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A METROPOLITAN HOUSING MARKET: LOCATIONAL IMPACTS OF SUPPLY AND DEMAND SHOCKS

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ABSTRACT

A full equilibrium model of local housing submarkets and their interaction within a metropolitan market is used to simulate the effects of several shocks and policies which impact on the supply or demand side of the market. The model consists of a set of econometrically-estimated supply equations, augmented by a simple demand equation, a market adjustment equation, and a definition of market clearance. The model predicts changes from 1960 to 1970 in housing supplies by mode of supply and structure type, as well as decade changes in demand, price and vacancies for a set of 89 geographically-defined zones in the Boston metropolitan area.

Interest is focused on the locational patterns of the impact, especially as the simulated pattern contrasts with patterns which might be predicted by a partial equilibrium approach which looked solely at either supply or demand.

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In 1960, the average central city in the United States seemed to cross a threshold in an evolving role within its Standard Metropolitan Statistical Area (SMSA), for in that year half the U.S. SMSA population was within central cities, and half outside. In 1950, central cities contained 57% of SMSA residents; by 1970 they were to contain only 46% (U.S. Bureau of the Census, 1973, Table 34). In most areas, central city population continued to grow over the decade from 1960 to 1970, but it did so more slowly than in the previous decade and more slowly than had the population of the rest of the SMSA. Some of this decline in the importance of central cities is to be expected because of expansion of SMSA borders over time, while central city jurisdictional lines remain unchanged. Some decline is also expected with the flattening of density gradients which accompanies improved transportation and increasing real incomes. But full understanding of the process of change in residential location patterns in metropolitan areas requires a geographically disaggregated model of the housing market. And to consider changes over the relatively long run, one needs a model that treats the supply of housing and the demand for housing both separately and simultaneously.

This paper is a first attempt to do that. It augments a fairly detailed model of housing supply with a simple demand equation and market clearing assumptions, and examines the simulated impacts of several shocks or policies that act on the supply or demand side of the market. The paper is intended, first, to indicate the importance of including both sides of the market, and second, to point to some possible implications of various policies or shocks on the geographic distribution of population within a metropolitan area.

The first section of the paper describes the simulation model and methodology. The second section presents the results of simulated shocks to housing demand, beginning with a location-specific demand shift to display the workings of the simulation process in a simple context. The third section of the paper explores policies which impact directly on the supply side of the housing market. The final section discusses some implications of the full set of simulations.

1. MODEL AND METHODOLOGY

The model of housing supply around which the simulation model is assembled consists of a set of six equations. The equations are econometrically estimated using data on the 1960 to 1970 decade changes in number of housing units by structure type and mode of supply for the 89 geographic zones comprising the Boston metropolitan area (14 districts in the city of Boston and 75 surrounding cities and towns). These estimated equations are displayed in Table 1, and the variables are defined in the appendix.[1]

TABLE 1

ECONOMETRIC ESTIMATES OF SUPPLY EQUATIONS

TOTAL NEW CONSTRUCTION

(Asymptotic standard errors in parentheses below estimated coefficients)

$$\frac{\text{NEW TOTAL}}{\text{TOTAL}_{60}} = \underset{(.0278)}{.120} + \underset{(.0113)}{.0714}\ \frac{\text{VACANT ACRES 60}}{\text{RESIDENTIAL ACRES}_{60}}\ \frac{\Delta\text{PRICE}}{\text{PRICE}_{60}}$$

$$- \underset{(.120)}{.237}\ \frac{\Delta\text{MANUF ACRES}}{\text{RESIDENTIAL ACRES}_{60}} + \underset{(.104)}{.262}\ \text{OPEN} \qquad (1)$$

$$- \underset{(1.45)}{2.80}\ \frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}} + e.$$

$R^2 = .4335$
Standard error of the regression = .132

CONVERSION-RETIREMENT EQUATIONS

(Asymptotic standard errors in parentheses below estimated coefficients)

$$\text{CONV SINGLE} = \underset{(67.3)}{34.2} + \text{OLD SINGLE}_{60} \left[\underset{(.0563)}{-.217} + \underset{(.0955)}{.191}\ \frac{\Delta\text{PRICE}}{\text{PRICE}_{60}} \right.$$

$$+ \underset{(1.52)}{3.75}\ \frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}} - \underset{(.0840)}{.0686}\ \text{PZ} - \underset{(.188)}{1.18} \qquad (2)$$

$$\left. \frac{\text{DETER60}}{\text{TOTAL}_{60}} - \underset{(.000156)}{.000271}\ \text{NEW TIGHT} \right] + e.$$

$R^2 = .7590$

Standard error of the regression = 322.

Table 1--Continued.

$$\text{CONV MULTI} = \underset{(41.4)}{82.4} + \text{OLD MULTI}_{60}\left[\underset{(.0438)}{.293} - \underset{(.0657)}{.345}\,\frac{\Delta\text{PRICE}}{\text{PRICE}_{60}}\right.$$

$$- \underset{(.973)}{6.55}\,\frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}} - \underset{(.0659)}{1.06}\,\frac{\text{DETER60}}{\text{TOTAL}_{60}} \tag{3}$$

$$\left. - \underset{(.0000812)}{.000166}\ \text{NEW TIGHT}\right] + \text{UNZONED OLD SINGLE}_{60}\cdot$$

$$\left[\underset{(.0746)}{.0230} + \underset{(.131)}{.0845}\,\frac{\Delta\text{PRICE}}{\text{PRICE}_{60}} + \underset{(3.11)}{10.8}\,\frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}}\right]$$

$$+ e.$$

R^2 = .9078

Standard error of the regression = 267.

$$\text{CONV APART} = \underset{(29.9)}{77.0} + \text{OLD APART}_{60}\left[- \underset{(.132)}{.508} + \underset{(.171)}{.929}\,\frac{\Delta\text{PRICE}}{\text{PRICE}_{60}}\right.$$

$$\left. - \underset{(3.16)}{18.0}\,\frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}}\right] + \text{DETER APART}_{60}\cdot$$

$$\left[\underset{(.551)}{2.34} - \underset{(.719)}{4.33}\,\frac{\Delta\text{PRICE}}{\text{PRICE}_{60}} + \underset{(7.88)}{29.5}\,\frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}}\right] \tag{4}$$

$$+ \text{OLD MULTI}_{60}\left[\underset{(.00948)}{.0431} + \underset{(.719)}{2.60}\,\frac{\Delta\text{VACANT}}{\text{TOTAL}_{60}}\right]$$

$$+ e.$$

R^2 = .9323

Standard error of the regression = 236.

Table 1--Continued.

NEW CONSTRUCTION STRUCTURE TYPE SHARES EQUATIONS

(Standard errors in parentheses below estimated coefficients)

$$\frac{\text{NEW SINGLE}}{\text{NEW TOTAL}} = \underset{(.0425)}{.958}\ PZ + UZ \cdot \Big[- \underset{(.00111)}{.00278}\ SEWER + \underset{(.119)}{.392}\ V1$$

$$+ \underset{(.123)}{.618}\ V2 + \underset{(.109)}{.700}\ V3 + \underset{(.110)}{.799}\ V4 + \underset{(.0854)}{.828}\ V5$$

$$+ \underset{(.0881)}{.907}\ V6 + \underset{(.0879)}{.768}\ V7 \Big] + e. \qquad (5)$$

$R^2 = .7921$

Standard error of the regression = .157.

$$\frac{\text{NEW APART}}{\text{NEW TOTAL}} = A \cdot UZ \cdot \Big[\underset{(.00105)}{.00276}\ SEWER + \underset{(.112)}{.518}\ V1 + \underset{(.117)}{.298}\ V2$$

$$+ \underset{(.103)}{.145}\ V3 + \underset{(.104)}{.130}\ V4 + \underset{(.0803)}{.0936}\ V5 + \underset{(.0815)}{.0644}\ V6 \qquad (6)$$

$$+ \underset{(.0779)}{.192}\ V7 \Big] + e.$$

$R^2 = .7770$

Standard error of the regression = .149.

Table 1--Continued.

MARKET ADJUSTMENT EQUATION

(Asymptotic standard errors in parentheses below estimated coefficients)

$$\frac{\Delta VACANT}{TOTAL_{60}} = \underset{(.00533)}{.00843} + \frac{\Delta PRICE}{PRICE_{60}} \left[\underset{(.0106)}{.0281} - \underset{(.000122)}{.000511} \ \%\ \text{RENTER-OCC}_{60} - \underset{(.113)}{.616} \frac{VACANT60}{TOTAL\ 60} + \underset{(.00510)}{.00515} \frac{POP60-POP50}{POP50} \right] \qquad (7)$$

$$+ e.$$

$R^2 = .3367$

Standard error of the regression = .00985.

The first equation models total new construction and the next three predict net changes in the stocks of each structure type through conversion-retirement. These four are estimated using two-stage least squares, treating decade price change and vacancy change as endogenous variables. In addition, new construction per vacant acre enters the first two conversion-retirement equations as an endogenous variable, reflecting the likelihood of increased demolitions of existing units to make room for new construction where vacant land is scarce. Equations (5) and (6) predict the structure type shares of new construction as a function of exogenous variables alone. The multi-family structure type (two to four units per structure) is treated as the residual difference between total new construction and the single-family and apartment unit shares. The final equation shown in Table 1 is the market adjustment equation which is introduced below.

