Hedonic Methods and Housing Markets

Chapter 3: A Brief Survey and Interpretation of Hedonic Parameters

Edward Coulson
Department of Economics
Penn State University
fyj@psu.edu

In this chapter the literature on hedonic pricing is reviewed, though not with the goal of understanding the entire corpus of the hedonic literature, an almost impossible undertaking[1]. Rather, the purpose here is to provide a context for the evaluation of hedonic parameters of different types. There are three overriding principles that can provide a framework for the discussion.

The first is that in some instances, we know what the coefficient/price "ought" to be, because of guidance from economic theory, and/or from a belief that the housing market is "efficient" and "fully capitalizes" the presence of some attribute. The theory of hedonic equilibrium (as discussed earlier and which is more fully developed in Chapter 5) suggests that the hedonic pricing schedule comes about when utility is equalized across residents. This trivially suggests that if two housing units are equally desirable in all respects, their prices ought to be identical. But it further suggests that if they are different along a particular dimension, then the price difference reflects the value of that dimension and in some cases we can objectively know that value from other information sources. The relevant question then is whether or not the estimated attribute price actually has the value that we expect. If it does not we can say that this attribute is "incompletely capitalized" or use similar phrases to express our indignation that the real world does not conform to economic theory.

Secondly, the magnitude of these attribute prices (more precisely, the regression coefficients) are heavily influenced by the presence or absence of other characteristics in the

---

[1]An impossible task, to be sure, but see Sirmans, MacPherson, and Zeitz (2005) for the closest thing yet. We will have occasion to reference their review below.

hedonic regression, and this should guide their interpretation. In Chapter 2 the problem of omitted attributes was discussed, and the problem of estimating "true" prices emphasized. We will find that this issue manifests itself in various ways in the discussion below.

Thirdly, the theory presented in Chapter 5 also suggests that in the long run hedonic prices of physical attributes ought to reflect construction costs; more generally the long run equilibrium of a hedonic market ought to reflect both the demand

The chapter is organized into sections which are concerned with broad classes of characteristics that form hedonic functions.

PHYSICAL CHARACTERISTICS

The physical characteristics of a property are naturally going to be prominent among the attributes included in a hedonic price regression. Sirmans, Macpherson and Zeitz (2005) collected 125 hedonic price regressions and found that physical characteristics are among the most commonly used. Among these are the square footage of the housing unit, the size of the garage, the existence of one or more fireplaces, the presence of a swimming pool, the presence and type of air conditioning and heating technologies and the number of stories in the unit. These authors find a remarkable consistency in the hedonic prices of many of these items, even when the studies come from a variety of neighborhoods/cities/regions. For example the elasticity of the hedonic price of interior square footage is nearly always between .0004 and .0007, while a fireplace seems to consistently add from 6% to 12% to the overall price of a house. This constancy would seem to reflect a long run equilibrium where capital which is traded across markets approximately obeys the law of one price across those markets, and that one price presumably reflects the cost of acquiring and installing that capital. Chapter 4 discusses this more fully in the context of variation in house prices across location).

Structural characteristics are undeniably important quality benchmarks. In particular, the number of bedrooms and bathrooms are often used as a shorthand reference for the overall size and quality of a unit (as in: "Three bedrooms, two-and-a-half baths). To a certain extent this focus does not seem to be misplaced: Linneman (1986) found that 31% of housing price variability could be explained solely by the number of bathrooms in the unit. This is not to be taken literally, merely a sign of collinearity of bathrooms with other features of quality. Using only bathrooms in a hedonic regression will quite obviously create an immense omitted variables problem.

On the other hand, the number of bedrooms is apparently an unreliable quality indicator; Sirmans, MacPherson and Zeitz report that a significant percentage of studies that include the number of bedrooms as a hedonic characteristic report a negative coefficient. If square footage is also included in these regressions then it is possible that number of bedrooms and square footage are highly collinear measures of the size of the unit. Indeed, holding square footage constant, an increase in the number of bedrooms implies a reduction in the amount of space that can be devoted to other uses, such as larger kitchens.

Presumably, the architectural features of a unit have some place in the price determination process. The type of roof, siding, flooring and other features increase or decrease the desirability of a unit and therefore buyers' willingness-to-pay. Many, if not most, hedonic studies omit such characteristics either because the data is not available, or in the belief that such details are of less importance than more prominent features such as interior square feet, and therefore will have no impact on the goodness-of-fit in the hedonic regression. However, datasets with large numbers of transactions can sometimes offer fairly precise estimates of the effects. The study by MacPherson and Sirmans (2003) offers some evidence on this point; they employ a Multiple Listing Service database with over 28,000 transactions and are able to estimate significant parameters for a number of relatively detailed style and fixture differences. Coulson and Lahr (2005) present similar findings.

AGE, VINTAGE and TIME

The age of the housing unit, or its vintage, is one of the most often used attribute in hedonic studies. Its impact is most easily discussed when the hedonic function is semilogarithmic; in that case the relevant part of the hedonic is

$$\log P = \ldots \beta * Age \ldots \tag{3.1}$$

and the coefficient β becomes the depreciation rate. The stylized fact that is often noted is that estimates of β are remarkably low, often in the range of .001 to .003. That is, the depreciation rate is less than one half of one percent per year. This feature of hedonic data was perhaps first noted by Margolis (1982) and confirmed in Coulson and Bond (1990) and Rubin (1993).

