3, the stock of vacant lots was at its lowest level for the pre-1971 period in March 1967. That is, in the period during which experimentation with the model is possible, the situation which corresponds most closely to the current situation in the City of London occurs early in 1967. The second reason for the choice of February 1967 is that, for a simulation which begins in October 1965, February 1967 is the first month in which the model can generate policy results on the basis of solved endogenous variables only, rather than some mix of actual and solved endogenous variables. As explained in the previous subsection, October 1965 is the earliest month for which simulation is possible. The experiment terminates in June 1970, three years after the initial change in the price of land, because changes in land prices would be expected to result in changes in $n\ell$ for periods longer than three years, and we are treating $n\ell$ as an exogenous variable.

Before turning to the results of this experiment, we first inspect the important dynamic relationships in the model and the interrelationships between the single-family detached land and housing markets, in order to be better equipped to intuit the simulation results. These relationships are shown schematically in Figure 14. Note that the rental market is excluded from this schema and from the discussion which follows.

The dynamics of the model and the various equilibrating mechanisms may be illustrated by assuming an increase in the number of new lots, $n\ell$. The number of new lots may increase as a result of some past land use policy change (including public land assembly--land banking--and public land development) or a current change in zoning regulations. This increase is shown on the left of Figure 14. The increase augments the stock of vacant lots available, by definition, in the next time period. Lot prices in this period therefore fall initially, as a result of the higher stock. Decreased lot prices imply lower housing production costs (for land, labour, and materials). Given house prices, lower housing production costs result in a higher level of housing starts in subsequent periods which are in turn added to the stock of dwellings per household.

Two subsequent effects ensue. First, the higher level of housing starts depletes the stock of vacant land, which causes a secondary increase in the price of lots and in housing production costs.[30] Second, a higher stock of dwellings per household reduces house prices. With

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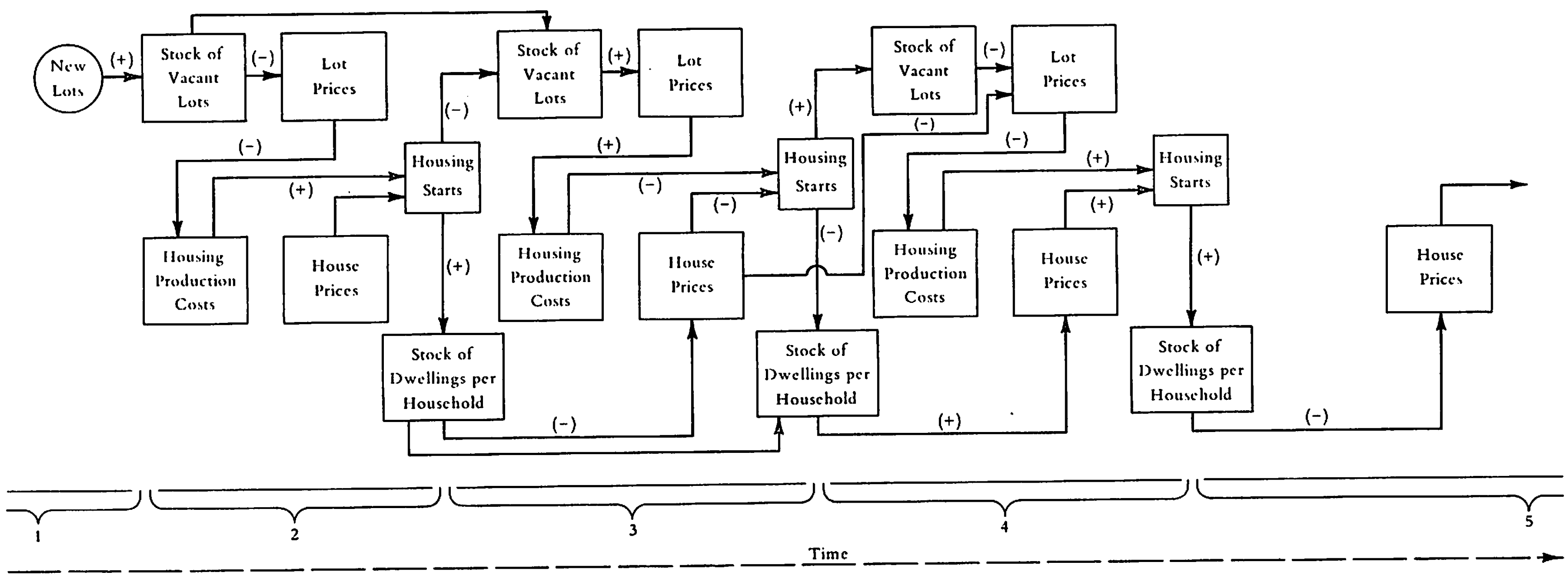
[30] In Figure 14, a (+) or (-) indicates the effect of the most recent change in the variable at the source of the arrow on the variable at the end of the arrow and not the net or cumulative effect of the one variable on the other.

