HEDONIC PRICES AND PRICE INDEXES IN HOUSING MARKETS: THE EXISTING EMPIRICAL EVIDENCE AND PROPOSED EXTENSIONS

by

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Lancaster (1966, 1971), Lucas (1975), Muellbauer (1974) and Rosen (1974) address the theory that permits modelling consumer preferences for characteristics of goods through examining the relationship between the transaction price of a good and the measured amounts of the characteristics associated with that good. While none of these authors directly address the peculiarities of the housing market, Lancaster and Rosen are often cited as having developed theories which lend support to much recent empirical work undertaken by economists exploring housing, public finance and environmental questions. The housing market has been a popular focus because it is not the asset itself which is transacted but rather the right to the use of that immobile and durable asset. The right to the use of the asset has a value which is influenced by a diversity of factors. Many of these factors are amenable to study (for example, accessibility and pollution) by observing their influence on the value of the right. Typically, some proxy for value is treated as the dependent variable and all other factors which might influence value are independent variables in a regression model.

There exists a problem with the housing literature which takes this approach. Although Rosen and Lancaster are often cited as providing a theoretical basis for the use of price-characteristics regressions to analyze housing market phenomenon, no one has examined in detail the nature of the assumptions which this implies and whether these assumptions can be met in the housing market. Elsewhere (Dale-Johnson, 1979) we have examined these assumptions and

noted the constraints which, of necessity, such applications must place on the nature of housing markets. The result of this analysis has been a restating of Rosen's model in a simplified form and in a manner which gives credence to some of the current empirical research. Although the empirical literature incorporating price characteristics regressions to examine housing market phenomenon is large, few authors carefully address the constraints on analysis implied by the theory.

This paper is derived from a larger research project designed to meet two objectives: (a) to devise a hedonic price model which is theoretically consistent but which is amenable to empirical application; and (b) to test this model through empirical application. Clearly, a review of the existing empirical work is required. That review is the prime concern of this working paper. The paper is structured as follows. First, the key aspects of the model which has been developed elsewhere will be summarized. Second, prior empirical work will be reviewed. Finally, the constraints on empirical work implied by our model will be summarized along with some possible avenues for further empirical work.

A. A Review of the Model

The basic model is of the form noted below.

$$p(\underline{z}) = \underline{\rho}'\underline{z} \qquad (1)$$

Here, $p(\underline{z})$ is the transaction or sales price of a dwelling unit and

$\underline{z}$ is a vector of quantities of characteristics which describe or services which can be derived from the unit. $\underline{\rho}$ is the vector of implicit or shadow prices.

The immobility of housing structures and the consequent importance of location causes access to local services, amenities and the like to be contingent on the possession of a dwelling unit; therefore, the differential among services associated with various housing units, neighborhoods or communities is capitalized into the value of each dwelling unit. This is in addition to the more obvious physical aspects of a housing unit which are clearly correlated with price.

In the model, the n dimensional vector $\underline{z}$ is decomposed into two subvectors where i=1,...,k are the subscripts for the k characteristics intrinsic to the dwelling unit (the physical characteristics of the house and the lot) and i=k+1,...,n are the subscripts for the n-k public service-property tax mix and amenity variables. To reemphasize, it is the possession of a housing unit which provides the license or opportunity to consume certain services (like education and recreational services in the community) or, alternatively, which prevents or prohibits avoidance of certain nuisances or obligations (like paying property taxes and experiencing air pollution).

The model, however, goes a couple of steps further. First, the relationship indicated by equation (1) is only one small part of the picture. If market segmentation or submarkets exist in the housing market, then it is likely that a piecewise linear function more

accurately represents empirical reality. If j submarkets exist, the market might accurately be depicted by equation (2).

$$p(\underline{z})_j = \underline{\rho}^{(j)'}\underline{z} \qquad (2)$$

for i=1,...,m

Each of the j price characteristic's relationships represents a market segment which could be determined by a combination of consumer characteristics and characteristics of the good being purchased.

This model is proposed with the objective of giving credence to already existing empirical procedures. Meeting this objective would not imply blanket agreement with all prior empirical work but rather a confirmation that the empirical approach, if appropriately used, is a valid one. The literature abounds with empirical studies which are attempts to use regression techniques to analyze the price-characteristics relationship.

B. Relevant Empirical Work

The objectives of the empirical work that is to be reviewed cover a broad range. In many cases, each author has a relatively unique hypothesis that he wishes to test for which the empirical test chosen incorporates some version of what we have termed the hedonic price model (a price characteristics regression). Most often the test

involves a market wide or aggregate regression of transaction price on characteristics. More sophisticated studies attempt segmentation of the market-wide data in order to attempt analysis of housing submarkets or, simply, to prove their existence. Some of the empirical work that will be reviewed deviates from the use of the hedonic price model as slightly different theoretical constructs are employed as a basis for hypothesis testing. Finally, some of the empirical work employs the hedonic price model to examine longitudinal and cross-sectional price variations by constructing price indexes.

i) Hedonic Price Studies: No Segmentation

There are numerous studies employing the hedonic technique where segmentation is not considered to be an issue. What is unique among many of such studies are the author's attempts to come up with a previously unanalyzed or unmeasurable characteristic which provides insight into certain aspects of the housing market. Typically, such studies have incorporated the basic assumption that the price of a housing unit is a function of the characteristics associated with that unit. Hence, these studies use data about individual housing units. For example, Bailey (1966) and Lapham (1971) explore the impact of race on property value, Brown and Pollakowski (1977) explore the impact of shoreline or water access; Dewees (1976) explores the effect of accessibility to rapid transit nodes; Smith (1970), King (1973), Wales and Wiens (1974), and Noto (1976), the effect of public services and property taxes; Maser, Riker and Rosett (1977), the

effect of zoning and externalities; and, Thaler (1978), the effect of crime control. Edelstein (1974), Grether and Mieszkowski (1974), and Zerbst and Eldred (1977) undertake more general studies looking at a broad set of factors influencing the price at which individual transactions occur.