There is certainly room for debate on the meaning of depreciation rate. If the hedonic specification does not include variables that indicate the unit's condition, and under the plausible assumption that age and condition are negatively correlated, then the estimate of β is going to overstate the "pure aging" effect. Thus the fact that β is so low is perhaps even more remarkable; in any case Rubin (1993) in particular employs a large number of such "condition" variables and still finds depreciation to be less than .005. However, such low estimates create a puzzle, for as Margolis (1982) points out, such low depreciation rates are perhaps inconsistent with filtering models. The basic point of the filtering model is that housing for low income households is generated by the passing of housing from high income to low income households. Such models are more plausible if the high income households' valuation declines more rapidly than that indicated by the hedonic estimates.

It is possible that the age coefficient confounds two different impacts: the pure depreciation (or age) effect, and the vintage effect, which is the hedonic effect of construction at a particular point in history. A vintage effect might arise because of a particular method or style of construction that was predominant at some point in the past and is now once again in fashion. It is certainly possible to include both attributes into a hedonic regression. A particularly simplistic version of this would have the relevant part of the hedonic equation be:

$$\log P = \ldots \beta_1 * Age + \beta_2 * YearBuilt.. \qquad (3.2)$$

where now β_2 captures the effect of the construction year. This specification does not really capture the vintage effect since this would rarely be linear, but even if it did it would be impossible to estimate if all of the observations are recorded at the same time, for then these two variables always sum to the year of the observation. This is an example of perfect multicollinearity.

The solution to both issues may be through changes in the functional form. First of all, we have noted that the vintage effect will typically be nonlinear; homes built in particular eras- say the 1920s– will, for artistic reasons, be more popular than those of, say, the 1910s or 1930s. This calls for a dummy variable approach: a binary variable that equals one if the home was built in the 1920s would be included in the hedonic function. This would allow the predicted price of houses built in the 1920s to "jump"[2]. However care must be exercised, since too many binary variables would simply reintroduce collinearity into the specification.

If age and vintage are both important, an important goal would be to include in the database prices from more than one time period (perhaps in a repeat sales context, see Chapter 4). Then one would have observations on properties with the same age and different vintages, or vice-versa, which allows the separate estimation of the effects. This leads to a further dilemma since, there can be yet another effect, that of time itself. If the database has sales or values from multiple time periods, it would probably be important to add the year of the observation itself as a regressor[3]. If all three are linear then the relevant piece of the hedonic function then looks like this

$$\log P = \ldots \beta_1 * Age + \beta_2 * YearBuilt + \beta_3 YearofObservation \qquad (3.3)$$

but of course, now the three variables are perfectly correlated, since Age+YearBuilt=Year of Observation. Again entering at least one of the three in some (possibly arbitrary) nonlinear fashion would solve the problem[4].

---

[2]Or decline if the period in question were in disfavor.

[3]This would allow a temporal house price index to be created. See chapter 4.

[4]See also Coulson and McMillen (2008)

We take up this set of issues in more detail in the next chapter on repeat sales and indexation.

SPATIAL CHARACTERISTICS AND THE PROBLEM OF SPATIAL SELECTION

Before turning to a review of the literature on the measurement of the hedonic value of spatial characteristics, some attention needs to be given to the problem of spatial selection. Simply put, this is the notion that locational decisions are not made in a vacuum but are influenced by the incumbent local characteristics. This problem is exemplified by some recent studies of the effect of greenery on neighborhood property values

GREEN NEIGHBORHOODS

Two recent example, Wachter and Wong's (2008) examination of the hedonic value of trees in various Philadelphia neighborhoods and Been and Voicu's (2008) analysis of the hedonic value of community gardens, illustrate the issues. Loosely speaking, these studies include measures of neighborhood tree and garden prevalence in hedonic regressions and find positive coefficients. There are policy ramifications that emerge from this hedonic analysis since creating green space of various types has been suggested as a cost-effective method of bringing about neighborhood improvement. Had the simple hedonic regression suggested above been the extent of these authors' analyses, one might have taken from this that a policy of tree planting or garden creation would have a positive social benefit. The positive hedonic price of trees/gardens would be a measure of the social benefit of the policy. However, such a view would be mistaken, as both papers point out. The neighborhoods in which the "greening" takes place are not selected at random; these are not controlled experiments. The neighborhoods may have had neighborhood traits in common that induced the "social planters" to use them in their trials. The important point is that the positive coefficient may have as much to do with the omitted traits as with the greening;, in which case the social benefit may not translate to other neighborhoods.

This is, at heart, another variety of the omitted variables problem. If we knew all there was to know about the neighborhood traits, then we could control for them, and then the hedonic regression would provide us with an accurate measure of the value of trees or gardens. But there is always the suspicion that we are missing something. How can we overcome that suspicion?

One prominent approach, taken by the authors above, and also by Carlino and Coulson (2004) in their study of the impacts of NFL franchises, is to model property prices "before and after" a change in the neighborhood or regional amenities. If we look at property prices in the same neighborhoods before and after the trees or gardens have been put in place, and use neighborhood "fixed effect" indicators as discussed in chapter 2, then we may overcome this problem (see also the discussion of repeat sales in chapter 4). The fixed effect control for all neighborhood traits that are unchanging over time, and this can go a long way toward correcting the omitted variable problem. Another strategy also put to good use in the above papers is to use neighborhood time trends (again, see chapter 4) if one suspects that the unobserved traits are changing in a constant fashion. Some other strategies are discussed below.

ENVIRONMENTAL QUALITY

One of the primary uses of hedonic pricing is evaluating the benefits of environmental goods , which otherwise would be unpriced. Indeed, as noted in the introductory chapter, the use of hedonic methods in housing markets arose from the desire to put a price on the level of air pollution. Thus the inclusion of environmental variables in the list of hedonic characteristics has a long history.