Figure 14

Schematic Representation of Model



house prices lower and housing production costs higher than in the second time segment, housing starts undergo a secondary decrease. These two effects carry into the fourth time segment, i.e., the secondary decrease in housing starts tends to increase the stock of vacant lots, which lowers lot prices and housing production costs, and it tends to decrease the stock of dwellings per household, which increases house sale prices. In addition to these two effects, there is a third effect relating the third and fourth time segments. The first change in house prices (a decrease, in the third time segment) causes builders to anticipate lower profits from buying lots and building houses: they therefore bid less for land in the third time segment, ceteris paribus. The tendencies for the stock of vacant lots to be higher and house sale prices to be lower in the third time segment therefore both act to reduce lot prices in the fourth time segment.

The same effects carry into the fifth time segment, etc. We would anticipate that, on the basis of the theoretical model in Section II and inspection of the equations of the empirical model, that the cumulative effect of an increase in the number of lots would involve a higher stock of dwellings per household and a lower price for single-family detached dwelling units.

The effects of a one-time increase in $n\ell$ of 250 in February 1967 are assessed by comparing the results from this policy experiment with the results from a standard case or reference simulation in which all of the exogenous variables take on their actual values over the whole time period. Figure 15 shows the time paths of the difference between the policy experiment values and the standard case values for single starts (SS), single completions (CS), other starts (SO) and other completions (CO); Figure 16 shows the time paths of this difference for the stock of land