Those familiar with the literature will recognize a further group of studies having similar objectives but all of which use aggregated data. For example, Oates' classic study of property tax capitalization (1969) uses as a dependent variable the median value of owner occupied dwellings in various communities. Naturally, the independent variables are at the same level of aggregation. Such studies depend theoretically on the same underlying model as those studies incorporating transaction specific data. However, much of the transaction by transaction variability is not observable. Studies other than Oates' which explore property tax capitalization and the valuation of public services include Orr (1968, 1970), Heinberg and Oates (1970), Hyman and Pasour (1973), Pollakowski (1973), Oates (1973), McDougall (1976), King (1977) and Rosen and Fullerton (1977). All of these papers incorporate empirical contributions to the literature. A further set of papers in the area of property tax capitalization contain theoretical comments based on this wealth of empirical research. These papers include Coen and Powell (1972), Orr (1972), Heinberg and Oates (1972), and Hamilton (1976). These studies essentially explore variable selection and model specification and the impact on the theory that can be derived.

Studies concentrating on the impact on housing values of other factors and which incorporate aggregated data include Stull (1975), who explores the impact of zoning. Ridker and Henning (1967) undertake an analysis of the effect of air pollution on property values. Their research sparked considerable controversy as is related and examined in Anderson and Crocker (1971, 1972), Freeman (1971), Wieand (1973), Polinsky and Shavell (1975) and Small (1975). These papers essentially conclude that the price characteristics regression is useful as a tool to examine the significance of variation among observations in a system under ceteris paribus conditions (Polinski and Shavell, p. 101). However, the standard hedonic price model is argued not to be suitable where the purpose is to measure the aggregate effect on property values of a public bad such as air pollution (p. 103).

Ball (1973) surveys a number of empirical studies, some of which are cited among the above. His survey of housing market research employing price-characteristics regressions is cited here, not only to be thorough but also because some of his general conclusions are relevant. Ball attributes the lack of comparability among studies not only to data and measurement problems, but also to variation in supply conditions and in the level and distribution of income of consumers. Clearly he perceives the problem of comparing results derived from different supply-demand regimes. However, he does not note that such problems might confound the results of each study individually. He concludes by emphasizing the need for "a well formulated detailed

model of an urban housing market incorporating both supply (including second-hand sales) and demand, which has as an output empirically measurable (and valid) coefficients giving relative valuation of attributes..." (p. 232). The following studies begin, either implicitly or explicitly, to address the issue of market segmentation.

ii) Hedonic Price Studies: No Explicit Tests of Segmentation

While the studies that follow do not explicitly structure and test a theoretical model of market segmentation, they each formulate a testable hypothesis which if not rejected would give credence to such a model. These studies show by using some fairly simplistic segmentation procedures that there is evidence that submarkets do exist because different price characteristics relationships can be identified within urban housing markets. Such segmentation is evidenced by the existence of significantly different implicit prices of characteristics in different submarkets or market segments.

Some of the earliest work employing the hedonic price model to explore market segmentation was undertaken by Kain and Quigley (1970, 1975). Specifically, the earlier study explores the value of measures of housing quality in renter and owner submarkets and urban and suburban submarkets measures. The quality measures are a set of 5 factors determined from 39 variables. The 39 variables represent data ranging from measures of dwelling unit conditions to measures of neighborhood environmental quality drawn from interviews of residents and

building inspections. Testing for segmentation is not an explicit objective of the study. However, hedonic price variation among the submarkets Kain and Quigley devised are clear evidence of such segmentation. The authors conclude that their results illustrate the "complexity of the bundle of residential services" and the "inadequacy of so much previous empirical and theoretical work." As well, they note the need for more complete data bases in developing a better understanding of the housing market (1970, p. 546).

A later study by King and Mieszkowski (1973) explores the segmentation hypothesis, but where segregation and racial discrimination are the factors influencing market segmentation. The authors have the advantage of data on individual housing transactions incorporating dwelling unit characteristics, a measure of accessibility and a measure of school quality. As well, the race of the owner (purchaser) is known. The study takes place in New Haven, Connecticut, where the researchers segment the market geographically "into three kinds of areas: white interior, the black-white boundary and the ghetto" (p. 600). The authors argue correctly that price differentials by race for the same quality housing unit must depend on the ability of the vendor to price discriminate or short-run differentials among market characteristics (shifts in demand, variations among elasticities of supply) in ghetto, boundary and non-ghetto areas (pp. 591-95). The authors conclude from their analysis that price discrimination can be observed in boundary areas where whites view the racially

mixed aspect of the neighborhood as a negative influence on value while this is not the case for Blacks. Both Blacks and whites are observed to pay more for housing in ghetto areas and this is viewed as the result of the "funneling" of Black immigrants into ghetto areas where supply is relatively inelastic as opposed to the predominately white suburbs (p. 604). The results are clearly peculiar to the market circumstances and data collected in New Haven, but the results lend support to the segmentation hypothesis.

In a study of property tax capitalization, Church (1974) inadvertently adds to the evidence regarding segmentation, although his data are sparse with respect to variables which are not associated with the site and building (i.e., no attempt is made to account for accessibility, environment or the level of public services). In order to be certain of the robustness of his model, Church tests the significance of capitalization effects using data from 5 separate neighborhoods. The results support his hypothesis of tax capitalization but demonstrate as well some results of interest to us. In particular, the data by neighborhood appear to represent quite different submarkets. First, the mean selling price by neighborhood varies from $15,800 to $29,860, and second, the mean year of construction by neighborhood ranges from 1925 to 1957 (the data represent transactions in Martinez, California from 1967 to 1970). Church is not explicit but states that the neighborhoods are homogenous with respect to age and condition of property along with various socioeconomic factors. While no

tests of significance of differences among coefficients by submarket were undertaken, the specification and the coefficients of common independent variables vary by neighborhood. While such observations are not conclusive, they provide interesting evidence in the light of later work.