There have been dozens of studies, using a wide variety of air pollution measures in wide variety of metropolitan areas and correspondingly estimated a wide variety of price impacts. A sampling of papers in this area include Nelson (1978), Palmquist (1982) and Kiel and Zabel (2000). Meta-analysis by Smith and Huang (1995) suggests that a robust statement on the property value impact of air pollution is difficult, if not impossible. In their survey of the literature Boyle and Kiel (2001) come to a similar conclusion, noting that many of the studies that they review find no statistically significant impact of air quality on housing prices. They speculate that the measures of pollution used by researchers (which generally measure the physical amount of pollutants in the air) may not correspond to the disutility that people experience.

The impact of airport noise on property values is well-documented: studies such as Nelson (1979), Mieskowski and Saper (1978), O' Byrne, Nelson and Seneca (1985) have found that this impact is negative. A survey and meta-analysis by Nelson (1980, 2003) have found that the decline in price is approximately .5% of property value for each decibel increase in measured noise level. McMillen (2004) notes that the due to improvements in aviation technology, the decibel level of aircraft has declined over time, and that therefore the effect of airport noise on property value will be, (shall we say) muted.

Unlike air pollution, which disperses over wide area, from sources both mobile and immobile, airport noise is localized, from a readily identifiable source. And like some other attributes discussed in this chapter, there is potentially a benefit to locations near airports in the form of increased accessibility. If hedonic studies fail to take this into account, then the coefficient on the measure of noise will in fact understate the true hedonic of noise itself. Two recent studies have tried to separate the accessibility of airports from the noise. While Tomkins et al (1998) do find that there is a positive benefit from location near an airport, Espey and Lopez (2000) find that location near the airport imposes negative costs on homeowners, over and above the impact of noise.

A very large number of studies have looked at the impact of noxious, hazardous and dangerous land uses on local property values. Kohlhase (1991)found that Superfund sites in Houston caused housing prices to fall. The effect was spatial; the further away from the site the less the impact at a rate of about $2,300 per mile. Kiel and McClain (1995) found that an incinerator in a Massachusetts town had impacts on the local prices. Their study features a price effect as the plant siting evolves from rumor to fact to operation. Perhaps surprisingly, the negative impacts on prices do not really occur until the plant is actually in operation. Kiel and Zabel (1995) examined the impact of Superfund cleanup on housing prices. The price impacts were large enough that the authors conclude that the Superfund cleanup likely exceeded the costs. Carroll et al (1996) examined property values around Henderson, NV after a 1988 explosion at a chemical plant. Since the environmental impact was transitory, the time frame of the study is of interest. While prices were seemingly depressed in the immediate vicinity of the plant, prices rebounded when it came to pass that the plant was to be rebuilt in a different location.

Perhaps all of these studies suffer from spatial selection. Neighborhoods that contain hazards or noxious material are fundamentally different from those without these things, and those differences are not adequately measured by the observable characteristics of average income and the like. Greenstone and Gallagher (2008) attempt to overcome this difficulty in their examination of the hedonic value of living close to Superfund sites. Their sampling strategy is to compare those sites to others which just missed being placed on the Superfund list, in the belief that the unobservable neighborhood characteristics in these two types of areas will be similar. They find, interestingly, that the negative economic impact of living near the Superfund sites is minimal.

NEIGHBORHOOD ATTRIBUTES

Beyond environmental pollution there are numerous other attributes of neighborhoods that can raise or lower property values. Like some measures of air, noise or toxic pollution there is typically a trade-off between the attractiveness of the local attribute and the congestion or other inconvenience that might arise. Examples include churches, where Do, Wilbur and Short (1994) find a negative relationship between proximity to places of worship and property values, and Carroll, Clauretie and Jensen (1996) who found a positive one; and golf courses, which according to studies like Do and Grudnitski (1995) have a positive impact; and group homes, which, according to Colwell (1994), have negative impacts.

Some neighborhood attributes have to do with the physical structure of the neighborhood itself. One aspect of this is the existence of gates. Gated communities are increasingly prevalent especially in newer residential developments (although this can not only refer to privately owned streets with single family homes, but also to apartment complexes with secure entrances) and LaCour-Little and Malpezzi (2001) have determined that houses inside such gated communities command a substantial premium, although they find a hedonic price that seems to be far greater than the cost of providing such gates.

In a pair of papers Tu and Eppli (1999, 2001) discuss the hedonic impact of being in a neighborhood that conforms to the style of "new urbanism"– that is, a neighborhood characterized by smaller lots, integrated commercial development within walking distance, and other characteristics associated with "traditional" neighborhoods. This is as opposed to what new urbanists call "conventional development" with its emphasis on larger lots, separation of commercial activity and car-based transport. Tu and Eppli find that new urbanist communities sell for a premium, compared to nearby similar properties. Similar findings are reported by Song and Knapp (2003), who find that physical characteristics of neighborhood layout (such shorter and more numerous streets and mixed land uses) that are congruent with the philosophy of the new urbanism create higher property values.

There are numerous ways to impose restrictions on the way property can be developed or maintained. This can be either through the public sector, in the case of zoning ordinances, or through private covenants. In the former case a local government restricts the use of land under its jurisdiction to specified ends, such as single-family residential, multifamily residential, commercial, etc. In the latter case, the urban developer (further) binds the purchasers of the land and structure to adhere to certain guidelines in the construction and/or enhancement of the property. This is often a requirement of minimum dwelling size but can also include requirements on the exterior color possibilities or about the care and upkeep of the property. Again, there are good and bad things about any such requirement– requirements that bind the individual property owner reduce the ability of the owner to put the land to the use that would best match his or her individual preferences, but they also keep one's neighbors from imposing negative externalities on everybody else. The net effect on the associated hedonic parameter is therefore ambiguous.