Figure 15

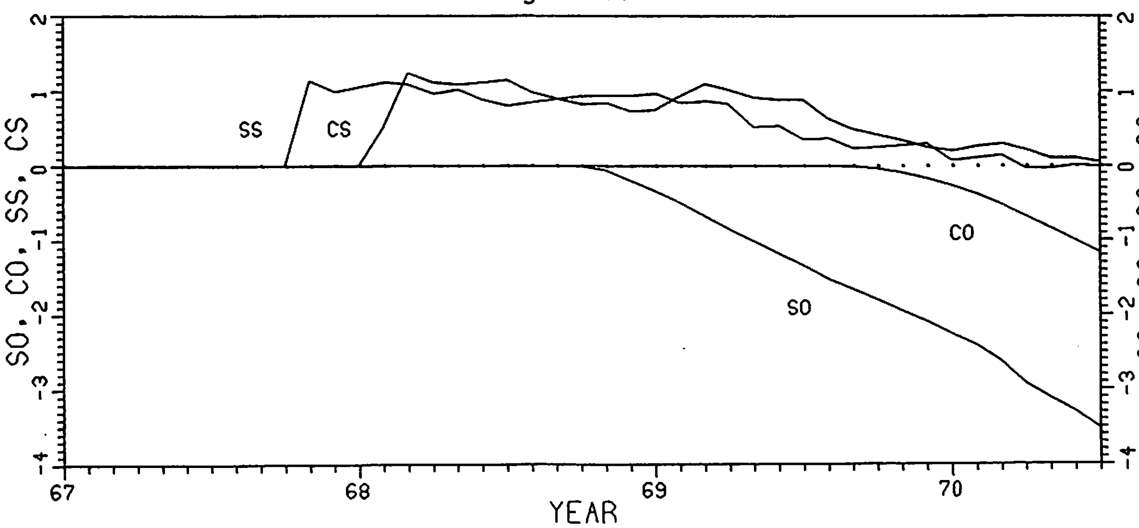


Figure 16

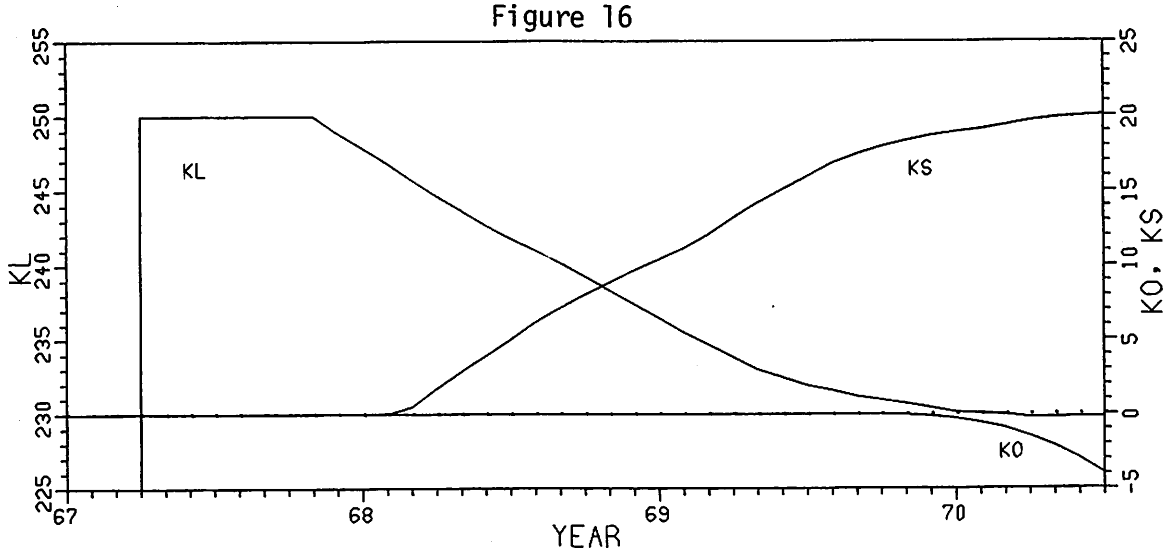
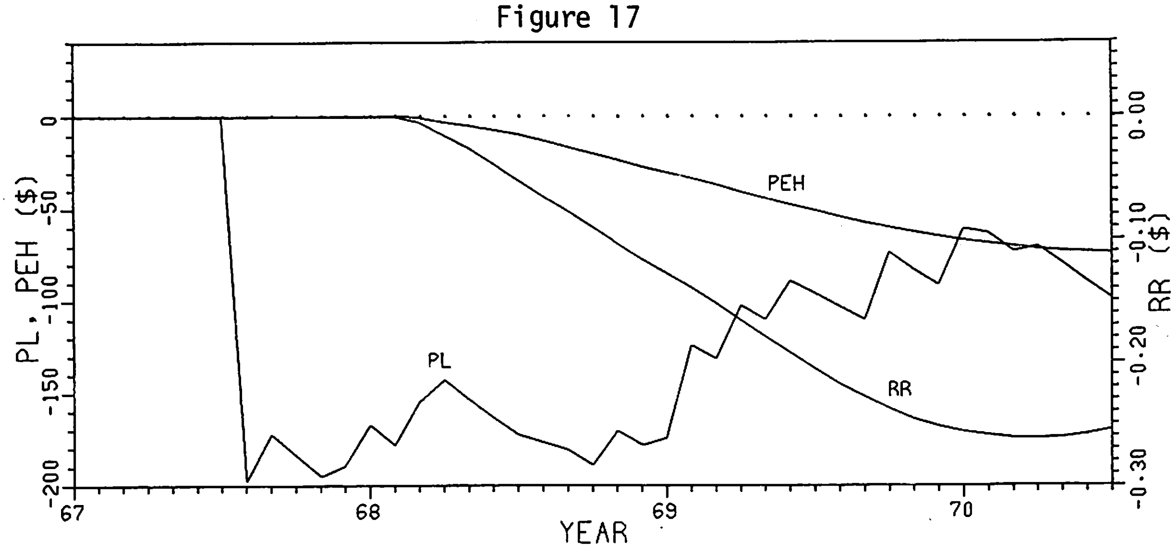


Figure 17



(KL), the stock of single units (KS) and the stock of other units (KO); finally, Figure 17 shows the time paths of this difference for the price of land (PL), the price of existing houses (PEH) and rental rates (RR). The dotted line in each figure indicates the zero axis, except in the case of the stock of land (KL) where it indicates the terminal difference in the stock (230 lots).

We first analyze the dynamics of this experiment with reference to these figures and to the estimated equations of the model. We postpone for the moment an analysis of the magnitude of the changes brought about by the policy change and a discussion of the effectiveness of $n\ell$ as a policy variable.