Edel and Sclar (1974) take a very imaginative look at some of the ideas presented by Oates (1969) and others.[1] The authors argue that in the short run there may exist supply inelasticities with respect to the public services provided in one or more of a group of contiguous market areas (communities or perhaps neighborhoods). Hence, as time passes supply adjustment may occur and it will be necessary to go beyond single period analysis to explore capitalization effects. In their article, Edel and Sclar analyze the capitalization of taxes, school expenditures, and road maintenance expenditures over five successive census periods in the Boston area. Their application of the hedonic price model employs aggregate data (as did Oates) and they argue that the results indicate a move toward equilibrium in the market for schooling, but not in all other markets for local public goods. Recent theoretical and empirical work would lead one not to place great confidence in the results since the model estimated is not well specified (no direct measures of housing quality) and the data are aggregate. Moreover, in the context of Rosen's model, there is no

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[1]The interested reader should refer back to the summary of empirical research exploring the question of property tax capitalization.

reason to believe that variation in demand and supply factors have been appropriately accounted for. Certainly, over a forty year period such variation should be explicitly accounted for in any analysis. In their favor, the authors point out the likelihood of longitudinal variation in price-characteristics relationships observed in housing markets.

iii) Hedonic Price Studies: Explicit Tests of Segmentation

Although they do not expressly address the issue of market segmentation, the previous four articles have been summarized because the nature of the research procedure employed led, in each case, to the uncovering of evidence about market segmentation. The following papers address that issue squarely. So as not to exclude related and important empirical work, this section and subsequent sections, (iv) and (v), include research that can be classified in three different groups according to the empirical methodology used. Only the first of these groups employs the methodology to which our model, as represented by equation (2), is oriented. The second group of papers uses Rosen's somewhat more complicated model as a basis for developing a methodology for empirical analysis. The third group draws upon a model of discrete choice as a basis for developing a methodology for analysis. The underlying theoretical models vary somewhat and, hence, the empirical tests are each unique. Nonetheless, there is a relationship among the three models which should become clear.

As well, the three models are based on the underlying presumption that in an urban area housing markets are best viewed as collections of submarkets or market segments each with their own unique characteristics.

Straszheim (1974), Schnare and Struyk (1976), Sonstelie and Portney (1977), and Palm (1978) explicitly examine the question of market segmentation. They do so simply by employing more carefully the traditional methodology of exploring the price-characteristics relationship using regression techniques.

Straszheim was one of the first researchers to be explicit regarding criticism of the growing hedonic price literature in the area of housing which had failed to address the heterogeneous nature of housing markets. Using transactions data for three urban areas within the San Francisco Bay Area, Straszheim is able to demonstrate significant differences between price-characteristics relationships derived in each of two zones for each of the three urban areas. F-tests reveal that the stratification within each urban area reduces the residual sum of squared errors. Unfortunately, the study is sparse with respect to descriptor variables (for example, no public service - property tax mix or neighborhood variables are included). As well, the sample is only segmented along geographic lines. However, he concludes, "The discussion of hedonic price estimation might more usefully be directed to the criteria which should be employed to define homogeneous submarkets within urban areas" (p. 406).

The study by Schnare and Struyk is one of the most sophisticated from the point of view of the model which we propose. Their approach is a natural extension of the work which proceeded. Their purpose is to test the relative merits of a "market-wide or unstratified model and its accompanying assumption of an effectively unified housing market (p. 147)." In the context of our model, this would imply that the segments denoted by the subscript (j) in equation (2) would collapse into one and $p(\underline{z})$ would be linear throughout the relevant range.

The authors seem to recognize the theoretical problems inherent in much of the analysis that has been undertaken. Their rationale for segmentation is summarized as follows:

> ...Market segmentation is likely to occur when the demand for certain housing attributes is highly inelastic and when that demand is shared by relatively large numbers of households. By a "highly inelastic" demand, we mean a very small elasticity of substitution between the particular attribute and the other attributes of the stock, as well as between the particular attribute and other goods in general; similarly, by a "relatively large" number of households, we mean a number that is large compared to the number of existing dwellings that possess the preferred attribute or set of attributes. (p. 149)

This state, of course, depends on the presumption that the supply of dwelling units possessing the relevant attributes is inelastic in the short run and that quasi-rents will result.

The authors test for evidence of market segmentation by defining a number of potential housing submarkets and then estimating hedonic price equations from samples drawn from the total market and from

each of the submarkets. This approach requires that some a priori decision be made with respect to the stratification of the data. In this case, the data are stratified using three variables (tract income, a measure of accessibility and the number of rooms), and a 2 x 2 x 3 factorial design resulting in twelve separate submarkets. An attempt was also made to stratify by municipality, but sample limitations precluded further stratification by neighborhood or structural type.

The data are for individual sales transactions of single family houses. Sales price is regressed on a set of n=18 independent variables (the vector $\underline{z}$), n-k=13 of which are intrinsic to the house and k=5 of which are neighborhood or public service variables. The authors find that although there are significant differences among coefficients from different segments, the standard error of the constrained or sample-wide regression is not appreciably reduced in the unconstrained or stratified case[2] (pp. 155-160). Tests are undertaken to test the predictive capability of the segmented and unsegmented models (pp. 162-63). The authors conclude that "...these two tests lend strong support to the general efficacy of the unstratified regression model

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[2]The standard error of the stratified case is calculated as follows:

$$SE_{UN} = \frac{m_1-n_1-1}{\Sigma\,(m_j-n_j-1)}\,SE_1 + \frac{m_2-n_2-1}{\Sigma\,(m_j-n_j-1)}\,SE_2 + \ldots + \frac{m_J-n_J-1}{\Sigma\,(m_j-n_j-1)}\,SE_J$$

where m_j is the j^{th} subsample and n_j is the number of independent variables in the j^{th} segment.

in analyzing intrametropolitan variations in the price of housing" (p. 163). There is, however, a caveat. The researcher must not be interested in the attribute or hedonic price but rather the overall price of services. Although the authors qualify their conclusion, the conclusion does seem unjustified given that most housing market research has concerned itself with the significance of particular attribute or hedonic prices. Certainly this is the case for the environmental quality and amenity literature and the public service - property tax mix literature. Finally, the authors note that their delineation of the segments may not be the most appropriate.

Sonstalie and Portney (1977) undertake a study of San Mateo County in the San Francisco Bay Area. The empirical work is oriented toward deriving new and better ways of specifying the hedonic price function. However, the authors also address the question of market segmentation.

The first deviation from the traditional model specification is the use of the notion of gross rent rather than aggregate price or capital value as the dependent variable in the $p = p(\underline{z})$ relationship. Gross rent is defined as

$$R = tP + dP + rP \tag{3}$$

where R is the gross rent of a dwelling, P is its market value, and t, d, and r are the effective property tax, depreciation and interest rates. The authors have used a somewhat simplistic notion of gross

rent in their calculation. Accounting for variability in property tax rates and not accounting for variability in marginal tax rate and the consequent effect at tax return time for mortgagors seems like a partial measure. The motivation of the use of gross rent (R) as a dependent variable is the concern that in long-run equilibrium it is possible to have no capitalization of public service - property tax mix differentials when the capital value is the dependent variable. The situation can only occur when the consumers within submarkets have homogeneous tastes with respect to public services and receive the benefits derived therefrom exactly offset by the property taxes imposed to generate the funds for expenditure on those services. Sonstalie and Portney cite Pauly (1976) for empirical evidence on this point. A further discussion is included in Bruce W. Hamilton (1976).