The set of supply equations is thus six equations in eight unknowns (endogenous variables): changes in number of housing units through two modes of supply by three structure types plus price change and vacancy change. To close the model, three equations are added, which include only one additional endogenous variable, demand. The three equations are a demand equation, a market clearing equation and a market adjustment equation, as follows:

$$\frac{\Delta V}{S6} = c_0 + \underline{c}_1\underline{x}_3 \left(\frac{\Delta P}{P6}\right) + \mu \qquad \text{Market Adjustment} \qquad (7a)$$

$$\frac{\Delta D}{D6} = a_0 + a_1 \left(\frac{\Delta P}{P6} - M\right) + \underline{a}_2\underline{x}_1 + \delta \qquad \text{Demand} \qquad (8)$$

$$\frac{\Delta D}{D6} \cdot \frac{D6}{S6} = \frac{\Delta S}{S6} - \frac{\Delta V}{S6} \qquad \text{Market Clearing} \qquad (9)$$

where ΔD is the change in number of housing units demanded

ΔS is the change in number of housing units supplied

ΔV is the change in number of vacant housing units

$(\Delta V = \Delta S - \Delta D)$

D6 is the total initial demand for housing units

S6 is the total initial supply of housing units

$\frac{\Delta P}{P6}$ is the percentage change in price

M is the metropolitan average percentage change in price

$\underline{x}_1$ and $\underline{x}_3$ are vectors of exogenous variables

δ and μ are random disturbances

the a's and c's are coefficients

and underlining indicates a vector of variables or coefficients.

The market clearing equation states that each zonal market is cleared when demand plus vacancies equals supply. The market adjustment equation models the relationship between the two local market equilibrators, price change and vacancy rate change. This relationship is hypothesized to depend on a set of exogenous variables. The parameters of the non-linear equation are estimated using two stage least squares, and are displayed in equation (7) in Table 1. The demand equation assumes that zonal demand is a function of exogenous variables and of zonal price relative to the metropolitan average price.

The coefficients of the supply equation and market adjustment equation are obtained through estimation, as shown in Table 1. There are no unknown parameters in the market clearing equation. This leaves as unknown the demand parameters, the $\underline{a}$ coefficients in equation (8).

For the current purpose of simulating the effects of various policies or shocks on the metropolitan and zonal housing supplies over the observed decade 1960 to 1970, not all of the demand parameters are needed. It is not necessary to know the coefficients on any variables which will not change in the simulation. Thus we need not know the constant a_0, nor any elements of the vector $\underline{a}_2$ if the policies or shocks change none of the elements of $\underline{x}_1$. But it is obviously necessary to have a value for a_1, the coefficient on the price change variable, since price is an endogenous variable, likely to change in every simulation regardless of where in the system the policy or shock initially impinges.

What is a_1? It appears to be a price elasticity of demand, since it expresses the responsiveness of demand to relative price change. But understanding just what sort of demand price elasticity it is requires closer examination of the context in which it is used. The demand in question is number of housing units demanded in a geographic zone. Although we usually believe that households' demand for housing services responds to price, it is not as clear that their demand for housing units does. That is, if housing prices rise, it is expected that a household may choose to consume less housing by moving to a smaller unit, but not by demanding fewer housing units. Most households will always demand one housing unit; only a very few households are on the margin of doubling up (or failing to form) in the face of increasing housing prices. Since this model does not measure housing services per housing unit, or even size or quality of housing unit, it would seem on the basis of the above argument that no price responsiveness would be expected.

However, in the usual conception of the workings of an urban area, households perceive housing units in different locations within a metropolitan area as substitutes in consumption. If the price of housing in one location rises, some residents there might see it as worthwhile to demand a similar housing unit in another location where prices have not increased. Therefore, if all housing prices within the metropolitan area do not move exactly together, demander response to price change in any one zone can certainly be expected. If prices in one zone rise, some residents will move to other zones and newcomers to the metropolitan area who might have located here locate in other zones; if prices here fall, demanders will be attracted away from other zones to locate here. The elasticity in question is therefore more of a substitution elasticity than a pure price elasticity. It answers the question of how responsive households are to relative changes in prices of closely substitutable groups of housing units, the groups being locationally defined.

There has been a fair amount of empirical work which investigates the price elasticity of housing demand, but it refers to the elasticity of consumption of housing services with respect to price. Some studies suggest a value close to minus unity.[2] As just mentioned, this is not the elasticity we are interested in using for a_1, because it measures services not units, and because it does not look at substitution among various types of housing consumption, only at housing as a class of expenditures against which one trades off consumption of other goods. We are interested in the long run (decade) interzonal price elasticity of demand for housing units.

We shall assume that for the metropolitan area as a whole, demand for housing units is not responsive to price, at least within the range of price change values under consideration; that is, each household in the given metropolitan area population alw _s demands one unit. The question then becomes whether households will choose units in different zones than they otherwise would, when they face the local price changes induced by the policy change or shock. It seems likely that over the long run, such responsiveness ought to be quite high. In the absence of moving costs, in fact, one might expect it to be infinite: two otherwise identical zones, one with higher prices than the other, ought to have everyone moving out of the more expensive one (a process which should bring the prices back in line before the entire evacuation has taken place). In fact, of course, moving is not costless and housing units in different zones are not perfect substitutes. It seems reasonable, however, that the substitution price elasticity across zones should be at least as great as the price elasticity of demand for housing services. Since changing the amount of services consumed may often require a move as well, people are likely to be more responsive in a substitution sense than for housing consumption as a whole.[3] Therefore, in the simulations which follow, minus one is used as the upper bound on the elasticity parameter. Several parameter values are used in each simulation, and minus one is the closest to zero in each case.

Expressing the local price change relative to the metropolitan average price change, M, implies that if prices in this zone change in exact relation to metropolitan average prices, no change in local demand will occur which can be attributed to the influence of price (demand may, of course, change anyway because of changes in elements of $\underline{x}_1$, or because of general growth in metropolitan demand which is probably expressed through a_0). The inclusion of M in the demand equation is what ties the local housing submarkets together into a cohesive metropolitan market from the demanders' point of view. Each zone has its own demand, supply, market clearing and market adjustment equations which represent the local housing market operations; and it is only through M that signals can be transferred across zonal boundary lines. A more detailed analysis of the demand side would probably want to pinpoint which zones are closer substitutes for each other, rather than using the metropolitan average as representing substitution possibilities.[4]

To summarize the discussion of the demand equation to this point, it is important to reiterate two important assumptions that have been made. First, the total metropolitan area demand for housing units is unaffected by the policy changes and shocks to be simulated; neither migration nor doubling up of households are important responses in the range of environment changes under consideration. Second, the interzonal price elasticity of demand for housing units is smaller (more negative) than minus unity. In addition, there are two other assumptions implicit in the way equation (8) is written: The endogenous vacancy change variable does not affect demand independent of price, and the endogenous housing supplies do not affect demand except through their impact on price. A more complete supply-demand system might want to incorporate such further interactions, but to do so for these simulations would require making assumptions about the responsiveness of demand to these variables as well. If higher vacancies indicate lower search costs, and increased supplies of some units are attractive to demanders, then the direct effects would act in the same direction as the (included) effects through price, and little generality is lost by excluding them.

Having specified the set of structural equations and obtained parameter values for them, the next step is to specify the changes in exogenous variables that represent the policy or shock being simulated. This is discussed specifically for each simulation later in the paper. A few general notes are in order at this point to clarify the approach. Policies or shocks originating on the supply side of the model are translated into changes in the variables appearing in the supply equations. The estimated coefficients are then applied to calculate the initial local supply responses. Shocks to housing demand are somewhat more troublesome, since the elements of the vector of exogenous variables, $\underline{x}_1$, have not been specified, and the corresponding coefficients (the vector $\underline{a}_2$ in equation (8)) are unknown. To simulate demand shocks, assumptions are made about the direct effects of the shock on $\frac{\Delta D}{D6}$, given the values of the other variables. That is, an assumption is made about the value of $a_{2j}(\Delta x_{1j})$, where $a_{2j}x_{1j}$ is the $j^{\underline{th}}$ element of the vector product $\underline{a}_2\underline{x}_1 = \Sigma_i a_{2i}x_{1i}$; and Δx_{1j} is the change in the specific variable x_{1j} caused by the shock. The term a_{2j} (Δx_{1j}) tells the shift in the demand curve in quantity terms, which the change in x_{1j} causes. These assumptions will be discussed in further detail for each simulation individually.

The final step is to trace out the effects of such exogenous variable changes on all the endogenous variables in the system. The reduced form equations provide the simplest means of calculating the full effect of a change in any exogenous variable on each of the endogenous variables. The reduced form equations are derived analytically from the set of structural equations by solving for each endogenous variable in terms of exogenous variables and the coefficients of the structural equations. The reduced form equations for each of the endogenous variables are derived treating M, the metropolitan average price change, as an exogenous variable. Then an iterative procedure of adjusting M is used in each simulation to guarantee that the sum of the predicted local demands is equal to the given metropolitan total demand. This procedure yields the value of M which equals the weighted average of the endogenous zonal price changes.