By the definition of the stock of land in equation [12], the increase of 250 in $n\ell$ in February 1967 brings about an increase of 250 in the stock of land, KL, in the next month, March 1967. This implies a relative increase in the stock of lots per household, which has a lagged impact on lot prices (equation [13]): four months after the increase in KL, i.e., in July 1967, the price of land, PL, decreases from the standard case experiment by almost two hundred dollars per lot, as shown in Figure 17. The lower price for land means, by the definition in equation [4], a lower cost of producing single-family detached houses, SDC. This in turn implies increased profitability in building and selling houses, given unchanged house prices. Builders respond to this increase in profitability after a lag of three months (equation [1]): single starts, SS, therefore increase over the standard case experiment, in October 1967.

By the definition of the stock of lots in equation [12], this increase in single starts begins the depletion of the additional stock of lots beginning in November 1967. Single housing starts remain at a higher monthly level than the standard case for as long as the decrease in lot prices is greater than the decrease in the price of houses. Consequently, the depletion of the initial increase in the stock of land continues for the entire period as shown in Figure 16, although the decreases in the stock of land level off toward the end of the period as the decreases in the prices of houses and land equalize. The increase in the number of vacant lots per household is also eroding over the period but more erratically than the increase in the total stock of land, due to uneven growth in the number of households. This shows up over the entire period, through the price of land equation [13], in an irregular narrowing of the difference in the price of land between the experimental and standard case values, as shown in Figure 17. There is no incentive for an increase in single starts greater than the initial increase which occurred in October 1967 as a result of the decrease in lot prices.

Through the single-family detached completions equation [5], the increase in single starts after September 1967 results in an increase in single completions, CS, after a construction lag. The initial increase in SS occurred in the fourth quarter of 1967: the construction lag is longer for starts in this quarter than starts in other quarters. An increase in completions of single units over the standard case is therefore not registered until December 1967, three months after the change in single starts. Thereafter, the relative increase in completions follows the pattern of starts with about a two month lag.

By the definition of the stock of single units in equation [7], the increase in single completions brings about an increase over the standard case in the stock of single units, KS, beginning in January 1968 and continuing to the end of the period, as illustrated in Figure 16.

The increase in the stock of single-family detached housing has an immediate impact in both the market for single-family housing and the market for other housing. It implies an increase over the standard case in the stock of single-family housing per family household and this, through the price of existing housing equation [8], brings about lower house prices relative to the standard case. As the increase in stock grows, the spread in house prices between the experiment and the standard case widens, although it does so at a decreasing rate, as shown in Figure 17. The market for other housing is also affected. Because the increase in the stock of single-family housing is occupied by households previously in other housing, the number of remaining households, RHH, declines, by the definition in equation [11]. This means that the stock of other housing per remaining household increases over the standard case. Through the rent equation [10], this results in lower rental rates beginning in February 1968; rents become relatively lower in each subsequent month until April 1970, as shown in Figure 17. Furthermore, the movements in house prices and rents complement each other through their respective equations [9 and 10], so that their decline relative to the standard case is uninterrupted.

As the price of houses decreases and the drop in the price of land moderates, the initial increase in the profitability of producing single-family housing falls to zero. The increase of single starts over the standard case disappears by the end of the period (see Figure 15), and the stocks of land and single housing stabilize (see Figure 16) as do the prices of land and existing housing (see Figure 17). It would appear that the single-family land and housing markets have reached a new equilibrium by the end of the period, June 1970.

This is not the case in the market for other housing. The drop in rental rates over the standard case means a lower rent to construction cost ratio and this, through the other starts equation [2], brings about a lower level of other starts beginning in October 1968 after an eight-month lag. This decline increases in each subsequent month to the end of the period, as illustrated in Figure 15. The minimum construction lag in the other completions equation [6] is ten months so the decline in starts is not reflected in a decline in other completions until September 1969, also shown in Figure 15.

From the definition of the stock of other units given in equation [8], the decline in other completions shows up as a decline in the stock of other units, KO, relative to the standard case, beginning in October 1969, as illustrated in Figure 16. The decrease in the number of remaining households over the standard case is proportionally greater than the decrease in the stock of other units, so that the stocks of other housing units per remaining household increases. From the rental rate equation [10], this increase in the stock of other housing per remaining household halts and even reverses the decline in rental rates by the end of the period, as shown in Figure 17. It would require another eight months before this change in rental rates could moderate the decline of other starts, so the market for other housing units is definitely in a state of relative disequilibrium at the end of the simulation period.