Thus, Cannaday (1999) proposes that covenants that are too soft, and those that are too strict will both be inferior to "baby bear" restrictions that are just right. He finds, apropos of this, that condominiums that do not allow pets, and those that allow both dogs and cats, have lower prices than those that allow just cats. Hughes and Turnbull (1996) make a similar point about covenants in single family neighborhoods, noting that covenants become less important in neighborhoods with low turnover. They find results consistent with this using data from Baton Rouge, LA.

As for zoning itself, finding the hedonic effect of zoning is actually rather difficult; zoning that, for example, separates residential and industrial uses of land is so pervasive that it is difficult to determine the value of that separation. Some special cases and indirect methods have been used, see for example Asabere and Huffman (1997) and McMillen and McDonald (1993).

Designation of a neighborhood (or a single property) as "historic" leads to a kind of covenant or zoning regulation. Designation can be at the national or local level, and there are large differences in the effects of such regulation, both between national and local designation, and across local areas. The literature on hedonic measurement of preservation's effects has generally found that the net effect is positive. While the effect of preservation seems to differ with respect to whether the designation is federal or state or local, and the amount of the tax preferences associated with designation, research by Ford (1989), Clark and Herrin (1997), Leichenko, Coulson and Listokin (2001) and Asabere and Huffman (1994) all find that designation and preservation have a positive impact on property values. Asabere, Huffman and Mehdian (1994) find that restrictions on designated properties had an adverse impact on property values in Philadelphia.

Historical preservation provides an interesting laboratory for the separation of the effect of covenants on individual properties versus the spillover effect, since both types of designation exist. While the "own-effect" of preservation might have an ambiguous sign (since there might be a certain cachet to designation, but also the limited ability to rehabilitate the property) the external effect should not. The effect of having designated properties in a neighborhood should have a positive impact on adjacent property, since the designated house has now had restrictions that require upkeep above and beyond the usual building code restrictions. Coulson and Leichenko (2001) find this to be the case for Abilene, Texas. The greater the number or percentage of designated homes in a census tract, the higher property values were in that tract.

However these papers may also suffer from spatial selections issues as well. Designation is a policy instrument, perhaps aimed at neighborhoods most likely to benefit from that policy. Coulson and Lahr (2005) use repeated observations on the same property to control for those unobserved effects. Noonan (2007) goes one better and looks at sales of the same property before and after designation takes place, an especially potent "before and after" estimation. He finds small impacts of preservation policies.

It seems almost a truism that higher crime rates in a neighborhood will bring about lower property values. Like many other environmental or neighborhood characteristics, though, there are numerous issues to grapple with in the specification of the hedonic, primarily concerning measurement of crime in a way that translates from people's utility functions. Contributions include Naroff, Hellman and Skinner (1980), Hoffman and Naroff (1979), and Lynch and Rasmussen (2001). In the latter, the authors use neighborhoods in part defined by police beats and the recorded crimes therein. They weight crimes by their seriousness and find that the hedonic costs of crime are rather surprisingly low. A recent paper of interest is that of Gibbons (2004) who uses spatial correlation methods to try and filter out unobserved neighborhood effects, and finds that crime that is particularly easily to observe, like graffiti and vandalism, causes substantial declines in property values.

As noted above, since the characteristics that create neighborhoods are the result of choices made by residents, voters, developers, and others, the possibility of reverse causality presents itself, and this creates problems for estimating hedonic prices. A nice example of how to deal with this using the Heckman procedure is presented in Munneke and Slawson (1998), who investigate the impact that mobile home parks reduce the value of housing in adjacent areas. The spatial selection arises in the following way. Mobile home park developers, recognizing their potential negative impact, choose their location carefully. The placement of mobile homes is not entirely random, in that they may be deliberately placed in low value neighborhoods. If the hedonic regression included all of the other neighborhood characteristics, then this would not be a concern, as the coefficient on mobile homes would be estimated holding other neighborhood characteristics constant. But suppose, as is likely, that not all neighborhood attributes are observable in the data base, and it is some unobservable difference in neighborhood that lead some places to be more ideal for mobile home location. In that case the characteristic "mobile homes" is correlated with the error term, and therefore its coefficient will be biased. It will be "too low" in the sense that it is also accounting for these unobserved neighborhood characteristics. It is not necessarily the case that mobile homes cause low prices, but that low housing prices create the incentive for the placement of mobile homes. Munneke and Slawson's solution to this problem is to supplement the hedonic model with an equation that describes the process of mobile home site selection. The Heckman procedure supplements the hedonic regression with a regression which asks which characteristics are correlated with mobile home placement. The residuals from this regression are correlated with the unobserved neighborhood traits, and a function of these residuals (the appropriate inverse Mills ratio) will control for these unobservables.

Another characteristic of neighborhoods is the existence of subsidized housing. There are several types of public and subsidized housing, having both supply side and demand side orientations. Traditionally (see for example Nourse (1963)) the literature has focused on the fact that such subsidies are likely to lower the average income in a neighborhood or bring about other undesirable neighborhood characteristics and this may in turn lower housing prices in these neighborhoods. Analysis of this issue is of substantial interest in light of in the increasing importance of policies like Moving To Opportunity that seek to disperse families receiving subsidies into non-poverty neighborhoods. Residents of the receiving neighborhoods may fear that new low-income residents will in some way bring this negative income about (Galster, Tatian and Smith (1999).