The authors fail to point out that if indeed the market were in long-run equilibrium and if the appropriate data were available (per capita tax cost and per capita public service expenditure) and if the market were as simple as their cited theory suggests, there would be perfect negative correlation between per household taxes and expenditure and one of the variables could simply be dropped. Of course, such a scenario is unlikely. In the gross rent model proposed by Sonstalie and Portney, when the market is in long-run equilibrium with no capitalization, a regression of gross rent on per household public service expenditure holding all else constant should yield a coefficient of unity (1). While the market may indeed

have these characteristics in the long run, the likelihood of reaching such an equilibrium is minimal. Certainty, in an unstratified case such an equilibrium is even less likely. Given the various sources of municipal revenues, the range of public services offered in a community and the range of individual preferences for a tax-service mix, maintaining the tax rate and public service expenditure as independent variables, is not unreasonable. In the ideal case suggested by Sonstalie and Portney it is unreasonable to think of varying services without raising or lowering taxes in the real world. Such a situation is possible and in fact quite likely.

Another unique aspect of the Sonstalie and Portney paper is their use of the Box-Cox transformation to test the suitability of functional forms ranging between the linear and semi-logarithmic form. The transformation takes the form

$$p^{[\lambda]} = \frac{p^{\lambda} - 1}{\lambda} \qquad (4)$$

where for $\lambda=1$ the result is a simple linear transformation and as λ approaches zero the result approaches the log of p. If segmentation is to be attempted, this empirical approach is inconsistent with the notion that careful segmentation of the market will permit linear approximation of the price-characteristics relationship in each submarket. The nature of the true market-wide relationship is, of course, an empirical question, and as Rosen notes, one need not expect $p(\underline{z})$ to be linear.

With respect to market segmentation, the authors use a Chow test to find that they cannot reject the possibility that the San Mateo County housing market is not homogeneous. Though they question their results, arguing that the County is extremely homogeneous with respect to racial and socioeconomic characteristics, it seems unlikely that in a county with in excess of 500,000 residents and 19 incorporated cities as diverse as South San Francisco and Atherton there would not be segmentation in the housing market. It should be noted that Sonstalie and Portney only stratified the sample in two ways: first, according to political boundaries and, second, according to accessibility to the North or South employment center in the County.

A recent paper by Risa Palm (1978) takes a somewhat different approach to the market segmentation issue by using a variant of the hedonic price model and incorporating information exchange as a basis of submarket definition. Palm derives her dependent variable from the change in average house price in a census tract adjusted by the change in the overall cost of home ownership reported in the consumer price index (CPI) during the period in question. This variable is regressed on the change in absolute average square footage in order to remove this effect from the price change. The residual from this regression becomes her dependent variable in subsequent analysis. The 12 independent variables in the model are derived from 20 neighborhood descriptor variables using principal component analysis in order to minimize the effects of multicollinearity.

Palm then attempts to demonstrate that housing submarkets are more effectively defined on the basis of real estate board jurisdictions than on the basis of economic or racial-ethnic characteristics. Examination of the adjusted R^2's and the F-ratios (which compare the reduction in error variance for the stratified and unstratified models) for the variously defined submarkets leads Palm not to reject her hypothesis.

While her conclusion seems reasonable, there are some aspects of her analysis which should be noted. First, her data are aggregated. Although there has been considerable empirical work undertaken using aggregated data, it does seem plausible that different submarkets could coexist within one census tract. Certainly, a great deal of variation among specific house prices and among the corresponding $\underline{z}$ vectors is lost in the aggregation. Second, price change is the dependent variable. While most studies have examined price or some proxy for price, Palm chooses to examine price change. Certainly, the last two criticisms are related as the use of price change as a dependent variable demands the use of aggregated data. In any case, the use of such a dependent variable implies that quite a different phenomenon is being examined. In fact, it is possible that Palm's hypothesis cannot be rejected simply because she has examined the correlates of price change and not of price. Finally, as in all of the market segmentation studies which are examined here, segments are established using some a priori choice of a variable suitable for

segmentation. In this case, income, racial-ethnic and spatial variables have been used individually to provide three separate sets of market segments.

Segments appear to exist in housing markets and these papers support that result. However, it may be that these segments are determined by a much more complex set of factors This completes the review of the set of papers which uses the statistical methodology toward which our model is oriented. Straszheim, Schnare and Struyk, Sonstalie and Portney, and Palm use relatively straightforward cross-sectional regression techniques to explore the hypothesis that segmentation occurs in urban housing markets.

iv) Studies Employing Rosen's Model

The second group of papers that addresses the issue of market segmentation do so by applying the model proposed by Rosen in his 1974 paper. As we have pointed out previously, this model, though conceptually similar to our model, requires relatively more data and analysis to yield useful results. Harrison and Rubinfeld (1978) and Nelson (1978) use Rosen's model and the empirical technique which is suggested in his 1974 article to examine the demand for urban air quality. As a consequence, these two papers are oriented toward dealing with some of the theoretical issues raised by Ridker and Henning (1967) and subsequent papers on the issue of air pollution and its impact on housing values.

The issue which motivates both of these papers and for which reason Ridker and Henning and other researchers are criticized is that one cannot assume that the value placed on a marginal improvement in air pollution concentration is independent of the level of air pollution and independent of household income and tastes. Harrison and Rubinfeld point out that prior research makes the assumption that there is a linear damage function for air pollution which is identical for all households (p. 98). More likely, there exists market segmentation such that there exists variation in the implicit prices or hedonic prices of housing characteristics. As we have pointed out, Rosen's model involves the identification of demand and supply functions for characteristics for each market segment. In fact, at the extreme such functions could be derived for each individual in the market. Our approach, of course, as represented by equation (2), is to run regressions in each submarket, thus estimating the coefficient or implicit price at the equilibrium point of Rosen's characteristics supply and demand functions (Rosen, p. 49).