Despite disequilibrium in the other housing market and without reference to the magnitude of changes, it is clear that in the medium term the effect of the initial increase in $n\ell$ has been to bring about a substitution in construction activity from building other units to building single-family units, a general increase in the stock of housing per household (the increase in KS is greater than the decline in KO), and a reduction in housing and land prices and in rental rates over what these variables would have been in the absence of the change in $n\ell$. The dynamic outcome of the experiment therefore corresponds with the results predicted in the theoretical discussion in Section II. We turn now to a discussion of the effectiveness of $n\ell$ as a policy variable.

Table 2 presents the difference between the experiment and the standard case for a number of key variables in the first month in which a difference occurred and in the last month of the period, June 1970. The differences are also expressed as a per cent of the standard case level of the variable. Initial differences are not presented for a few of the variables because they are too small to be considered.

Examining the initial differences, we see that the policy change of 250 lots constituted a 10 per cent change in the stock of vacant lots, KL. The resulting drop in the price of land, PL, amounted to half that, or roughly 5 per cent. In the short run, a change in the stock of lots therefore has a strong effect on the land market. The drop in the price of land nearly doubled our measure of the profitability of producing single-family housing (the increase was 185 per cent) but this resulted in an increase in single starts, SS, of only 1.33 per cent. Single starts is the key variable in the model linking the housing and land markets, so it follows that the effect of the policy change in $n\ell$ on the two housing markets is almost negligible. Scanning the column of terminal difference percentages bears this out. The price of housing, PEH, and rental rates, RR, change by less than one per cent and the stocks of housing, KS and KO, change by less than one-tenth of one

Table 14

Initial and Terminal Difference in Selected Variables
Between Experiment and Standard Case

Variable	Initial Difference			Terminal Difference	
	Month	Actual	Per Cent	Actual	Per Cent
KL	67·03	250.0	10.47	228.8	5.74
PL	67·07	$-197.60	-4.58	$-98.92	-1.70
(PEH-SDC)	67·07	$ 197.60	184.96	$ 24.65	1.02
SS	67·10	1.13	1.33	-.01	-.01
KS	---	N.A.	N.A.	20.1	.05
KO	---	N.A.	N.A.	-4.0	-.01
PEH	---	N.A.	N.A.	$-74.27	-.36
RR	---	N.A.	N.A.	$ -.26	-.21

Note: N.A. indicates not applicable.

per cent. The number of new lots therefore fails to be a meaningful policy variable in this experiment for either of the housing markets. The terminal difference in the price of land is still approximately half of the initial difference, which demonstrates the lasting influence of the policy change on the land market.

It would be premature to disregard n_ℓ as a policy variable on the basis of this experiment, particularly if the stock of vacant lots continues to decline in the City. The reason lies in the empirically established nonlinear relationship between the stock of land and the price of land in equation [13]. The lower the level of the stock of land, the more sensitive is the price of land to changes in the stock. The stock of land at the end of 1973 was less than half what it was for any month during the period of this experiment so that an increase of 250 in the stock in early 1974 would have a much greater impact on the price of land than it had in 1967. All that this experiment establishes is that when there is a reasonable supply of vacant lots in the area, single starts, and, consequently, the price of housing and rental rates are relatively insensitive to changes in the number of new lots.

A second consideration is that the model we have developed may not accurately quantify the relationships in which we are interested. To determine whether this might be the case, we re-estimated three equations in the model which are crucial to the simulation results: the land price equation, the single housing starts equation, and the rental rate equation. Extensive experimentation with alternative specifications and functional forms revealed that the values of the relevant elasticities in these equations were almost totally independent of the specification of the equations. Some simulation experiments were attempted with variations of the equations, but the results were likewise almost totally insensitive to the particular form of the equations included.

In the next section we give a brief overview of the model, summarize the results of the policy experiment, and suggest directions for further research.

VIII. SUMMARY

We have presented comparative information on the housing and land markets in the City of London, developed a comparative static model of these markets, described in considerable detail the specification and estimation of a set of equations describing these markets, and used the resulting model to test the effects of changes in land supply on housing capacity and land prices, house prices, and rents.