The most comprehensive analysis– comprehensive in terms of the number of types of subsidies– has been Lee, Culhane and Wachter– who use data from Philadelphia to examine the hedonic effect of public housing, subsidized construction of low-income units (such as Section 8 New Construction and Rehabilitation), and Section 8 certificates and vouchers, as well as homeownership assistance programs. These authors find that the estimated effect depends very heavily on whether controls for other neighborhood characteristics are present; it appears that subsidized housing is correlated with these other attributes. When they are included in the hedonic model, public housing and the demand-side Section 8 programs have a small negative effect on property prices. However the impact in general attenuates fairly rapidly with distance. Interestingly, the Section 8 New Construction and Rehabilitation sites also generated positive hedonic spillovers.

Another study of the hedonic effects of Section 8 Certificate Holders is Galster, Tatian and Smith (1999) finds that there are positive impacts (perhaps surprisingly) in higher income neighborhoods when the number of certificate holders remains modest, but that influxes into what the authors call "more vulnerable" neighborhoods can have more negative price consequences.

Another set of neighborhood characteristics are the characteristics of the residents themselves. The spatial selection issues become more intricate now, because the spatial selection arises from the interaction of all the market participants, and not simply a single entity like a tree planter or mobile home park developer. Coulson, Hwang and Imai (2002, 2003) find that neighborhoods with higher rates of owner-occupation also command a premium. Since educated and home-owning households are just as deliberate with their location as the developers of mobile home parks, these authors have also tried to deal with the problem of reverse causality of characteristics and prices, in the latter case by directly accounting for self-selection into homeownership. Another paper that has attracted much interest is Rockoff and Linden (2008) who look at prices in very small neighborhoods before and after criminals (as defined by sex offender registries) move in. By using small neighborhoods and a before-and-after strategy on the same property they hope to overcome the issue of selection into neighborhoods.

In the case of the ethnic composition of neighborhoods, the interpretation of hedonic parameters becomes particularly difficult since the willingness to pay for such characteristics may greatly depend on one's own characteristics. This is, of course, no different from any other characteristic. One's demand for living area will depend on one's household size. But the market process that allocates bigger houses to larger families doesn't change the size of the houses (at least in the short run) whereas the movement of households does change the attributes of the neighborhood. Bajari and Kahn (2005) attempt to grapple with these issues, using a method discussed in Chapter 5, by attempting to find the underlying bids that different households have for various properties.

TAX CAPITALIZATION

The Tiebout hypothesis (Tiebout, 1956) has spawned an enormous literature, of which a substantial component involves testing the implications of the hypothesis using hedonic models. Roughly speaking, these models ask whether higher taxes result in lower property values, or whether additional public goods raise property values, other things equal.

All such studies must deal with an inherent identification issue that was first raised by Linneman (1978). The behavior of local governments is governed in part by its budget constraint:

$$T + F = G = PX \tag{3.4}$$

where *T*=tax collections from residents, *F*= other sources of revenue, such as federal transfers, *G* = spending on local public goods, *X*= quantity of local public goods, and *P*= price per unit of public goods. G may be thought of as the sum of expenditures on a variety of goods; likewise P and X may be vectors.

Tests of the Tiebout hypothesis typically involve estimating a hedonic regression with variables that are part of the above budget constraint. Such regressions, which begin with Oates (1969) can contain a wide variety of specifications with respect to their fiscal component, but as a first example consider a hedonic regression that for tractability is presented with a linear functional form, with the *per capita* fiscal variables represented by:

$$P = \ldots + \beta_T T + \beta_G G + \beta_F F \ldots \quad (3.6)$$

Because they are in per capita terms, the three variables are constant within each jurisdicition but vary across jurisdictions. As such, this model breaks down due to the perfect multicollinearity between T, G, and F. No test of capitalization is possible. Once could omit one of the variables: if F (for example) is omitted from the equation, then the model becomes estimable if F varies across jurisdictions. In that case β_T is a measure of (average) tax capitalization– the decrease in property price implied by an increase in T, *holding G constant.* If both P and T are annual measures of housing prices and taxes, "full capitalization" implies β_1=-1. Every increase in T implies a dollar-for-dollar reduction in V. Note that F cannot be constant across communities, otherwise the regression breaks down due to the perfect correlation between T and G. But neither should it be correlated with T or G, otherwise the coefficient will be biased in its role as a test of tax capitalization. It should be noted further that under these conditions β_G also provides a test of government spending capitalization. Holding T constant, an additional dollar of government spending should raise the annual price by that same dollar, i.e. β_G=1. However, β_G might be greater or less than one, depending on how efficiently the local government is allocating its tax revenue. That is to say, if the additional government spending is taking money and throwing it into the ocean, then β_G

would be zero. A more mundane inefficiency would occur if the value of the public services created by the government with the marginal dollar were to bring less than a dollar's worth of happiness to the local residents.

Now suppose (as is sometimes the case) that *both* F and G are omitted from the hedonic, but continue to assume that F is uncorrelated with both G and T. Now β_T represents the impact of both G and T on property values (since these two variables will be correlated). If they are perfectly correlated (which would be the case if F were the same across jurisdictions) and government spending is efficient, then the net impact of these two variables on housing prices cancel each other out. Thus "full capitalization", in the sense of the Tiebout model, implies β_T is zero. A value of β_T less than zero would presumably imply that the additional government spending created by the additional taxes was not "worth it" and a positive value the opposite. In a similar fashion, if T and F are omitted, and only G is included in the regression, β_G would be zero if the Tiebout hypothesis were true.