The procedure proposed by Rosen and employed by Harrison and Rubinfeld and Nelson involves three main steps. The steps are:

Step (1) Estimate the price-characteristics relationship for the market <u>including</u> the characteristic of concern as an independent variable (estimate $p(\underline{z})$);

Step (2) Estimate each household's marginal willingness to pay for a marginal change in the quantity of the character-

istic (calculate $p_i(\underline{z})$ for each household). Implicit here is the assumption that the quantity of the characteristic in question not have a linear relationship with price. If the relationship is linear, then there is no variation in marginal willingness to pay and the problem which the technique is meant to address does not exist; and

Step (3) Estimate a marginal willingness to pay function which is the analog of a standard demand function and a profit compensated supply function which is the analog of the firm's marginal cost curve. Note that for air pollution the supply is assumed to be exogenously fixed, hence the demand function can easily be identified.

These steps are discussed in detail elsewhere. See Rosen (pp. 48-51) and Harrison and Rubinfeld (pp. 82-85).

The results of the analysis in both of these papers (Harrison and Rubinfeld, and Nelson) support Rosen's theory, and, in turn, support the idea that market segmentation is an important factor in examining the implicit prices of housing characteristics. Specifically, Harrison and Rubinfeld conclude that the level of pollution, household income and household size are significant at the .01 level with respect to the household's willingness to pay for a reduction in the level of air pollution (p. 89). Here, the household's willingness to pay is the set of $p_i(\underline{z})$ derived in Step (2) above. Similarly,

Nelson finds that the inverse of the particulate air pollution level, median family income, and median number of persons per housing unit are significant at the .05 level with respect to the implicit marginal price of air quality (p. 366). Both of these studies use aggregate data (1970 census data for Boston, SMSA and Washington, D.C., SMSA, respectively). Each confirms the other's results except to the extent that Nelson estimates a characteristics supply function (arguing that air quality does vary over the region), and Harrison and Rubinfeld extend the study to examine the welfare benefits of a decline in pollution levels.

As has been pointed out, this research is not conceptually inconsistent with our model. However, to the extent that a three stage procedure is involved to examine the effect of market heterogeneity on implicit prices, Rosen's approach for some purposes may be unnecessarily complicated. Nonetheless, the above articles are cited because they provide convincing evidence of implicit price variation due to market segmentation.

v) Studies Employing a Discrete Choice Model

The final set of empirical studies to be discussed are based on a different conceptual and theoretical approach to analyzing consumer behavior in housing markets. The theory, however, is not inconsistent with that which we have discussed so far. Rather, starting from the same basic view of the housing commodity as a bundle of characteristics, a model is developed which attempts to

predict what sort of consumer is most likely to occupy a house with a specified set of characteristics.

An interesting contribution due to Ellickson (1978) is his categorization of the Muth and Alonso formulations of the basic model of residential location as special cases of the hedonic price model due to Rosen (pp. 1-3). In particular, Alonso's bid function (1964, pp. 68-71) is seen as a special case of Rosen's bid function where housing characteristics are limited to accessibility and lot size, and the money cost of transportation is introduced explicitly into the budget constraint. Alonso does not incorporate the indirect utility function or the hedonic price function explicitly. But, nonetheless, his formulation of the residential location model proves to be a special case, albeit a restrictive one, of the consumer side of Rosen's model. Of course, Alonso's bid function is that of an individual consumer, while Rosen describes the whole market using β as a shift parameter which varies among types of consumers.

Using Alonso's model as a base and the extensions due to Rosen, Ellickson formulates an empirically testable model. Ellickson suggests a consumer's bid function of the form $\theta^{(j)}(\underline{z})$, where j denotes a type of consumer. This is a similar form to our model developed elsewhere (Dale-Johnson, 1979, Chapter 5, equation (5-11)) except that Ellickson suppresses the prices of other goods p_x, the income parameter $y^{(j)}$, and the equilibrium level of utility $u^{(j)}$. Prices of other goods do not change and income and utility are constant for all consumers of type j. Ellickson then postulates that the bid

function is stochastic; this in turn allows him to make the probabilistic statement

$$PR(j|\underline{z}) = PROB\{\theta^{(j)}(\underline{z}) + \varepsilon^{(j)} > \theta^{(j')}(\underline{z}) + \varepsilon^{(j')}\} \qquad (5)$$

where $j' \neq j$ and $j', j \in J$, and J is the set of all household types. Assuming that the error terms are independently distributed Weibull, equation (5) can be rewritten

$$PR(j|\underline{z}) = \frac{EXP\ [\theta^{(j)}(\underline{z})]}{\sum_{j' \varepsilon J} EXP\ [\theta^{(j')}(\underline{z})]} \qquad (6)$$

Thus, Ellickson has reformulated the traditional residential location model into a probability model and he proceeds to estimate a linear form of this model using San Francisco Bay Area data (28,000 households, 1965). A reference for the technique involved (logit) is McFadden (1974). Using à priori assumptions about market segments (whether children are present and income category), Ellickson finds that the results provide "strong confirmation of several hypotheses that have appeared in the housing literature" (p. 9). For example, higher income households tend to prefer newer housing, larger lots, and so on.

As has been noted, Ellickson's work provides a useful discussion of the relationship between traditional residential location

models and a hedonic price model such as Rosen's. With respect to the analysis itself, the vector of characteristics $\underline{z}$ is sparse in comparison to most recent studies that employ simple regression techniques rather than logit (for example, Schnare and Struyk (1976)). In particular, a measure of the property tax rate is not included. Also, the measures of the quality or supply of local public service that are included are less than adequate and this may be the reason that they prove to be insignificant. Presumably, variables z8 and z9 are meant to be measures of school quality (percent of Black elementary school students and percent of Black junior high school students, respectively). In a similar study property tax rate is found to be significant using virtually the same technique as Ellickson (Friedman, 1975, pp. 73-76). While Ellickson's data appear somewhat limited, his model appears to work in a manner consistent with theories about housing market behavior. Most important, his results fail to reject the existence of market segmentation using an alternate methodology.

The Friedman paper is similar to the Ellickson research in that the logit technique is employed. However, rather than estimating the probability that a consumer of type j will occupy a house described by $\underline{z}$, Friedman estimates the probability that a particular community (implicit in $\underline{z}$) will be chosen by a consumer of type j. Equation (6) expresses the model estimated by Ellickson. Equation (7) is the model estimated by Friedman and Quigley (1976). See,

for further discussion, McFadden (1977).

$$p(\underline{z}|j) = \frac{\text{EXP } [u^{(j)}(\underline{z},p(\underline{z}))]}{\sum_{\underline{z}'\varepsilon K} \text{EXP } [u^{(j)}(\underline{z}',p(\underline{z}'))]} \tag{7}$$

Here, $\underline{z}\neq\underline{z}'$, $\underline{z}'\varepsilon K$ and $u^{(j)}(\underline{z},p(\underline{z}))$ is the consumer's indirect utility function. Consumer income and the prices of other goods are assumed (as in Ellickson's model) to be invariant among all households or consumers of type j. The indirect utility function is assumed to be linear in the parameters.