An example of the underlying demand adjustment process which the inclusion of M represents should make the procedure clearer. Take the case of minimum lot size zoning restrictions being lifted. According to the estimated coefficients in the supply equations, this would induce an increase in housing supply in the zones which previously imposed such restrictions. However, such increases in local housing supplies would also cause local prices to fall and vacancies to rise in those zones. Thus the fully simulated increase in housing stock would be smaller than that predicted simply by summing across equations (1) to (4) the results of multiplying the relevant coefficients times the change in the zoning variable. Ignoring vacancies, this difference is shown in quantity-price space in the top half of Figure 1, where the vertical shift in town A's supply curve a distance q, attributable to the elimination of zoning, causes a smaller change in equilibrium quantity of $(Q_1^A - A_0^A) < q$, because the shift involves movement along the nonvertical

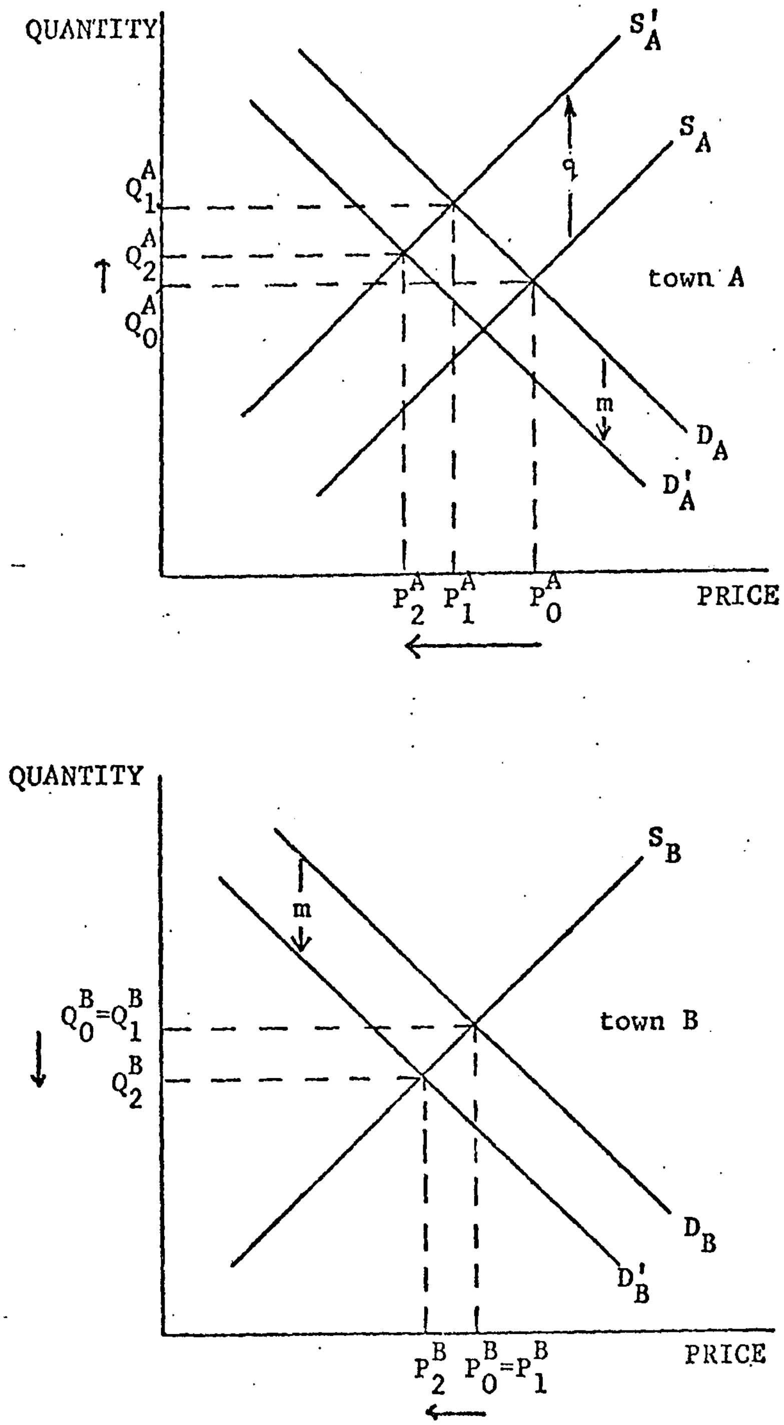


FIGURE 1. **Zonal Demand Shift as Relative Prices Change.**

demand curve. This smaller (but still positive) supply increase would be predicted by the first round of reduced form calculations with the change in the zoning variable included. The reduced form demand equation would show an increase in demand (in proportion to the assumed value of a_1) in response to the price decrease (as represented by the difference between Q_1^A and Q_0^A in Figure 1, which are two points on the demand curve, the slope of which is related to a_1).

Note, however, that the zones where the supplies were increased show an increase in demand, but the zones which had no zoning to start with, and hence have no change in exogenous variables in the simulation, will show no change in any endogenous variables in the first round. With demand increases relative to the control values in some zones and demand constant in others, clearly the required total metropolitan demand must be exceeded. This is because the end of the first round reflects the additional attractiveness of the zones where prices decreased, but not the fact that the other zones are thereby made relatively less attractive. When prices in one zone or group of zones decline and the others are unchanged, then the average metropolitan area price has decreased. This is reflected in the model by a negative increment to the constant M (constant across zones). It was argued earlier that if the metropolitan average housing price decreased, the unchanged price in any one zone looked less attractive. Therefore demand in that zone decreases.

This phenomenon is represented in both panels of Figure 1. In the second panel, demand and supply curves are drawn in quantity-price space for a second town in the metropolitan area, town B, which had no zoning restrictions, so the initial shock had no effect. Since the axes in each panel represent local zonal price and zonal quantity, a decrease in the metropolitan average price appears as a shift down in the local demand curve: at any zonal price, less housing is locally demanded. The vertical shift in the demand curve must be the same for all towns if the price elasticity of demand, a_1, is constant across zones and if the relevant price comparison for all is the metropolitan average price change. But given this identical vertical demand shift (in Figure 1 m represents the equivalent of $(-a_1 M)$ if the analysis were translated into quantity-price space), the change in equilibrium quantity (in moving from D to D' along the supply curve S_B or S_A') depends on the slope of the supply curve, which varies across zones in the metropolitan area. (It is this different response among zones to the same shift parameter which requires an iterative process rather than simple analysis to obtain a solution.) But it is clear from Figure 1 that the net result of this process is an increase in equilibrium quantity and decrease in price in zone A where the quantity increase originated, and a decrease in both price and quantity in zone B. The shift down in the demand curve in zone A cannot more than compensate for the shift upward in supply, given downward-sloping demand and upward-sloping supply; that is, the net result must be an increase in quantity. Equation (8) makes this clear, since the term $a_1 \cdot (\frac{\Delta P}{P6} - M)$ must be positive: a_1 is negative and the zonal price term $\frac{\Delta P}{P6}$ must fall more than the SMSA average price term (M), so $(\frac{\Delta P}{P6} - M)$ is negative.

After convergence is achieved, that is, demanders have chosen zones according to the demand curves and total metropolitan demand is correct, the equilibrium value of M and all the exogenous (some shocked) variable values are used in the reduced form equations for the other six endogenous variables. This produces simulated values of price change, vacancy rate change, total new construction, and single, multi-family and apartment unit conversion-retirement for each zone, in addition to the demand change predictions resulting from the iterative process. The change in total new construction is then split into structure types according to equations (5) and (6), which may or may not be directly affected by the shock, depending on whether shocked variables are among those which enter those equations.

It is all of these changes in housing unit supplies by structure type and mode of supply across the zones which are the simulation outcomes of interest. For ease of presentation, most of the results are aggregated across groups of zones and the metropolitan area as a whole. Figure 2 is a map showing the grouping of the zones into three geographic summary regions. The emphasis is placed on the general locational impacts of the policies or shocks on the supply of housing. A model of this sort, with a simple prototypic demand equation and supply equations delineated by structure type and mode of supply (but not unit size or general quality), cannot produce exact answers as to the quantifiable impacts of the policies or shocks on residential location. However, it can provide a valuable insight into the forces at work on the supply side of the market, and indicate the relative magnitude and direction of response to such shocks. One of the important findings of this model is that a given policy applied uniformly across the metropolitan area may produce highly different results in different parts of the metropolitan area, because the supply

FIGURE 2. Boston metropolitan summary regions.

responsiveness varies geographically in a systematic way. A further use of the full equilibrium model is to contrast its results with partial equilibrium results often assumed for policies on the basis of models which include only the demand or supply side of the market. The immediate effect may be very different from the full effect of the complete set of market interactions.

2. SIMULATED DEMAND SHOCKS

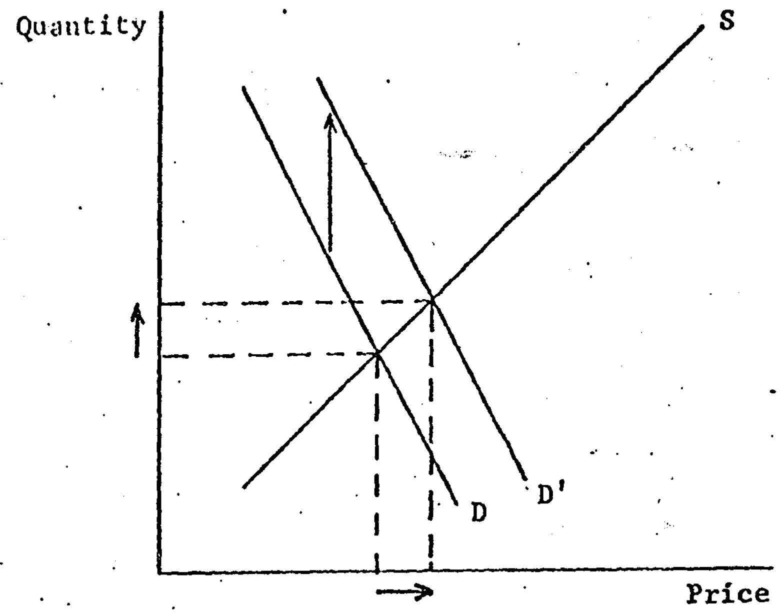
The first shock originating on the demand side to be simulated with the full equilibrium set of equations is a simple locational shift in demand due to an unknown cause. The hypothetical situation is that over the decade something happens which increases demands in all the zones bordering on the ocean by 10% over their actual 1970 levels. At the same time, demands in all other zones are decreased proportionately to reflect the preferences of some of their residents to move to the ocean. Such a shift could occur because demanders' tastes change or because of some change in external conditions which makes ocean breezes more attractive, for example, a decrease in ocean pollution or an increase in inland air pollution or an increased reliance on sea transportation as roadways became more crowded. The cause is not important, because the purpose of this simulation is to clarify somewhat how the full equilibrium simulator works in a simple context.