What about the implications of the Tiebout hypothesis within jurisdictions? Here, one is faced with the problem that G and F are, to a first approximation, the same for everybody within a jurisdiction. However the tax burdens may be different across housing units within the same jurisdiction and this variation is often observable because generally T is a property tax and is specific to the housing unit (i.e. its attributes) (and as such is sometimes available in assessor or MLS databases). With G and F omitted, and assumed to be identical across individuals in the same city, the value of β_T depends on the physical attributes (as suggested by Hamilton (1983)). If the housing unit's attributes are "below average" then a rise in T due to an increase in the property tax rate will increase (per capita) G by more than the rise in T for that particular unit and the coefficient on T will be positive. The opposite occurs for "above average" houses and the coefficient would be negative. Thus a constant coefficient on T cannot be supported. Either the regression coefficients need to be specified with this mind, or G must be included in the regression (to hold it constant while taxes are varied).

Very often the focus of the hedonic regression is on a particular component of G. In this case an alternative strategy presents itself, which is to omit other components of G from the specification. Many variations on this strategy are possible. Assume that G consists of spending on two public services, 1 and 2:

$$G = G_1 + G_2 = P_1 X_1 + P_2 X_2 \qquad (3.8)$$

where X_1 and X_2 are the quantities of public service provision, and P_1 and P_2 are the corresponding prices. If the analytical focus is on, say, fire protection– good 1-- then it might be assumed that good 2 is unimportant and has a hedonic weight of zero. Then the budget constraint would not bind the coefficients, both G_1 and T could be included in the regression and the hedonic impact of expenditure on fire protection expenditure could be estimated. This would be incorrect of course if the true coefficient of G_2 were not zero and there is correlation between G's two components. But this strategy is often used by researchers. In researching the impact of school spending, that variable is often included, and other types of public expenditure excluded.

Another strategy, perhaps more appealing, is to include X_1 (say, number of fire stations or number of firemen) , rather than G_1 in the regression. In general this has considerable appeal. First it is presumably the fire stations and firemen that provide hedonic value, rather than the expenditure on fire protection as such. Second, using X rather than G breaks the collinearity that would be imposed by the government budget constraint. A researcher could include X_1, X_2 ,and T in the regression, and as long as different communities faced different prices (perhaps because they have different levels of efficiency) coefficients for all three could be included.

The literature in this area begins with Oates (1969) along with Edel and Sclar (1974). The plurality if not the majority of work in this area has to do with public school education. The property characteristic "education" operates in a market which is interesting for a number of reasons. The first is its importance: it is the public good of primary interest to many households, and it is one which guides the selection of jurisdictional location for many families. Secondly, its jurisdiction is often distinct from that of other public goods– school districts do not necessarily coincide with municipal boundary lines, so it is easier to separate the effect of school provision from other municipal actions, and school taxes are sometimes separately collected. Thirdly, it is possible to observe both the inputs (in the form of teacher/student ratio, or the like) and well as the outputs (as in standardized test scores, or similar) of the educational production function. Thus many of the different specifications discussed above and have been used in the literature. The literature on this topic is vast, but recent contributions include Brasington (1999). Bogart and Cromwell (1999), Downes and Zabel (2002), Gibbons and Machin (2003) and Ries and Somerville (2004). A key paper in this research agenda is Black (1999) who attempts to solve the "unobservables problem" by looking within school districts and comparing prices for houses that were very near each other but on opposite sides of elementary school district line. The neighborhood qualities are very much the same, presumably, and therefore the only thing that is different is the quality of the elementary school, whose hedonic value can thereby be determined. This is similar to the strategy employed by Greenstone and Gallagher discussed above.

One particular aspect of fiscal and tax capitalization that has received some particular attention is impact fees. Impact fees are fees assessed by local governments on the development of new housing. As such they are meant to close the gap between the average and marginal cost of extending infrastructure services such as sewer and road development to the area covered by the new development. They are imposed on the developer; the developer will presumably pass the fees on to the homebuyer in the form of higher prices. But since the new homeowners will, in the fullness of time, also be paying property taxes on this housing the presence of the impact fee implies that the total tax burden on new housing is higher than that on older housing for what is presumably the same level of public services. Thus the traditional view of impact fees is that they can be analyzed using the standard model of tax incidence, because the expenditure implications can be ignored. The prediction of the incidence model (Rosen (1989)) is that the price of new housing should rise but by an amount less than the tax; the exact amount of the rise will depend on the relative supply and demand elasticities of new housing.

A puzzle of the early research on impact fees (see the excellent survey by Ihlandfeldt) is that the price impacts were much larger than that. Delaney and Smith (1989a, 1989b), Singell and Lillydahl (1990), Skaburskis and Qadeer (1992), and Dresch and Sheffrin (1997) all report that new home prices rose by an amount greater than the amount of the impact fees, which contradicts the theory. Yinger (1998) proposed a "new view" of impact fees that takes into account the fact that overall property taxes can be reduced in the face of increased impact fees, and, depending on the relationship between the old and new construction can lead to property value increases that are greater than the impact fees themselves. The overcapitalization of impact fees would therefore presumably not survive the inclusion of controls for property taxes, at least as long as the property tax measures were themselves properly specified.

DISTANCE TO JOBS

Hedonic modeling using the monocentric model

There is a long history in urban economics of describing the relationship between housing (or land) prices as a function of their distance from job centers. The "negative rent gradient" is a hypothesis that increasing distance ought to have a negative impact on prices, and moreover that the decline ought to be equal to the increase in transportation costs. This hypothesis has its roots in Alonso (1964), Muth (1969), and Mills (1969). In the simplest (yet quite powerful) version of this very familiar framework, jobs are exclusively located in the urban center and the surrounding ring is exclusively occupied by residences. Commuting to and from jobs (and possibly other tasks such as shopping) is costly. The cost is given as kt, where k is the unit distance cost of travel and t is the distance from the housing location to the center. The unit cost, k, is assumed constant and therefore not dependent on the characteristics of the commuter or the distance. The budget constraint of the representative urban consumer is

$$y = P(L,t) + kt + z \qquad (3.12)$$

where

y = income

L= land consumption at distance t

z= consumption of a numeraire composite commodity

For convenience, housing capital is omitted. Thus the hedonic function consists of two arguments: location, and the quantity of land. The utility function, which is assumed to have the usual nice properties, is $U=U(L,z)$ so that location, *per se,* does not enter the utility function.