Friedman's results are consistent with Ellickson's and again support the hypothesis of the existence of market segmentation. Specifically, stratifying the sample by income, age of household head and household size indicate that variables such as local public education expenditure (educational quality) are more important to low income households whose head is 42 years old or younger, and households with four or more persons. It should be noted, however, that in Friedman's formulation the hedonic price function $p(\underline{z})$ is actually imbedded within a variable called quantity of housing services or standardized housing units (pp. 60-69). Hence, the estimated model is not easily compared to the traditional hedonic price model, whereas Ellickson's model is more amenable to this comparison.

The work by Ellickson, Friedman, McFadden et al. begins to deviate from what we might call the "mainstream" of research employing

hedonic prices. Some of their work has been summarized here simply because their results are not inconsistent with much of the empirical work discussed prior.

vi) Price Index Studies Employing Hedonic Prices

All of the empirical work which has been discussed thus far, except, perhaps, for the paper by Edel and Sclar, has been cross-sectional in orientation. We would like to extend our theory into the area of hedonic price indexes with the view that series of cross-sectional price-characteristics regressions can be used to derive quality adjusted price indexes. Such indexes could, of course, be used to measure price differences in two ways: (1) through time for a specific community or submarket; and (2) among different communities or submarkets at the same point in time. Some empirical work has been undertaken in this area and those studies will be reviewed here.

Gillingham (1975) undertakes a thorough exploration of the problems inherent in generating meaningful inter-city price indexes. He combines Bureau of Labor Statistics Housing Survey Data with census data to arrive at a set of variables which include the rent level of the unit along with a set of physical and household characteristics for both the unit and the neighborhood. These data are available for ten major U.S. cities: Chicago, Los Angeles, Detroit, Boston, Pittsburgh, Cleveland, Washington, Baltimore, St. Louis and San Francisco. Indexes are derived which indicate the variation in

price of a standard unit of housing services among the ten cities.

We will relate Gillingham's model using notation consistent with that elsewhere in this paper. Rather than comparing hedonic price functions in period 0 and period 1, here we want to compare such functions for city A and city B or submarket A and submarket B. Gillingham uses the semilog functional form[3] for $p(\underline{z})$ complicating the index derivation. The semilog hedonic price functions for cities A and B are related in equations (8) and (9).

$$\ln P(A) = \underline{\rho}'(A)\ \underline{z}(A) \tag{8}$$

$$\ln P(B) = \underline{\rho}'(B)\ \underline{z}(B) \tag{9}$$

The Laspeyre's hedonic price index follows:

$$I_{AB} = \frac{P(A)^*}{P(B)} \tag{10}$$

where $\ln [P(A)^*] = \underline{\rho}'(A)\ \underline{z}(B)$

Taking the natural log of equation (10) gives us

$$\ln I_{AB} = \ln [P(A)^*] - \ln P(B) = [\rho'(A) - \rho'(B)]\underline{z}(B)$$

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[3]The specification of $p(\underline{z})$ is an empirical issue. Lancaster presumes the relationship is linear while Rosen assumes it is not. The real issue, however, is not one of functional form but rather one of measurement.

and taking the antilog of the relationship above gives us

$$I_{AB} = \text{EXP}\ [\ln I_{AB}] = \text{EXP}\ \{[\underline{\rho}'(A) - \underline{\rho}'(B)]\underline{z}(B)\} \qquad (11)$$

So, if the hedonic price functions are estimated as in equations (8) and (9), equation (11) gives us a Laspeyre's hedonic price index.

Gillingham's conclusions are not surprising given that we already know there is a high likelihood that hedonic prices may vary significantly among submarkets and across time. He notes that the results indicate,

> ...that there is substantial variation among place to rent indexes constructed for different reference groups, and that specification of the group to be represented by the index is a crucial aspect of index design. However, it was also shown that the construction of indexes under a partitioning of rental units by city yields indexes with a high degree of within group variation. Future research should be aimed at developing disaggregation methods which will yield indexes with low variances so that households within the coverage of an index will have a measure which is not only representative of them in the expectational sense, but also a close approximation to a measure which is designed specifically for them. (p. 166)

Ferri (1977) undertakes a longitudinal hedonic price index study using Multiple Listing Service Data from Fayette County, Kentucky covering an 11 year period. The analysis included in this paper is simple and straightforward except that the technique used for calculating the index itself is somewhat unusual. The author estimates for each of the 11 years a regression in semilog form as follows:

$$\ln P = P(\underline{z}, D_1, \ldots, D_{12}) \tag{12}$$

Here, the vector $\underline{z}$ is comprised of the standard set of housing characteristics variables[4] and the variables D_1 through D_{12} are dummy variables for the month in which the particular transaction occurred. The author argues that the estimated coefficient of D_{i+1} minus the estimated coefficient of D_i gives the percentage increase in price from month D_i to month D_{i+1} after adjusting for variation in quality. If this is the case, the author then argues that stringing together 132 of these differences (11 years x 12 months) will give a quality adjusted price index. The resulting index is compared to an index derived from sample means and found to be less volatile while still preserving the trend of the index of sample means.

There are, however, three major potential areas of difficulty with this approach. First, implicit in this approach is the assumption that the housing market within the county is not segmented (yearly regressions were run on a county-wide basis). Second, it is assumed that there is not significant variation in the market conditions within each year. Such changes might lead to variation in the implicit prices of housing characteristics within the year which would bias the coefficients of the D_i's. Third, although equation (12) was estimated on a year-by-year basis (see Exhibit 1, p. 458), it was assumed that the D_i's from each regression can be

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[4] Ferri does not include a location variable or public service - property tax variables. The exclusion of these variables seems unjustified given that the data are county wide.

strung together to create the index. This presumes that the nature of the sample in December meshes well with the nature of the sample in January of the subsequent year (i.e., the quality adjusted price for December is the base price for quality adjusted prices derived from the subsequent year's data and so on).

Because of these problems, Ferri's results, though intuitively appealing, leave something to be desired. It is possible that the MLS data are adequate and that the Fayette County housing market lacks volatility such that the results are not biased. However, the research has not addressed either of these possibilities.