Thus the first round shock is a 10% increase in 1970 simulated demand in the twenty zones which border on the ocean. These twenty zones contained 28% of the metropolitan housing units in 1960 and 22% of the area's vacant land. For the total metropolitan area 1970 population to remain constant, the 10% increase in ocean demand implies a 3.8% decline in demand in the other sixty-nine zones lacking ocean frontage. These shifts in the demand curves of the two groups of zones then set off rounds of price, vacancy and supply adjustment, which feed back into further demand adjustment. In terms of conventional supply and demand curves, the initial shift in the demand curves causes the equilibrium point to move along the supply curves to the new intersection, with its associated price and quantity. These price changes in each zone, aggregated across the metropolitan area, then cause further (equal) shifts in each demand curve reflecting changes in relative attractiveness as the metropolitan average price changes relative to each zonal price. Thus the final outcome is not a 10% increase in quantity demanded along the oceans and a 4% decrease in quantity demanded elsewhere, since that would be the case only if prices did not change in response (supply curves were perfectly elastic). However, the final outcome is indeed an increase in quantity of housing demanded in the ocean zones and a decrease in quantity demanded in the inland zones. The increased demand is accommodated partly through increased supplies and partly through lower vacancy rates, with the opposite responses to demand decreases.

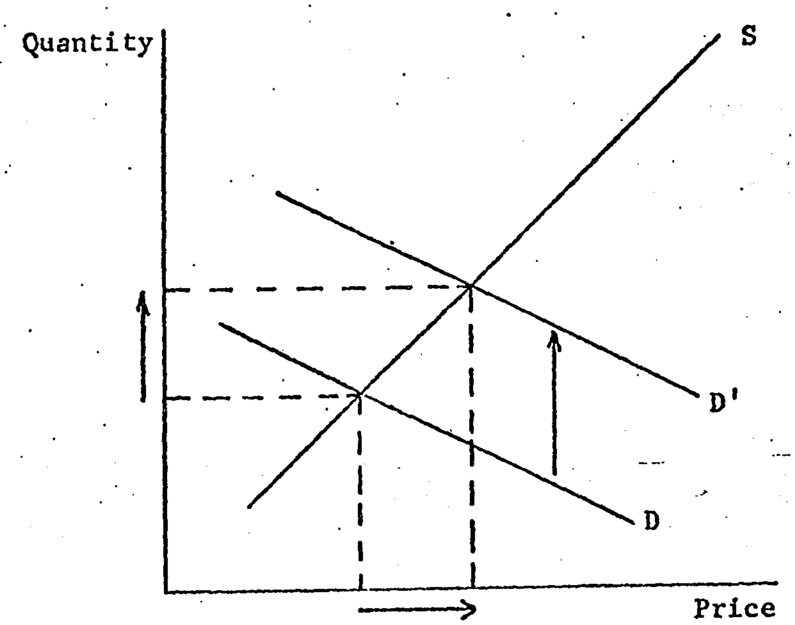
The actual magnitudes of each of these adjustments depends on the value assumed for the cross-price elasticity of demand, A1. The simulation was run with four alternative values of this parameter, -1, -2, -3, and -5. The more negative the chosen value, the more responsive are demanders assumed to be to relative price changes, and hence the smaller the price changes required to bring about any given demand adjustment. When prices change less, supplies change less as a consequence. That is, the more responsive demanders are assumed to be, the more adjustment to any shock takes place by people moving across zone boundaries, than by local price and supply changes. Figure 3 represents, in price-quantity space, the difference just described between elastic and inelastic demand. The two diagrams show the impacts on equilibrium price and quantity of a given shift in a local demand curve (measured in the quantity dimension) with a fixed identical supply curve under assumptions of elastic and inelastic demand. Where demand is elastic, much less quantity and price change occur because people simply consume less local housing (they move to other zones) as the local price rises.

When A1 is assumed to be -1, the final change in quantity demanded for the oceans group taken as a whole is a half percent increase, while the inland group shows a decrease of .2%. With A1 = -3, the results show an average demand increase of .2% in the ocean zones, and a decrease of .08% for the rest of the metropolitan area. When A1 is -5, the outcome changes are even smaller, since the price changes which occur in response to the original shifts in demand induce greater retreat. With A1 = -5, the inland group shows an average decrease of .06% in units demanded, and the ocean group shows an average increase of .1%; that is, a net final increase one one-hundredth the size of the original shock. These results and those for the other endogenous variables are displayed in Table 2.

Simulated prices for 1970, by the same token, show an increase in the ocean group of zones and a decrease for the inland group, with average metropolitan prices also higher. Supplies, similarly, increase in the



Elastic Demand



Inelastic Demand

FIGURE 3. Demand Elasticities.

(Both diagrams have supply curves with the same slope and the same vertical demand shift.)

Table 2

Percentage Differences Between Simulated Outcomes

and Controls for Prototypic Demand Shock: Oceans More Attractive

	1970 Total Supply	1970 Price	1970 Demand
A1 = -1 (Demand inelastic)			
Ocean zones*	+.3%	+7.7%	+.5%
Inland zones	-.2	-1.8	-.2
SMSA total	0	+ .7	0
A1 = -3			
Ocean zones	+.2	+2.7	+.2
Inland zones	-.1	- .5	-.1
SMSA total	0	+ .3	0
A1 = -5 (Demand price elastic)			
Ocean zones	+.1	+1.6	+.1
Inland zones	0	- .4	-.1
SMSA total	0	+ .2	0

*Zones are grouped according to the direction of the initial shock to demand: the twenty ocean zones have 10% greater demand; the 69 inland zones have 3.8% fewer housing units demanded initially.

ocean zones and decrease in other zones, but not to the same degree as demands change, since vacancies move in the opposite direction, taking up some of the slack. The size of the supply change is a direct function of the price change, so the A1 = -1 case has considerably greater supply changes than when A1 = -5, although both are very small. The model also predicts the individual components of supply: units of new construction and outcomes of the conversion process, by structure type. However, since there has been no direct shock to the supply side of the market, these supply changes are attributable to price and vacancy rate changes alone. This means that the composition of supply changes in any zone is virtually the same for any demand shock, even though the total direction and magnitude depends on the direction and magnitude of the price (and vacancy) change. For looking at the outcomes of demand shocks, therefore, the fully detailed supply responses are of less interest that the totals, which represent the general response of suppliers to the spatial shifts in attractiveness.

The individual zones within each group do not, of course, have uniform outcomes for all these endogenous variables. The price elasticity of demand and the shift term M are the same for all zones, but the market adjustment parameters and the price and vacancy rate elasticities of supply vary across zones in systematic ways. While the ocean group as a whole showed the demand increase discussed above as a result of the initial shock and market adjustment, five of the 20 ocean zones actually showed demand decreases in the final outcome. These are zones in which the total market signal elasticity of supply (price and vacancy rate responses combined) is negative. This means that when the demand curve shifts upward, as in Figure 4, to reflect the 10% higher demand at each price, the intersection moves along a downward sloping supply curve, and hence the outcome is higher prices and a smaller equilibrium quantity. Such a market is stable, but "perverse," in the sense that any price increase not accompanied by a shift in the supply curve must cause a decrease in housing supply.

Prices, on the other hand, move in the expected direction, regardless of the slope of the supply curve. That is, the outcome prices are higher in all the ocean zones and lower in all the other zones, relative to the control outcomes. The magnitude of price change does, of course, depend on the supply slope; as Figure 4 shows, the price increase is larger in a zone with negative supply slope than it would be in a zone with the usual positive slope, for any given shift in the demand curve. This is because the usual positive supply response tempers the price increase caused by greater demand, whereas as negative supply response exacerbates it.

One of the reasons for reporting this simulation is to preview what will be a recurring problem in understanding the results of the simulations which follow. Some of the results of this demand shock are the opposite of what would be expected, because of the negative price elasticities of supply in some of the geographic zones of the central region. Policies or shocks simulated later will also reflect these negative central price elasticities. To the degree that the negative elasticity is not well understood, or has an explanation which reflects a phenomenon beyond the bounds of this model, sorting out what part of a result is due to the perverse elasticity and what part due to the character of the policy or shock will be a concern.

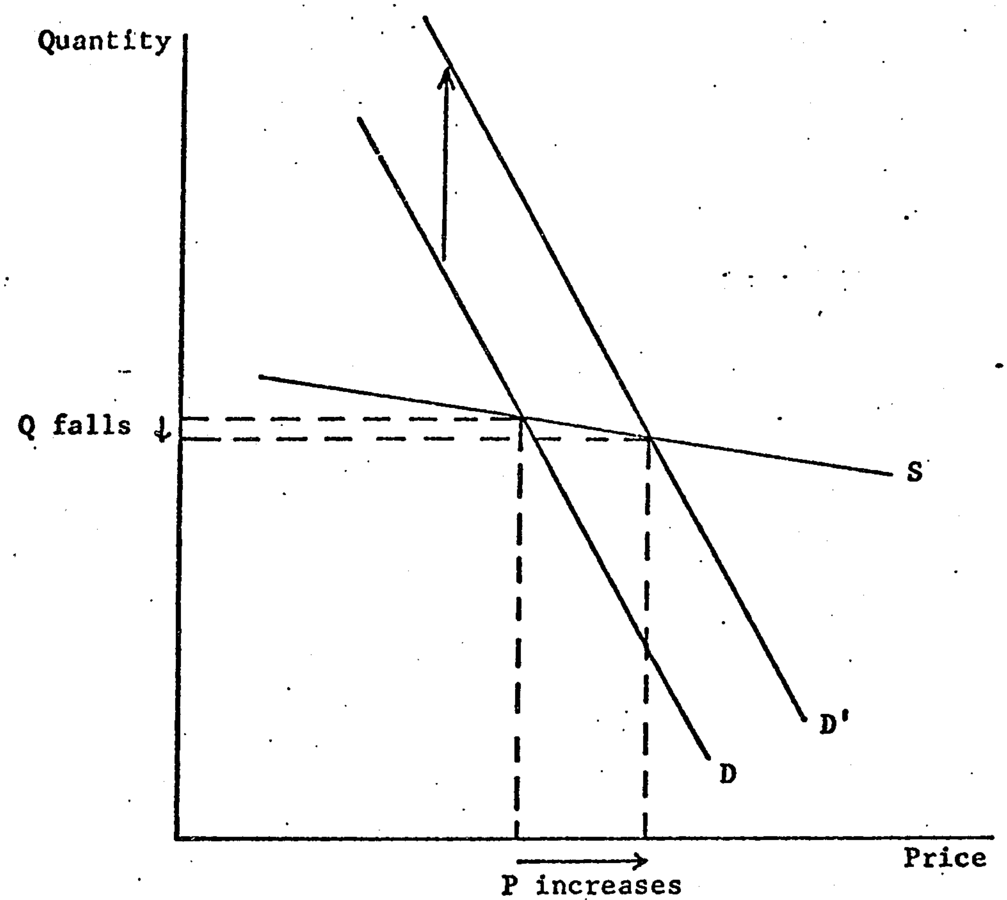


FIGURE 4. The effect of a demand increase in a zone with negative price elasticity of supply.