In the model, builders augment the stocks of housing units of each type in response to changes in the profitability of construction of that type and to changes in the mortgage rate, after appropriate information and construction lags. House prices and rents on other types of units change in response to changes in the respective stocks of the two types of units, in response to changes in the price of the alternative form of housing, and in response to changes in the mortgage rate. In addition, inflation in the market for owner-occupied dwellings affects the market price for these units and rental rates respond to changes in household income. The stock of lots is augmented by subdivision approvals and depleted by single-family detached housing starts. The price of lots changes in response to changes in the stock of lots per household, to changes in the rate of inflation in lot prices, and to changes in the prime rate of interest.

The interrelationships in the model and the dynamics of the model were illustrated by assuming a one-time increase in $n\ell$, the number of lots brought onto the market through the subdivision approval process. This change resulted in a higher stock of single-family detached units, lower house prices, a lower stock of other types of units, lower rental rates, and a lower price of lots. The changes in these variables which resulted from the change in $n\ell$ were not large, however, except for the change in the price of single-family detached lots which was relatively somewhat greater. The implication is that increasing the stock of land is not a powerful policy instrument, at least when there is already an adequate supply of lots in the municipality.

As we have noted, the work presented here constitutes only the first version of the model and the results have therefore received little critical exposure. Subsequent work with the model will include the following:

- The data set will be improved by obtaining, where possible, observations which are currently missing on some of the variables and by updating all of the time series used in the model.

- An attempt will be made to treat $n\ell$ as an endogenous variable. We might expect subdivision approvals in the current period to be related to some measure of the expected returns to land development in a much earlier period. However, there are enough reasons to cause us to be pessimistic about finding a satisfactory empirical relationship: the lags involved in the subdivision process are very long and, over the whole period, somewhat variable and the process itself may be influenced by a wide range of other factors which it may not be possible to satisfactorily quantity, e.g., changes in the tax treatment of land development corporations. Moreover, it is certainly beyond the scope of this study to model the land assembly process, which is a prerequisite for subdivision development.

At a more general level, we are of the opinion that the formulation and implementation of more effective public policy instruments would benefit from a much more intensive research effort into the entire process of land assembly and land development. Such an effort is unfortunately beyond the bounds of this particular study.

- Single-family detached housing starts will be disaggregated, if possible, into private and public single starts. Public housing starts of single units are defined here to be those which occur under a program such as the H.O.M.E. program of the Ontario Government. Public single starts would be treated as exogenous and private single starts as endogenous, in much the same way as total single starts are treated as endogenous in the specification presented in this report. Likewise, starts of other units will be disaggregated into private and public starts of these units. Private starts of other types of units would be treated as endogenous in the way we have treated total starts of other units as endogenous here; public starts of other types of units (as, for example, senior citizen or public housing units) would be treated as exogenous in the revised formulation.

- The specifications of other equations in the model may be altered in the light of critical comments and other research findings.

- The revised model will be estimated using Two Stage Least Squares and, possibly, a simultaneous equation system estimator.

- The revised model will be used to project the endogenous variables under different sets of assumptions about the future behavior of the exogenous variables.

- Finally, the revised model will be used to test a wider range of policies, including changes in mortgage rates, increases in single-family detached housing starts which might be induced under a program such as the H.O.M.E. program, increases in starts of other units induced by Federal, Provincial, and Municipal joint construction of multiple units for senior citizens (for example), as well as changes in the supply of land resulting from changing the restrictions on the subdivision development process or from public land assembly (land banking) and public land development.

APPENDIX I

Equations of the Model

[1] $$SS_t = 206.447 + 32.9854\ dp_t - 40.0574\ w_t + .00572349\ (PEH_{t-3} - SDC_{t-3}) - 15.0707\ rm_{t-1}$$

subject to $0 \le SS_t \le KL_t + n\ell_t$

[2] $$SO_t = 545.831\ (RR_{t-8}/RC_{t-9})^2 - 54.4473\ rm_{t-3}$$

subject to $SO_t \ge 0$

[3] $$RC_t = \begin{cases} 3.34965\ \ell c_t + .829686\ mcc_t, & t = \text{January 1965 to December 1970} \\ 3.34965\ \ell c_t + .829686\ mco_t, & t = \text{January 1971 to December 1973} \end{cases}$$