Goodman (1978) undertakes a study of the New Haven area using data originally employed by King in his 1973 study. The data cover a three-year period and are segmented into five submarkets (geographical areas within the New Haven area). The results are consistent with our ideas about market segmentation and variation of price structures through time. Specifically, stratification of the sample by year for the whole sample or for each neighborhood leads to the rejection of the hypothesis of the equality of coefficients across time. Stratification by neighborhood for the whole sample or year-by-year leads to the same result. An analysis of covariance confirms these results (p. 476). The authors, as well, use the Box-Cox procedure as employed by Sonstelie and Portney (see equation (4)). The use of this approach leads to a choice of $\lambda = 0.6$ which is consistent with the value for λ derived by Sonstalie and Portney.

Since the segmentation hypothesis appears to have been confirmed by the initial results of the analysis, the author goes one step further. Essentially, he experiments with the data to demonstrate the effect that segmentation has on the derivation of hedonic price indexes. To do this, he chooses "three separate structures of physical components and three separate neighborhoods of neighborhood components" (p. 479) yielding a matrix of nine possible types of housing unit (each representing a certain vector of structural and neighborhood characteristics). The general conclusions are that heterogenous implicit or hedonic prices when rebundled with standardized housing packages reveal significant price differences between submarkets that are obscured by single market assumptions and estimation procedures. Controlling for both neighborhood and structural variables, prices in New Haven versus the suburbs are up to 20 percent higher. Suffice to say, the indexes vary enough that the author concludes,

> ...judicious subdivision of the metropolitan market reveals valuable information about price variation within the metropolitan area. Although single equation models can give servicable answers about prices, on average, separate equations may offer more insight into the important short-run behavior of markets within the metropolitan area. (p. 483)

The author, however can be criticized on a few points. First, the list of independent variables lacks a property tax variable. This is particularly damning since the author undertakes comparison of standardized units among municipalities. Second, segmentation

was undertaken on a municipal and year-by-year basis. There is no reason to believe that those are the most appropriate criteria even though the author's hypothesis appears not to be rejected.

C. A Proposal for Further Empirical Work

An extensive amount of empirical work in housing markets has been undertaken both employing the hedonic price model and exploring related concepts. However, as yet, there does not appear to be a complete package of theory and related empirical application in local housing markets, particularly where the issues of market segmentation and price indexing are addressed. To this end we have imposed constraints on Rosen's model to give theoretical structure to the standard price-characteristics regression. The cost of developing this theoretical structure is the resulting need to recognize the role of housing submarkets in the price-characteristics relationship. Submarkets, then, must also be considered when price indexes are constructed. To move toward the "complete package" mentioned above we will conclude this paper with a summary of the assumptions or constraints which are peculiar to our model and which must be imposed on Rosen's model, and then suggest avenues through which the existing body of empirical work might be extended.

i) The Assumptions Peculiar to Our Model

Rosen's model is a general one and it questions the validity

of many of the interpretations drawn from existing empirical work involving price-characteristics regressions in housing markets. Essentially, if the $p(\underline{z})$ function is non-linear, one cannot be confident that implicit prices derived from groups of transactions have any meaningful interpretation if individual consumers or groups of consumers are the object of analysis. Rosen's model provides an empirical methodology to avoid this shortcoming of much existing empirical work. However, the data involved and the analysis required are more extensive than typically have been employed in recent empirical work.

Our model, which is a simplification of Rosen's model permits the type of analysis which heretofore has been common among housing economists. To do so the model incorporates assumptions which seem as though they are reasonable for the short run in the housing market. These assumptions both simplify the model and reduce the data necessary for analysis.

The assumptions underlying Rosen's model have been made explicit elsewhere (Dale-Johnson, 1979, Chapter 3). What follows are a series of constraints which must be imposed on Rosen's model in order that the traditional empirical approach of using price-characteristics regressions be feasible. These constraints are implicit in our model.

1. In the short run, the existing stock of housing units must dominate any flow effects. Specifically, this implies that we can observe the price-characteristics relationship in a

submarket by looking at all transactions which have recently occurred. Since many of these transactions involve existing homes offered for sale by their current occupants, we cannot assume that producers' offer functions or profit-characteristics indifference curves and have a short-run impact on the prices at which housing units are offered for sale. However, we can assume that the interaction between home purchasers and occupant-vendors leads to a set of transactions which yield the price characteristics function $p(\underline{z})$. In the long run, this function would be influenced by the supply of new units as occupant-vendors compete with developer-vendors. As well, this function would influence the nature of new units being constructed. Suffice to say, price-characteristics regressions represent the result of the interaction of demand with the stock of housing units, a short run phenomenon.

2. There exists market segmentation such that the housing market in an urban area can be divided into submarkets and that the price-characteristics relationship in each such submarket can be approximated by a linear function which is stable in the short run. The price-characteristics relationship, however, may vary significantly when compared with that derived in another submarket. Specifically, the linear relationship within a submarket should remain similar or constant through short periods of time, but should not be expected to be similar to that rela-

tionship identified in another submarket or to that relationship identified in the same submarket after the passage of a long time period. In other words, the price-characteristics relationship is not likely to remain constant in the long run.

3. Market segments or submarkets are identifiable by a combination of demand and supply characteristics. More precisely, demographic and socioeconomic data about purchasers or existing occupants and neighbors along with response data (characteristics of the good or service being consumed) can be used together to isolate market segments or submarkets. However, rather than using this information to identify one demand function and one supply function (as does Rosen with the vectors α and β), we will identify j groups of demand and supply equilibria. Within each j^{th} submarket (as determined by our analog of Rosen's α and β) there exists a series of equilibria, each representing a transaction. What associates all of the transactions within a submarket is that the value or implicit price each consumer ascribes to a unit of the characteristic or service is identical. The reason that there is not one equilibrium in each submarket is that it is possible for consumers in the same submarket to purchase varying amounts of each characteristic yet all of the consumers in a submarket will ascribe to each characteristic the same implicit price.