For example, one explanation of the negative elasticity is that in the "overbuilt" central areas, one response to a demand (or price) increase is to raise the quality of the units offered on the market. To the degree that this is accomplished by destroying particularly bad units and merging others to offer more services per unit, the total supply of housing (that is, the number of housing units) falls. Given that explanation, one can still wonder whether it is reasonable to expect that response to all price increases, caused by a variety of shocks or policies. The simulation model must assume that it is. To the degree that the econometric estimates do correctly indicate the direction of response by suppliers, the quantity result is valid, regardless of the explanation. That is, if suppliers respond to price increases by offering fewer housing units (though perhaps more housing services per unit), this decrease in quantity of units is an outcome of great interest because it affects the possible geographic distribution of demander households, each of whom consume one housing unit.

Energy Shortage

Analysts have recently expressed concern about how the spatial form of U.S. metropolitan areas will be affected by a long-term energy shortage like that begun with the Arab oil embargo of 1973. This is a particular concern in Boston and other New England urban areas because their dependence on imported oil makes them more vulnerable to these external conditions. There are several important aspects of housing in which high energy costs or short supplies make themselves felt, including the costs of heating and lighting homes, but most concern has centered on the effects of the shortage on commuting patterns. The basic literature on urban form (Mills, Muth, Alonso) shows the locational distribution of household residences around a metropolitan center to depend largely on commuting costs, which help determine the .erms of trade" between space and accessibility in the residential location decision. An urban area with higher per mile commuting costs is expected to have steeper land rent and density gradients. That is, higher transport costs cause people to live closer to their jobs (which, in these models, are assumed to be in the center).

Gasoline and oil prices are affected by the current energy "crisis." It seems likely that a substantial gasoline price increase will affect the behavior of housing demanders, in particular, their decisions about how much to commute. This is to be expected because gasoline and oil comprise a significant part of auto operating costs[5], autos are used for a large fraction of urban commuting to work[6], and transportation expenditures are an important part of consumer budgets[7]. Given a known workplace, the decision about how much to commute becomes the residential location decision.

Without a demand equation which expresses how responsive demanders are to changes in commuting costs, the energy shortage can be simulated only by making assumptions about how demanders respond. It might be argued that this then assumes the outcome to be predicted, but one of the important motivations for all these full equilibrium simulations is to demonstrate that second round effects, in this case, supply constraints in the face of demand shifts, are an important part of the picture, often ignored in discussions of policy (or in this case, shock) impacts. That is, even though we assume the spatial form that the first round of responses to the energy shortage will take, the model has significant information to contribute to prediction of the likely outcome.

The simulation assumes that an energy shortage causes people's demands for residential location to cluster more closely to job locations.[8] This case taken to the extreme, would suggest that demand for residential locations would become exactly proportional to job locations. That is, a town which contained 2% of the metropolitan area's jobs would contain 2% of the metropolitan area's households. However, considering the actual disparity between the spatial configuration of jobs and that of housing, to assume perfect correspondence as the initial shock would be a startling jolt to the system. For example, not the worst disparity, the town of Cambridge in 1970 had about 6.9% of the SMSA's jobs and 4.2% of the SMSA's households. If demands were to increase to 6.9% of metropolitan demanders, over 23,000 more households would be trying to find homes in Cambridge, along with the 37,000 households already there.

In addition to it being an unreasonably large shock to expect the market to handle (or more to the point, an unreasonably large shock to expect this model of the market to handle), there is another reason not to assume that the energy shortage causes full proportionality of demand to employment. This would ignore the fact that jurisdictions are not isolated islands but are a group of spatially contiguous entities. One can live just as close to some Cambridge jobs by living in the neighboring jurisdictions of Somerville, Arlington, Belmont, Watertown or Boston, as by living in Cambridge itself. Certainly the current residential location pattern recognizes these proximities to job locations which disregard jurisdictional lines. Therefore the shock simulated is a partial move toward proportionality with jobs, from the starting point of the actual current residential configuration. Specifically, it is assumed that demand curves shift in such a way that, with current prices, demand is 90% of actual demand plus 10% o what demand would be, were it proportional to jobs. This involves a change in zone of residence for at least 29,000 households, about 3 1/3% of the metropolitan population (as compared with moves by one-third of the area's households required for full proportionality). These initial shifts in zonal demand can be added up for the three geographic regions. They represent an increase of 10,200 households in the central region (a 3% increase), and decreases of 5,600 and 4,600 in the inner and outer rings, respectively (or 2 1/4 and 1 1/2%, respectively).

The final results displayed in Table 3 show that under the assumption A1 = -1, these initial shifts are turned around by the negative central supply elasticities. Thus the zones in the inner and outer rings end up with increased demand relative to the controls, and the zones in the center show decreases, in general. But of the 23 zones "over-supplied" with jobs, hence initially more attractive, 18 do have positive final outcomes, ranging from 10% higher final demand (and supply) to 1 1/2% higher final demand. Prices in all zones increase, but much more in the zones assumed to be more attractive because of their job concentrations than in zones moved away from initially. The SMSA average 1970 housing price is about 10% higher after everyone moves around, relative to the control value.

However, when demand is assumed to be more elastic, say A1 = -5, then the reversal of the (identical) initial shock is not as complete. Under this assumption, demanders are more responsive to price changes

Table 3

Percentage Differences Between Simulated Outcomes and Controls for

Energy Shortage: People Try to Move Closer to Jobs

	1970 Total Supply	1970 Price	1970 Demand	First Round Demand Shock**
A1 = -1 (Demand inelastic				
Employment zones*	-1.2%	+16.8%	- .8%	value of A1 is irrelevant
Residential zones	+ .2	+ 6.2	+ .3	
SMSA total	- .2	+ 9.6	0	
Central region	-2.3	+12.1	-2.1	
Inner ring	+ .6	+ 7.6	+ .8	
Outer ring	+1.8	+ 7.2	+2.0	
A1 = -3				
Employment zones	- .1	+ 9.0	- .1	+11.6%
Residential zones	0	+ .4	0	- 4.6
SMSA total	0	+ 1.5	0	0
Central region	- .3	+ 2.0	- .3	+ 2.9
Inner ring	+ .1	+ .9	+ .1	- 2.3
Outer ring	+ .2	+ 1.0	+ .3	- 1.6
A1 = -5 (Demand price-elastic)				
Employment zones	- .1	+ 2.1	0	
Residential zones	0	+ .1	0	
SMSA total	0	+ .7	0	
Central region	- .2	+ 1.1	- .2	
Inner ring	0	+ .4	+ .1	value of A1 is
Outer ring	+ .1	+ .5	+ .1	irrelevant

*Zones are grouped according to the direction of the initial demand shock: employment zones are those with a greater share of employment than share of population, hence employment zones experience a demand increase; residential zones have a greater population share than employment share and hence experience a first round demand decrease.

**The first round shock to demand for each zone varies with the disparity between employment share and population share. The reported figures are weighted averages for each group.

and hence the price changes required to bring the market to equilibrium are smaller. The smaller average price change implies that each local price change is less different from the metropolitan average price change (the term $(\frac{\Delta P}{P6} - M)$ in equation (8) is smaller), and many of the zones experiencing initial declines in demand are left with final demand below the control value as well. The shift toward living nearer to jobs decreases the attractiveness of some zones more than others, depending on how job-poor they are, and hence has different first round effects on price. Zones where prices initially fell, of course, are more attractive relative to the SMSA average price change. The positive shift in demand constant across all zones reflecting the higher average price is greater than the initial downward shift in some job-poor zones, and less in others, leaving some with net gains and others with losses. Forty-one of the 66 zones losing demanders in the initial shock end up with less final supply than in the controls, losses ranging from .7% to virtually zero. Prices are down relative to the control outcome as well for most of these zones, as is quantity demanded. For A1 = -3, this is closer to thirty zones; the largest loss is about .8%.

3. SIMULATED SUPPLY POLICIES

The first round effects of supply policies are introduced into the model through changes in exogenous variables which enter the housing supply equations.[9] It is assumed that none of the supply policies affect demand except through their effects on endogenous housing prices. For example, the first simulation implicitly assumes that the existence of minimum lot size zoning constraints in a town is not an attribute which directly affects the town's attractiveness to demanders. Changes in zoning will, however, indirectly affect demand through their effect on supply and hence price.

No Minimum Lot Size Zoning

Zoning regulations which require residential lot sizes to be greater than 25,000 square feet were in use in forty-five towns in the Boston metropolitan area, with the fraction of town area so restricted ranging from 12.5% to 100%. These forty-five towns accounted for 24% of the metropolitan housing stock in 1960, and 69% of the land area. To simulate the effects of removing all such zoning, we set to zero all observations on the variable PZ, which measures the fraction of town land subject to minimum lot size restrictions of greater than 25,000 square feet.

Minimum lot size zoning enters the model in several ways. The fraction of land which is both vacant and not subject to minimum lot size zoning has a positive effect on total new construction. In addition, the fraction of land subject to minimum lot size zoning has a one-for-one effect on the single-family fraction of new construction. Land not subject to minimum lot size zoning is divided among new construction structure types on the basis of vacant land scarcity. Finally, minimum lot size zoning affects the conversion-retirement decisions of owners of single family units, and in particular, affects the conversion of old single family units into multi-family units.