[4] $$SDC_t = PL_t + 130.858\ RC_t$$

[5] $$\begin{aligned} CS_t = {} & .158247\ SSQ1_{t-2} + .372628\ SSQ1_{t-3} + .469125\ SSQ1_{t-4} \\ & + .197850\ SSQ2_{t-2} + .455534\ SSQ2_{t-3} + .346617\ SSQ2_{t-4} \\ & + .171159\ SSQ3_{t-2} + .466766\ SSQ3_{t-3} + .362075\ SSQ3_{t-4} \\ & + .452249\ SSQ4_{t-3} + .547751\ SSQ4_{t-4} \end{aligned}$$

[6] $$\begin{aligned} CO_t = {} & .124392\ SO_{t-10} + .188629\ SO_{t-11} + .190724\ SO_{t-12} \\ & + .128865\ SO_{t-13} + .155245\ SO_{t-15} + .212145\ SO_{t-16} \end{aligned}$$

[7] $$KS_t = \begin{cases} 32{,}818, & t = \text{January 1963} \\ KS_{t-1}(1 - .0002434) + CS_{t-1}, & t = \text{February 1963 to June 1971} \\ KS_{t-1}(1 - .0000365) + CS_{t-1}, & t > \text{June 1971} \end{cases}$$

[8] $$KO_t = \begin{cases} 19{,}207, & t = \text{January } 1963 \\ KO_{t-1}(1 + .0001387) + CO_{t-1}, & t > \text{January } 1963 \end{cases}$$

[9] $$PEH_t = 80{,}231.1 - 92{,}759.8\ (KS_t/fhh_t)$$
$$+ 78.0726\ RR_{t-4} + 69.9236\ RR_{t-5}$$
$$+ 7{,}599.99\ ((PEH_{t-5} - PEH_{t-6}/PEH_{t-6})/rs_{t-3})$$
$$- 721.565\ rm_{t-4}$$

[10] $$RR_t = 188.508 - 172.689\ (KO_t/RHH_t)$$
$$+ .00109550\ PEH_{t-2} + .000843641\ PEH_{t-3}$$
$$+ .142165\ yp_{t-1} + .211103\ yp_{t-2}$$
$$+ 3.96992\ rm_{t-3}$$

[11] $$RHH_t = hh_t - KS_t$$

[12] $$KL_t = KL_{t-1} - SS_{t-1} + n\ell_{t-1}$$

[13] $$PL_t = 8{,}232.80 + 2{,}164.56\ dp_t$$
$$- 118{,}618.\ (KL_{t-4}/hh_{t-4}) + 857{,}320.\ (KL_{t-4}/hh_{t-4})^2$$
$$+ 15{,}215.0 \left(\frac{PEH_{t-4} - PEH_{t-5}}{PEH_{t-5}} - \frac{RC_{t-4} - RC_{t-5}}{RC_{t-5}} \right) / rd_{t-3}$$
$$- 91.0710\ rp_t$$

Glossary of Variables

Mnemonic	Definition
CO	completions of housing units other than single-family detached
CS	completions of single-family detached housing units
dp	binary variable in single housing starts and land price equations = 1 for t > January 1969 and 0 otherwise
fhh	family households in the area
hh	total number of households in the area
KL	number of lots zoned and approved for the construction of single-family detached units
KO	stock of other housing units
KS	stock of single-family detached housing units
ℓc	index of labour costs in residential construction
mcc	index of material costs in residential construction for Canada
mco	index of material costs in residential construction for Ontario
$n\ell$	number of new single-family detached lots created by subdivision approvals
PEH	median sale price of existing houses
PL	median sale price of vacant lots zoned and approved for the construction of single-family detached dwelling units
RC	residential labour and material cost index

Mnemonic	Definition
rd	interest rate on 90-day deposit receipts
RHH	remaining households, i.e., number of households not in single-family detached housing units
rm	mortgage interest rate
rp	prime rate of interest
RR	rental rate on other housing units
rs	rate on savings deposits
SDC	land, labour, and material cost index for single-family detached housing
SO	starts of other housing units
SS	starts of single-family detached housing units
SSQ1	starts of single-family detached housing units if t = January, February, March; 0 otherwise
SSQ2	starts of single-family detached housing units if t = April, May, June; 0 otherwise
SSQ3	starts of single-family detached housing units if t = July, August, September; 0 otherwise
SSQ4	starts of single-family detached housing units if t = October, November, December; 0 otherwise
w	binary variable in single housing starts equation = 1, in February and March, and 0 otherwise
yp	permanent disposable income

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