4. The constraint on Rosen's model which is implicit in the prior discussion (point 3) is that within each submarket, at any point in time, the supply of any particular characteristic is infinitely elastic within the relevant range. This must be so if the implicit price of a characteristic is constant over the range for a particular submarket. This requirement of our model simply presumes that the consumer must be able to choose among groups of housing units for sale such that although the supply of a characteristic or service associated with each individual unit is inelastic, the opportunity of choosing among a group of slightly different housing units permits us to view the supply of a characteristic as infinitely elastic within the relevant range.

ii) Possible Extensions of Prior Empirical Work

Having defined the set of constraints on Rosen's model which are implicit in the model we have proposed, it would be appropriate to suggest some extensions to the prior empirical work. Presumably, these extensions would provide some further and more convincing evidence regarding the acceptability of the unique aspects of a market segmentation model such as we propose.

The studies reviewed in section (B,iii) have shown that using some fairly simplistic segmentation procedures, there is evidence that submarkets do exist because different price-characteristics

relationships can be identified within urban housing markets. Such segmentation is evidenced by the existence of significantly different implicit prices of characteristics in different submarkets or market segments.

Further work should undertake a similar approach, but the data and the tests should be much more extensive. Specifically, the data employed should cover a majority of transactions in a large urban area with a relatively active housing market. As well, these transactions should be available on a quarterly basis for at least a two-year period so that some longitudinal analysis can be undertaken. In addition to comparing different submarkets or market segments cross-sectionally, it should be possible to observe what happens to the price-characteristics relationship in a particular submarket or market segment as time passes. The rationale for this longitudinal orientation is the desire to test the viability of an hedonic price index.

Using such a data base, attempts should be made to identify market segments or submarkets. First, some of the standard à priori assumptions with respect to segmentation criteria should be used in an attempt to replicate some of the prior empirical work. Hopefully, the size of such a data base would permit much more extensive analysis than has been undertaken in the past even though the methodology would be similar.

In addition to the replication of prior approaches to segmentation, an attempt should be made to use a numerical taxonomic device

to determine how the data in each period should be segmented. The rationale here is that there is no à priori evidence which suggests precisely how the data should be segmented. A possible strategy which could lead to a fairly precise determination of the characteristics of the segments would involve the application of a multivariate data grouping technique. While such grouping techniques have not generally been commonly applied in economics, they are used in marketing, psychology, and the biological sciences. The underlying notion is that there exist natural groupings in vectors of variables describing individuals or cases (in this case, transactions). Statistical methods such as cluster analysis and Q-type factor analysis have been devised with the objective of determining these natural typologies. Statistical tests could be undertaken of the data where the cases or transactions have been segmented in such a manner so as to check the validity of the procedure. Presumably, if different price characteristics relationships can be identified in market segments whose membership is determined using some taxonomic devise, the classification method would be confirmed as meaningful.

While prior research has tended to confirm the existence of market segmentation, an issue which has not been addressed, is how the researcher decides when the correct market segments have been identified. More precisely, what criteria should be used to determine market segments and how detailed should be criteria be. In this study we intend to address the issue by taking advantage of

a large and extensive data base and using it to undertake relatively precise segmentation procedures. Presumably, the more precise we can be at pinpointing market segments and their corresponding price-characteristics relationships, the more certain we can be of the implicit prices so derived. At the same time, the ability to define submarkets with such precision should cause us to have less faith in price characteristics relationships derived for submarkets defined with less precise techniques or for less extensive data bases.

Thus far, our tests have been oriented towards determining effective techniques for market segmentation. A separate but not unrelated problem is the generation and evaluation of an hedonic price index. Presumably, if market segments can be identified, the only meaningful price indexes are price indexes which are derived from transactions in market segments or submarkets as determined by the best of our segmentation procedures. Presumably, developing price indexes in this way would alleviate the possibility of producing a price index which aggregates over submarkets among which quite different price trends are evident. Unfortunately, there is no obvious way in which a price index (in this case, an hedonic price index) can be evaluated. While we can discuss theoretically how close our index may be to a true price index, the accuracy of our approximation to the "true" price index depends crucially on the accuracy of the shadow or implicit prices in the price characteristics relationship. The accuracy of the shadow prices depends first on the precision with which the

market segment or submarket has been determined and second, on the econometric problems which may turn up in the determination of the price-characteristics relationship.

Equation (2) expresses the price-characteristics relationship which is to be tested.

$$p(\underline{z})_j = \underline{\rho}^{(j)'} \underline{z} \qquad \text{for } j=1,\ldots,m$$

where m represents the number of line segments which in turn represents the number of market segments or submarkets. To account for the longitudinal nature of the analysis, it would be useful to add a second subscript to represent the time element. Rewriting the above relationship gives us:

$$p(\underline{z})_{jt} = \underline{\rho}^{(j)(t)'} \underline{z} \qquad \begin{array}{l}\text{for } j=1,\ldots,m \\ \text{and } t=1,\ldots,s\end{array} \tag{13}$$

where there are s time periods. Cross-sectionally, the hypothesis of significantly different submarkets would not be rejected if

$$\underline{\rho}^{(a)(t)} \neq \underline{\rho}^{(b)(t)} \qquad \begin{array}{l}a,b=1,\ldots,m \\ a \neq b\end{array} \tag{14}$$

where there are m submarkets and hence the two vectors of implicit prices are derived from separate submarkets.

Using the information derived from each of the above j submarkets for each of s periods, we can compute a Laspeyre's hedonic price index (equation (15)) and a Laspeyre's hedonic quantity index (equation (16)). Indexes such as these will be computed under various segmentation criteria in order that

$$\frac{\underline{\rho}^{(j)}(t)' \, \underline{z}(0)}{\underline{\rho}^{(j)}(0)' \, \underline{z}(0)} = I_{LHP} \qquad (15)$$

I_{LHP} = Laspeyre's type hedonic price index

$$\frac{\underline{\rho}^{(j)}(0)' \, \underline{z}(t)}{\underline{\rho}^{(j)}(0)' \, \underline{z}(0)} = I_{LHQ} \qquad (16)$$

I_{LHQ} = Laspeyre's type hedonic quantity index

We can observe how the segmentation procedure influences these indexes. Specifically, we should use similar techniques to those employed by Goodman but over a larger number of periods and involving more varied segmentation schemes. Hopefully, such efforts would be meaningful in terms of improving our ability to evaluate housing price movements within submarkets.

In general, further empirical work should focus on two areas

in which questions remain. First, more thorough testing of the segmentation hypothesis should be undertaken. Presumably, such testing would involve using more precise means of à priori segmentation which could only be undertaken with a better data base than has been available heretofore. As well, alternative segmentation procedures should be extended (e.g., usage of a numerical taxonomic technique). Second, hedonic indexing procedures should be evaluated in the context of the segmented housing market model.

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