Let income be fixed and identical across all households, so that the utility level is the same at all locations. Temporarily, let us also impose the condition dL/dt=0-- that is, because of zoning or for any other reason you would like to dream up, all lot sizes are the same (and equal to one unit of land). Then in order to maintain equal utility across locations-- that is, dU/dt =0, it is necessary that

$$dP/dt=-k. \qquad (3.13)$$

This is very clear and intuitive. It says that a plot of land that is one mile further away than an otherwise identical plot of land, must have a price that is lower by exactly the amount of money it takes to get from one plot to the other. That is, the change in land prices across different locations must exactly compensate for the increased transportation/commuting costs. This negative rent gradient, as it is sometimes called, could be estimated in a hedonic price function. We in fact have a theory that implies linearity of that hedonic function:

$$P = a_0 + a_1 distncetoCBD \qquad (3.14)$$

where a_0 is the price of location at the CBD (i.e. where distance =0), and is also the constant of integration for the above differential equation, and a_1 would in theory be equal to -k. Obviously no other characteristic belongs in the hedonic function since in this simple world there are no characteristics that vary across locations.

In a real world application of this hedonic model, such a simple regression would of course go seriously awry. In the absence of controls for other characteristics, the coefficient of distance would reflect the empirical unconditional correlation between distance and housing sale prices, which is very often positive, because suburban housing sells for higher prices than central city housing. This may be due to the existence of non-central jobs or other specification issues. That early tests of this model often yielded this conclusion led Richardson (1985) to discuss the theoretical plausibiltiy of a positive rent gradient. But it is a lack of appropriate controls that cause this to happen.

Now imagine two scenarios in which the amount of land does vary from plot to plot. In the first scenario, plots are random in size, and any size plot could potentially be found at any given distance. Size and distance are roughly uncorrelated. In this case the hedonic function could look like this:

$$P = a_0 + a_1 dis\ \ tncetoCBD + a_2 * lotsize \qquad (3.15)$$

and the coefficient on distance would still be -k, and the coefficient on lotsize would reflect the marginal rate of substitution between land and the composite commodity. The *ceterus paribus* property of regression models manifests itself in this equation; the difference in price between two lots with the same number of square feet, is still equal to the transport cost differential (Coulson, 1991). One could obviously extend this to other physical attributes. In a regression of the form

$$P = a_0 + a_1 disttoCBD + a_2 * lotsize + a_3 * squarefeet + \ldots other \qquad (3.16)$$

the coefficient of distance has the same interpretation regardless of the inclusion of other hedonic attributes.

The monocentric model is perhaps best estimated in cities that are in fact monocentric. Yinger (1985) and Coulson (1990) do this by using data from smaller US cities, which may fulfill the monocentricity requirement more readily. Both find confirmation of the negative rent gradient; the further a housing unit is away from the central business district, the lower the price, other things being equal. Soderburg and Janssen (2001) find a negative price gradient for Stockholm, Sweden (though not for rents). In an interesting addition to the literature, Tse and Chan (2004) use Hong Kong to study rent gradients. Hong Kong is a noteworthy case study not only because its particular geographic circumstances mandate a monocentric pattern of jobs, but also because those circumstances make the use of private automobiles nearly impossible. Because of the near-universal use of mass transport (and to a lesser extent, walking) for commuting, they are able to reconstruct fairly exact money and time costs for work trips from the ferry, bus and rail schedules. These authors find (somewhat surprisingly) that money costs matter more than time; the latter only obtains for longer trips (i.e. from other islands).

The monocentric model is made richer and more realistic, when optimal lot size is endogenously determined at each distance. In such a case, we might write the consumer choice problem as

$$\max U(L,x,t)$$
$$s.t.$$
$$Rl + x + kt = Y$$

where l is the quantity of land chosen at distance t and R is the per unit rental price of land. The optimizing choice implies that location will be chosen such that

$$dR / dt = -k / l \qquad (3.18)$$

where *l* is now to be understood as the optimizing choice of land quantity at distance *t*. Since it can be shown (Wheaton, 1977) that

$$dl / dt > 0$$

this seems to imply a nonlinear hedonic function. But note (along with Coulson (1991)) that in a hedonic context the implications of this are less profound. Equation (3.18) is not a ceterus paribus statement about the relationship between rent and location, since the amount of land is not held constant, whereas in a hedonic regression like (3.17) the coefficient of distance purports to measure the impact of distance precisely holding land constant. Thus it is still the case that even in the endogenous location model the coefficient on distance should be equal to the negative of transport cost, as long as the regression controls for land area (Shepherd (1997)). Nevertheless these two ways of thinking about the gradient of land prices *per force* imply something of a contradiction, as pointed out in Berliant and McMillen (2005). The following example is adapted from their paper. Suppose that the present value of all future commuting costs is \$2000 per mile, and that a one acre plot one mile from the city center sells for \$50,000. For there to be an absence of arbitrage, a two-acre plot at the same distance will sell for \$100,000. At a distance two miles from the CBD, one-acre plots and two-acre plots are also available. But at this distance two different pricing principles are at work: (1) each plot should be priced \$2000 less than its one-mile counterpart of the same size (as in (3.14)); and (2) the two-acre plots should have twice the price of their one acre counterparts at the same distance. These two are clearly inconsistent. Under (1) the one acre plot at two miles should sell for 48,000, and the two acre plot for \$98,000 – i.e., \$49,000 per acre, while under (2) the latter should have a price of \$96,000 (i.e. \$48,000 per acre). Thus the usual equilibrium conditions imply a violation of the law of one price.