The estimated coefficients in the supply equations imply that the first round effect of removing the zoning constraint is to make more housing units available at any given price in those zones where the constraint had applied, especially multi-family or apartment units. Clearly this increased supply will reduce housing prices in those zones, making them relatively more attractive to demanders living elsewhere in the metropolitan area. If demanders are fairly sensitive to such changes, demand should rise in the affected zones at the expense of the rest of the area.

Under the assumption that A1 = -5, (demand is fairly price-elastic), this is exactly what the full equilibrium simulation results suggest, as is shown in Table 4. The final outcome is a .3% increase in metropolitan housing supplies, concentrated in those zones where the zoning constraints existed. Removal of the constraints yields 1% more housing in that group of zones, and virtually no change in total supply for the rest of the metropolitan area. 1970 prices fall in all zones, falling more, as would be expected, where the direct supply augmentation effect occurred. Because of these general price declines, new construction activity is reduced in most zones, and falls by 7 1/2% for the metropolitan area as a whole. However, these effects of price are offset in some zones by the positive effect on new construction of removing the zoning constraint; the net result for 20 zones is an increase in the number of new units. The decline in new construction is therefore more slight for the group of towns with zoning constraints than for all other zones taken as a group.

The policy reduces the single fraction of new units and increases the fraction of multi-family units and apartments, both for the individual

Table 4

Percentage Differences Between Simulated Outcomes and Controls for Elimination of

Minimum Lot Size Restrictions

	Supply					Partial Equilibrium Supply Results		
	Total 1970 Supply	Decade New Construction	1970 Percent Single**	1970 Price	1970 Demand	Total 1970 Supply	Decade New Construction	1970 Percent Single**
A1 = -1 (Demand inelastic)								
Towns with zoning*	- .9%	-11.3%	-3.8	-23.5%	-1.4%	+5.7%	+20.2%	-2.0
Other zones	+ .9	-17.0	-2.5	-23.8	+ .5	0	0	0
SMSA total	+ .5	-14.9	-3.0	-23.8	0	+1.5	+ 7.7	- .1
Central region	+3.3	-16.5	-1.8	-24.2	+3.0	0	+ .1	- .1
Inner ring	-1.4	-14.3	-2.3	-23.3	-1.8	+ .2	+ .9	- .1
Outer ring	-1.5	-14.3	-3.4	-23.5	-2.2	+4.4	+15.7	- .1
A1 = -3								
Towns with zoning*	+ .9	- 2.7	-3.3	-16.9	+ .5			
Other zones	+ .1	-11.3	-1.6	-16.0	- .2			
SMSA total	+ .3	- 8.0	-2.0	-16.2	0			
Central region	+1.4	- 9.3	-1.1	-15.5	+1.2			
Inner ring	- .9	-10.0	-1.7	-16.5	-1.2			
Outer ring	0	- 6.2	-2.8	-17.1	- .4			
A1 = -5 (Demand price-elastic)							Value of A1 is irrelevant	
Towns with zoning*	+1.1	- 1.7	-3.2	-16.3	+ .7			
Other zones	0	-10.9	-1.5	-15.4	- .2			
SMSA total	+ .3	- 7.4	-1.9	-15.6	0			
Central region	+1.2	- 8.7	-1.0	-14.8	+1.0			
Inner ring	- .9	- 9.7	-1.6	-15.9	-1.2			
Outer ring	+ .2	- 5.4	-2.8	-16.5	- .2			

*Zones are grouped according to whether the policy change is applied locally or not: towns with minimum lot size zoning restrictions are assumed to eliminate them; other zones are affected indirectly by these changes.

**These are percentage point differences.

zones and for the metropolitan area as a whole. (The second does not necessarily follow from the first, since total new construction is shifting among zones with different structure type shares.) At the same time, the conversion-retirement process is affected, both by the price changes and the zoning relaxation. The result is that the single-family percent of the 1970 SMSA stock, after relaxation of minimum lot size restrictions, is lower by two percentage points. This decrease is larger for the group of zones where minimum lot size restrictions applied.

Demand for housing increases where prices are relatively lower, so the previously-zoned areas gain .7% more demanders, which is a loss of a quarter of a percent for the rest of the metropolitan area. Vacancies increase almost everywhere, to take up the slack between increased supplies and constant demand. They increase most where supplies increase most--where zoning was eliminated--but also increase in the rest of the metropolitan area where demand fell relative to almost unchanged supply.

For A1 = -3 or -2, the results are similar to those described above. When demand is assumed to be price-inelastic (A1 = -1), however, the results look quite different. Housing supplies and demands fall in the previously-zoned towns. This strange result is produced by the negative price elasticities of supply in some of the central zones combined with the greater price changes required for market clearing in the inelastic demand case. The central zones with negative supply elasticities are zones where minimum lot size zoning constraints did not apply. However, when the constraints are loosened elsewhere and demand curves shift inward everywhere to reflect the drop in metropolitan average prices, the price reductions in these negative elasticity zones are so much greater than elsewhere that they end up attracting more demanders than before the policy change occurred.

These full equilibrium results can be compared with expected results based on a supply analysis alone. The predictions of the supply equations are displayed in the three right-hand columns of Table 4. Under the assumption that demand is reasonably responsive to relative price changes (that is, setting aside the A1 = -1 case), the two sets of results indicate similar patterns of response, and disagree in the expected ways. Both show supplies increased in places where it was previously constrained by zoning, and both show the single-family share of units declining. Adding the "market test" of demand to the model spreads the effect of the policy change to areas not directly involved in zoning restrictions. Where a supply-side-only analysis would show no decreases offsetting the additions to stocks in previously zoned areas, the full model indicates that additions in the zoned areas are carried out at the expense of unzoned areas, and are accompanied by general price decreases and vacancy increases.

Eminent Domain to Produce Vacant Land

This simulation examines the impact on housing supplies of the availability of at least 5% vacant land in every zone in the metropolitan area as of 1960. In those zones that did not actually have that much vacant land, the government hypothetically "produces" it by using its power of eminent domain to claim land not currently in residential use; for example, land used for outdoor recreation (parks), or commercial and industrial uses. It is assumed that after the government has cleared it, the new vacant land appears in the land market just as any other vacant land would, some of it being bought and used by housing producers.

This policy affects only the fifteen zones in which less than one-twentieth of the area was vacant at the beginning of the decade. These fifteen zones contain 5% of the metropolitan land area, and 31% of the total 1960 housing stocks. They have a 1970 gross residential density (housing units per total acre of land) of 8.6, as compared with 1.1 for the rest of the metropolitan area. All but one of the affected zones are in the central geographic region; in fact, nine are within the city of Boston. Taken as a group, the affected zones have almost 3% vacant land, or roughly 900 acres vacant. Another 600 acres are taken from non-residential uses and added to the vacant category in this simulation.

This policy represents, in a sense, a cost reduction to housing producers and other land users in the 15 zones applying the policy. The change in initial vacant acres enters the model through five of the six supply equations, and the first round effect is an increase in the supply of housing available at any price in these zones. (These first round effects are shown on the right side of Table 5.) As these increased housing supplies come on the market, prices in these zones should fall, attracting increased demand from other zones. The other zones, losing demanders to the cost-reduced zones, should also experience falling prices, and decreased supplies in response.

As the full equilibrium results in Table 5 indicate, that description applies quite well to the simulation results. When demand is quite price-elastic (A1 = -5), the 15 zones to which the policy was applied show an increase in new units built during the decade, while the rest of the metropolitan area shows a decrease. Prices in all zones fall relative to the control results, and the decrease in the decade price change variable is greater for the zones subject to the policy. Vacancies increase everywhere. Conversion-retirement activity also responds to the change in vacant acreage and in prices and vacancy rates. The final outcome is a very slight increase in total metropolitan 1970 housing stock, made up of an increase of 1 1/2% in the previously land-scarce zones and a decrease of half a percent in housing available in the zones with more than 5% vacant land to start with. Final demand moves much the same way as supply. When demand is less price-elastic, e.g., A1 = -1, the effects are stronger, but much the same.

The structure type composition of the stock in each directly-affected zone is also altered by the policy change, since it depends on the fraction of land vacant. There is a "notch" in the equations predicting the structure type shares of new construction at 5% land vacant, and this policy pushes all the affected zones into the second percent land vacant category. This substantially increases the single family share of new construction, with an offsetting decrease in the apartment fraction. This change in the structure type composition of new units has an effect on the structure type composition of all of the 1970 stock, as shown in Table 5.

These simulations give some indication of the importance of vacant land in the metropolitan housing market. A comparison of the supply predictions and the full equilibrium results also reiterates the importance of

Table 5

Percentage Differences Between Simulated Outcomes and Controls for Policy of Eminent Domain in

Areas Where Vacant Land is Scarce

	Supply						Partial Equilibrium Supply Results			
	Total 1970 Supply	Decade New Construction	1970 Percent Single**	(no notch)	1970 Price	1970 Demand	Total 1970 Supply	Decade New Construction	1970 Percent Single**	(no notch)
A1 = -1 (Demand inelastic)										
Zones using policy*	+2.1%	+4.2%	+2.0	-.3	-7.6%	+2.0%	+1.7%	+10.1%	+2.6	+ .2
Other zones	- .7	-6.3	- .8	-.8	-6.9	- .8	0	0	0	0
SMSA total	+ .1	-4.2	- .2	-.9	-7.1	0	+ .5	+ 2.0	+ .6	- .1
Central region	+1.9	+1.5	+1.0	-.4	-7.8	+1.8	+1.2	+ 7.4	+1.8	+ .1
Inner ring	- .5	-4.3	- .6	-.7	-7.0	- .6	0	+ .3	+ .1	0
Outer ring	-1.6	-7.3	- .5	-.5	-6.2	-1.7	0	0	0	0
A1 = -3										
Zones using policy	+1.6	+7.2	+2.3		-4.3	+1.6				
Other zones	- .5	-4.4	- .5		-4.5	- .6				
SMSA total	+ .1	-2.1	+ .1		-4.4	0				
Central region	+1.3	+4.4	+1.4		-4.4	+1.3				
Inner ring	- .3	-2.7	- .3		-4.5	- .4				
Outer ring	-1.2	-5.4	- .3		-4.4	-1.3				
							Value of A1 is irrelevant			
A1 = -5 (Demand price-elastic)										
Zones using policy	+1.5	+7.4	+2.3	0	-3.9	+1.5				
Other zones	- .5	-4.3	- .5	-.5	-4.3	- .6				
SMSA total	+ .1	-2.0	+ .1	-.6	-4.2	0				
Central region	+1.3	+4.7	+1.4	-.2	-4.1	+1.2				
Inner ring	- .3	-2.6	- .3	-.4	-4.3	- .4				
Outer ring	-1.1	-5.3	- .3	-.3	-4.3	-1.3				

*Zones applying the eminent domain policy are those which would otherwise have less than 5% land vacant.