As Berliant and McMillen (2002) note, there are two ways around this problem. One is to invoke the pricing condition suggested by (3.18) in the Mills-Muth model. This works because it denies the possibility of more than one plot size at any given distance. There cannot be (in the context of the example) one-acre plots at two miles or two-acre plots at one mile. This of course violates the no-arbitrage condition in any case because a hedonic regression model is supposed to be able to determine the price of any combination of attributes. Moreover, it almost surely violates the empirical fact that many different size plots (as well as other attributes) can be observed at any given distance.

The second way is to view land as something whose distribution across properties is predetermined, presumably through the actions of developers in the past, and thereby immutable. One of the two no-arbitrage principles has to go, and what this suggests is that the principle that requires the two acre plots to have double the price of the one-acre plot is the one that is eliminated, because we deny landowners the ability to divide up their property. As mentioned in Chapter 2, Rosen (1974) noted that linearity and arbitrage are observed only when landlords are able to "combine, alter and divide" the extant characteristics of the units. We can assume the transactions cost of redrawing boundary lines is too great. Thus (3.14) remains a valid test of urban models, even, or especially, when the standard Muth-Mills model is violated– but only (to repeat) when other characteristics are properly controlled for. Moreover the model of Berliant and McMillen suggests that hedonic functions must be nonlinear (for characteristics other than land) and these authors suggest nonparametric or semiparametric regressions to fully capture the inherent nonlinearity.

The polycentric model

A further difficulty in observing the hedonic implications of the monocentric model is the observation that cities are not monocentric. The observation of the negative rent gradient depends to a certain extent on the existence of a single location of jobs in the center of a metropolitan area. Thus sharp tests of the hypothesis have been limited because larger US cities do not conform particularly well to the assumptions of the monocentric model Even in non-monocentric cities, one might expect that access to jobs plays an important role in housing price determination, though the impact might be muted in such a polycentric world. A study that analyses the possibility of multiple gradients is Heikkila et al (1989). In their study of Los Angeles, these authors run a hedonic regression which contains, among other characteristics, the distance to ten different locations: the Los Angeles CBD, the ocean, and eight other employment centers. Remarkably, access to the CBD was the only one of the ten that did not carry a significant coefficient. Almost all of the other access coefficients were negative, as the theory would have it. The lack of orientation toward the CBD is perhaps expected given the usual characterization of Los Angeles as a very decentralized metropolitan area.

Other studies have taken a slightly different approach. They observe the geographic distribution of housing prices on a map and basically identify price spikes on the map (controlling for other characteristics) as evidence that the location of the spike is an employment (or other kind) of subcenter. Studies within this general framework include Plaut and Plaut (1998) who perform this sort of analysis on Haifa, Israel, and McMillen and McDonald's work on Chicago.

On the topic of land prices, a small, though interesting literature has developed concerning the shape of lots, and whether the dimensions of a lot matter independent from the size of the lot. This literature has mainly been concerned with the pricing of vacant lots, and so avoids much of the complexity of the hedonic regression model (this research strategy, of course, has much to recommend it). Using a Cobb-Douglas (double log) functional form for tractability, the relevant part of the hedonic (whether or not the lot is vacant) is:

$$\ln V = \ldots + \beta_1 \ln F + \beta_2 \ln D \ldots$$

where F= lot frontage and D=lot depth. (Assume that all lots are rectangular.) If the total size of the lot were all that mattered, then $\beta_1=\beta_2$. This common coefficient would then be the elasticity of property value with respect to lot size. Colwell and Scheu then assert that this cannot be the case in a (long-run/endogenous supply) hedonic regression. Imagine a developer parceling out a section of land. If the cost of providing frontage is greater than that of depth (and Colwell and Scheu discuss why this might be the case) then lots will be as narrow as possible given whatever institutional or zoning constraints might be in place. Since this is not necessarily what we observe, it must be the case that it is not profit maximizing, and this can only be the case if $\beta_1>\beta_2$. The authors provide regression results from two housing markets where indeed this is the case.

ACCESS TO TRANSPORTATION

Like many other neighborhood goods, the proximity of highways is a two-edged sword. They provide speedier access to other locations, but they also create noise and congestion for those who are proximate. Many studies have examined the effect that highways have on property values. Two recent examples are Voith (1993) and Boarnet and Chalermpong (2001), both of whom find that the reduced travel times that new highways create cause property values of the affected homes to rise.

Similar to highways, railways, and more particularly railway stations, offer both increased access and increased congestion and noise. Several studies have examined the impact of this tradeoff, including the well-known studies by Dewees (1976), McDonald and Osuji (1995), Gatzlaff and Smith (1993), Voith (1991, 1993) and Ihlanfeldt and Smith (2001) and several others. As might be expected, the results are not consistent across the various time frames and metropolitan areas studied by these authors, but most of the studies (and all of the ones cited here except for Gatzlaff and Smith) find that the accessibility benefit outweighs the negative externalities and property values rise in the proximity of a rail station. Ihlanfeldt and Smith (2001) note however that this holds most strongly in suburban areas, and that increases in crime around stations closer to the CBD may drive property values around stations in those areas down.