**The numbers reported in these columns are percentage point differences.

including demand constraints when considering the effect of local policies within a linked metropolitan housing market.

New Construction Subsidy

One of the policies often suggested for alleviating U.S. housing problems is a subsidy to builders to encourage the building of more new units. It is thought that this policy will increase new construction activity, perhaps also increase the retirement of old units, but result in there being a larger stock of units than otherwise would have been the case. The subsidy simulated here takes the form of a refund to the supplier of 10% of the total costs of the finished unit, and hence is modeled by increasing the price perceived by suppliers of new units 10% higher than the market clearing price in each of the 89 zones. Any effects of the financing of the subsidy are ignored.

The first round supply increases attributable to builders' perceptions of a higher price are shown on the right side of Table 6. Not surprisingly, since more units in total are supplied at any demand price, this reduces the market clearing price in every zone. However, the full equilibrium impacts of the changes in relative attractiveness set off by this policy are such that the final outcome shows increases in new construction in only a few zones. That is, the price declines are so great that in most zones 110% of the market clearing price is lower than the "control" price, or not enough higher to outweigh the negative effects of increased vacancy rates. Under the assumption that A1 = -5, new units increase in only 13 of the 89 zones, by an average 1% over their "fitted" values.

Table 6

Percentage Differences Between Simulated Outcomes and Controls for Subsidy to New Construction

	Supply					Partial Equilibrium Supply Results		
	Total 1970 Supply	Decade New Construction	1970 Percent New*	1970 Price	1970 Demand	Total 1970 Supply	Decade New Construction	1970 Percent New*
A1 = -1 (Demand inelastic)								
SMSA total	+ .2%	-5.7%	- .9	-11.9%	0 %	+ .8%	+5.8%	+ .7
Central region	+1.9	-6.5	- .8	-12.2	+1.7	+ .2	+2.3	+ .2
Inner ring	- .5	-5.0	- .6	-11.7	- .7	+ .4	+3.1	+ .4
Outer ring	-1.2	-5.8	-1.0	-11.4	-1.5	+2.0	+9.3	+1.6
A1 = -3								
SMSA total	+ .2	-2.4	- .4	- 8.1	0			
Central region	+ .9	-2.6	- .3	- 7.8	+ .8			
Inner ring	- .2	-2.6	- .3	- 8.3	- .4			
Outer ring	- .4	-2.1	- .4	- 8.4	- .6			
A1 = -5 (Demand price-elastic)							Value of A1 is irrelevant	
SMSA total	+ .1	-2.1	- .3	- 7.7	0			
Central region	+ .8	-2.3	- .3	- 7.4	+ .7			
Inner ring	- .2	-2.4	- .3	- 8.0	- .3			
Outer ring	- .4	-1.7	- .3	- 8.1	- .6			

*These columns report percentage point differences.

The net metropolitan outcome, however, is a 2% decrease in new units. This decline is fairly uniform across the geographic regions, only slightly smaller in percentage terms in the outer ring than in either the center or inner ring, where the decrease is greatest.

The subsidy program does, however, increase the total 1970 supply of housing units, as one would expect (although only by a small amount since demand is constant). The increase comes through conversion-retirement supply. Almost 4,000 more units come out of the conversion-retirement process, into the 1970 stock than in the control situation, a decline of 8 3/4% in the net loss of units. These increases are concentrated in the central area, where net conversion-retirement losses are down by 14%, but also occur in the inner and outer rings, reducing losses there by 4% and .6%, respectively. The net outcome is a small increase in the metropolitan area housing supply, predominantly concentrated in the central region where conversion-retirement is most important. Supply in the center increases slightly, while the inner and outer rings show small net losses. Since total metropolitan demand is the same in the control and policy cases, vacancies are up in most zones, by 6% on average. Vacancies rise more in the outer and inner rings (15% and 10%, respectively) than in the center (2 1/2% increase), because the center's slightly lower prices are more attractive to demanders. The final changes in demand are a small increase for the center and small decreases for the inner and outer rings.

When A1 is assumed to be -1, the impacts of the policy are similar to those reported above, but more severe. The decline in new units averages 6%, and the decrease in net losses through conversion-retirement averages 21%. The net increase in total units is higher, with wider divergence between center and outer ring changes in total units supplied. Vacancies increase an average 9%; 5% in the center, 15% in the inner ring, and 21% in the outer ring. Demands, too, have shifted more.

This set of results contrasts sharply with those usually projected for a new construction subsidy. For example, deLeeuw and Struyk (1975) with Ozanne and Schnare simulate a subsidy to new construction with the Urban Institute Housing Model.[10] Their subsidy takes the form of a decrease of 7 1/4% in the price per unit of housing service for new dwellings. The market response they predict is an increase in the number of new dwellings and a corresponding increase in the number of withdrawals from the stock (they have no vacancies). They also find that the price of all dwellings declines more than the price of new housing, because of the excess supply of low quality existing units.

One source of contrast between the two models is immediately obvious: they model the subsidy as a decrease in the price faced by demanders, whereas it is here modeled as an increase in the price received by suppliers. The very aggregate way in which demand is treated in the model presented here makes it impossible for demanders to distinguish among units in a zone in terms of source of supply: all units within a zone are implicitly taken to be perfect substitutes, and their prices must move together. Presumably in a general equilibrium context, a subsidy to new construction both lowers the price to demanders and increases returns to suppliers. However, deLeeuw et al. assume perfectly elastic new construction supply; therefore the full subsidy must be passed on to demanders, demanders who presumably can distinguish among units along several dimensions, including source of supply.

Despite this difference in methodology, their finding that all housing prices decline considerably is exactly analogous to the finding above. With a 7% subsidy, they get an average price decrease of 9%; with a 10% subsidy, the average metropolitan price decrease for the simulations reported above is 8 to 12%, depending on how price elastic zonal demand is assumed to be. DeLeeuw et al. have a positive price elasticity of supply of existing units, and so find increased withdrawals when new construction is subsidized. Since all new construction occurs in a zone separate from changes in existing housing, they may not be able to capture all the interactions among sources of supply which are represented here by zonal submarket clearing. The model here obtained econometric estimates of conversion-retirement supply elasticities which are negative in many zones. This result combined with the assumed substitutability in demand of new and old units produces the increment to supply through conversion-retirement attributed to the subsidy program.

Another "simulation" of a new construction subsidy was carried out by Sweeney (1974) with his commodity hierarchy model of housing.[11] He finds that a subsidy to a limited number of new units at specified quality levels will have no effect on the equilibrium vector of prices or supplies; subsidized units are simply substituted for unsubsidized units. Demanders in Sweeney's model can distinguish units along the quality dimension, but not among new and old units at any level. If the subsidy is extended to all units constructed at specified quality levels, the equilibrium price and supply vector will be affected. If all quality levels at which new construction occurs are included in the program, all housing prices may be reduced and supplies increased. However, depending on the form of the program (e.g., subsidy increasing or decreasing with quality, the choice of a quality level below which no subsidy is offered), some housing prices might actually increase as a result of the program. Sweeney points out that while his results refer to a subsidy program, they are "applicable to any influence which changes new construction costs. Tax laws, land prices, lumber prices, construction wage rates: all could influence new construction costs" (p. 310).

The full equilibrium results obtained here are interestingly contrasted with the first round supply effects generated by the model when demand is ignored. In the first round, the subsidy program increases new units considerably, especially in the suburban regions of the metropolitan area. When the test of demand is added to the model, making the absorption of all the new units impossible, prices fall, towns become relatively more or less attractive on the basis of changed prices and demanders move around. The net result is still more units, but not as many more as when demand constraints are ignored, and not all from the same source of supply as was indicated when the full price interactions among supply types were ignored.

4. CONCLUSIONS

What can these simulations tell us about housing markets and housing market research? The answers to these two questions are related. The most important single implication of these simulations is that the supply and demand for housing interact in important ways, both within local submarkets and across them, and these interactions are likely to undermine any simple predictions we make about policy impacts.

On the surface, we find that a partial analysis can predict the direction (although not the magnitude) of impact of those policies which shift the supply curve but predicts incorrectly the direction of quantity response to demand shifts.[12] However, this result cannot be generalized, because it is a product of the specific model assembled. In particular, this model has focused on obtaining a better representation of the supply side of the market than is generally available. Some of the estimated parameters are not in agreement with economists' a priori expectations. This detailed model of housing supply is combined with a simple demand equation which assumes that demanders act as economists say they do. Thus when we shift the supply curve, it moves along a demand curve which satisfies the usual assumptions of good behavior, and we get results in line with our expectations; whereas when we shift the demand curve, it moves along a supply curve which in some zones is estimated to have a negative slope, so the results are surprising.

To the degree that the estimated parameters capture aspects of the actual market operation, these are surprises we want to be aware of--and finding them through modeling and simulation is less costly than the possible surprise or disappointment involved in an actually implemented policy. If effort were also put into econometrically estimating a more disaggregated and carefully-specified set of demand equations, we might find some surprises in simulating supply shifts as well.

The particular contribution of this research, however, is a careful study of the supply side, with a focus on geographic variation in the crucial supply parameters. Many demand-based models of the housing market implicitly or explicitly assume that housing is perfectly elastically supplied in the long run. This model finds that over a ten-year period, the supply of housing is relatively unresponsive to price changes, especially in the denser regions of the metropolitan area, but for the metropolitan area as a whole, as well. When this model is used to simulate the impact of shocks which have a spatial dimension, it can provide some valuable and interesting cautions. For example, when we talk about an energy shortage making people want to move closer to the central city, we often forget that the supply response may inhibit such a move. Households do not end up living closer because price increases discourage them. This additional information about the supply side gives us a picture of future urban form very different from that obtained when the geographical shift in demand is assumed to be unhampered by housing supply constraints.

In spite of the general focus on supply, it is interesting to ask what, if anything, these simulations have taught us about demand, other than that it is important to investigate it further. Alternative assumptions about A1, the price elasticity of demand, generate quite different results. The distribution of more and less sensible results would seem to point toward the higher elasticities (A1 = -5 rather than A1 = -1) as being more reasonable. But that might be a statement about the model as much as about the sensitivity of housing demand to relative housing prices in a set of zones making up a metropolitan area.

It would seem that a full equilibrium model does have some insights to add to our understanding of the evolution of metropolitan form. While the specific implications of the simulations presented here--as reported in the "center, inner ring, outer ring" results of Tables 3 to 6--may be subject to some question, they do suggest that if we want to predict policy impact or understand current patterns of change, an analysis deeper than we usually apply is necessary.

APPENDIX

Variable Definitions and Data Description

All variables are observed for the sample of eighty-nine zones in the Boston metropolitan area.

Basic Measures of the Housing Stock

$SINGLE_{60}$ ($SINGLE_{70}$) Number of single family housing units in 1960 (1970)

$MULTI_{60}$ ($MULTI_{70}$) Number of multifamily housing units in 1960 (1970) (a multifamily unit is in a structure containing two to four units)

$APART_{60}$ ($APART_{70}$) Number of apartment housing units in 1960 (1970) (an apartment unit is in a structure containing five or more units)

$TOTAL_{60}$ ($TOTAL_{70}$) Total number of housing units in 1960 (1970)

NEW SINGLE Number of 1970 single family housing units built since 1960

NEW MULTI Number of 1970 multifamily housing units built since 1960

NEW APART Number of 1970 apartment housing units built since 1960

NEW TOTAL Total number of 1970 housing units built since 1960

CONV SINGLE 1960 to 1970 decade change in number of single family housing units not due to new construction (CONV SINGLE = $SINGLE_{70}$ - NEW SINGLE - $SINGLE_{60}$)

CONV MULTI 1960 to 1970 decade change in number of multifamily housing units not due to new construction (CONV MULTI = $MULTI_{70}$ - NEW MULTI - $MULTI_{60}$)

CONV APART 1960 to 1970 decade change in number of apartment housing units not due to new construction (CONV APART = $APART_{70}$ - NEW APART - $APART_{60}$)

$DETER_{60}$ Number of housing units deteriorating in 1960

$DETER\ APART_{60}$ Estimate of the number of 1960 apartment units deteriorating

$OLD\ SINGLE_{60}$ Estimate of number of 1960 single family units built before 1940

$OLD\ MULTI_{60}$ Estimate of number of 1960 multifamily units built before 1940

$OLD\ APART_{60}$ Estimate of number of 1960 apartment units built before 1940

$UNZONED\ OLD\ SINGLE_{60}$ Estimate of the number of 1960 single family units built before 1940 which are not subject to minimum lot size zoning restrictions ($UNZONED\ OLD\ SINGLE = UZ \cdot OLD\ SINGLE_{60}$)

NEW TIGHT Number of housing units built between 1960 and 1970 per acre of vacant land initially available ($NEW\ TIGHT = NEW\ TOTAL/VACANT\ ACRES_{60}$)

$VACANT_{60}$ ($VACANT_{70}$) Number of housing units vacant for rent or vacant for sale in 1960 (1970)

$\%\ RENTER\text{-}OCC_{60}$ Percent of 1960 housing units renter-occupied

Local Public Sector

SEWER The percentage of population served by public sewers

PZ Fraction of residential and vacant land zoned for minimum lot sizes greater than 25,000 square feet

UZ Fraction of residential and vacant land not zoned for minimum lot sizes greater than 25,000 square feet (UZ = 1.0 - PZ)

A Dummy variable equal to zero where zoning regulations prohibit apartment structures, equal to one otherwise

Land Use

TOTAL ACRES   Acres of land, total area minus acres of open water (not dated because no jurisdictions in the sample changed area over the study decade)

RESIDENTIAL ACRES$_{60}$ Acres of land in residential use

VACANT ACRES$_{60}$ Acres of vacant land (forest land, woodland--not state or national forest, or orchard); agricultural uses and vacant lots (beach--not public or commercial, crops, dairy farm, grassland, greenhouse, livestock, nursery, open land--vacant lots, orchard, pasture, vineyards)

MANUFACTURING ACRES$_{60}$ (MANUFACTURING ACRES$_{70}$)   Acres of land devoted to manufacturing

VACP   Fraction of land vacant (VACP = VACANT ACRES$_{60}$/TOTAL ACRES)

V1-V7   A set of dummy variables for ranges of value for VACP:

$V1 = 1$ if $VACP < .05$, $= 0$ otherwise

$V2 = 1$ if $.05 \leq VACP < .1$, $= 0$ otherwise

$V3 = 1$ if $.1 \leq VACP < .2$, $= 0$ otherwise

$V4 = 1$ if $.2 \leq VACP < .3$, $= 0$ otherwise

$V5 = 1$ if $.3 \leq VACP < .4$, $= 0$ otherwise

$V6 = 1$ if $.4 \leq VACP < .5$, $= 0$ otherwise

$V7 = 1$ if $VACP \geq .5$, $= 0$ otherwise

Other Variables

PRICE$_{70}$/PRICE$_{60}$ Estimate of ratio of 1970 average housing unit price to 1960 average housing unit price, for unchanged units existing in both 1960 and 1970

$\Delta PRICE/PRICE_{60}$ Percentage change in housing unit price 1960 to 1970 ($\Delta PRICE/PRICE_{60} = (PRICE_{70}/PRICE_{60}) - 1$)

OPEN Estimate of fraction of land both vacant and not subject to minimum lot size zoning restrictions ($OPEN = UZ \cdot VACANT\ ACRES_{60}/TOTAL\ ACRES$)

POP50 (POP60) Population in 1950 (1960)

Delta Convention

a "Δ" always refers to the simple arithmetic difference between the 1970 and 1960 observation, thus

$\Delta PRICE = PRICE_{70} - PRICE_{60}$

$\Delta VACANT = VACANT_{70} - VACANT_{60}$

NOTES

[1]For a more complete description of the supply model, see Bradbury (1976) or see Bradbury, Engle, Irvine and Rothenberg, forthcoming, for new construction, and Bradbury (1977a) for conversion-retirement.

[2]See, for example, R. Muth (1970, p. 72) and M. Reid (1962, p. 381).

[3]This assertion is made intuitively convincing if we take a simpler example than locational groups of housing as substitutes in demand. Consider a market for tea in which there are two brands, A and B, perfectly elastically supplied at prices P_A and P_B. They are not perfect substitutes (perhaps just because of brand loyalty), but <u>are</u> both tea. If the price of brand A goes up, and the price of brand B is constant, we espect consumption of A to fall and consumption of B to rise. Since they are not perfect substitutes, total tea consumption is also likely to decrease. However, the total consumption of (A + B) is likely to fall by considerably less than the consumption of A falls, since some users of A have have switched to B. That is, the price elasticity of demand for tea is closer to zero than the price elasticity of demand for one brand of tea. The argument made in the text is that the price elasticity of demand for housing is closer to zero than the price elasticity of demand for one sort of housing, in this case, housing in a particular zone.

[4]The demand functions developed by the M.I.T. Urban Modeling Project (Anderson et al. (1976) and work in progress) do incorporate a more careful consideration of substitution possibilities. They include two relative price change variables in each of the income class demand for zonal housing equations. The first expresses the local price change relative

to the average price change in the set of zones considered to be close substitutes for this zone. The second term reflects the average price change in this set of close substitutes relative to the metropolitan overall average price change. Thus the substitution process is divided into two steps: (1) demanders move within a set of similar zones in response to their relative prices; and (2) move into less similar zones when relative prices across groups change.

[5]Alexander Ganz reports that gasoline and oil account for 16.2 billion dollars out of total personal consumption expenditures on user-operated urban transportation of 55.6 billion dollars in 1966, almost 30% (A. Ganz, January 1968, p. 110, Table 28, for which the cited source is Survey of Current Business July 1967, U.S. Dept. of Commerce, Office of Business Economics, Washington, D.C.)

[6]Seventy-nine percent of respondents always used automobiles for the journey to work, and another 6% sometimes did, in a study by J. B. Lansing and G. Hendricks, 1967, p. 40 (Table 8).

[7]A. Ganz, (1968) cites total 1966 personal consumption expenditures of 465 billion dollars; hence user operated urban transportation is 12% of the total.

[8]There might also be some long run change in the geographic distribution of jobs as a result of the energy shortage. This possibility is not considered here.

[9]See Bradbury (1977b) for a more complete description of partial equilibrium supply-side-only simulation results.

[10]F. deLeeuw and R. J. Struyk (1975). The results summarized here are largely from pp. 141-147.

[11] J. L. Sweeney (1974). The policy results described here are largely drawn from pp. 309-311.

[12] The new construction subsidy is a supply-side policy for which we did not correctly predict the direction of impact. However, it is not a policy which simply shifts the supply curve in price-quantity space. The subsidy opens a wedge between the supply prices for the two basic sources of supply, and therefore has more complicated effects in the full equilibrium situation than could be predicted with the partial equilibrium approach.

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