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Hedonic pricing with redevelopment options: A new approach to estimating depreciation effects

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ABSTRACT

The standard hedonic model of durable assets is a special case of a more general model that contains two additive terms: (1) use value of the existing hedonic vector and (2) the value of the option to reconfigure hedonic characteristics. One empirical implication is that the two parts of value are related: e.g., use value increases with interior area whereas option value decreases with "intensity," the ratio of structure value divided by land value. Increases in building age reduce use value but increase option value. Data from Greenwich Connecticut indicate that intensity has the expected negative effect. Coefficients on building age are shown to be better measures of depreciation when intensity variables are included in the regression.

1. Introduction

Durable assets are typically sold in pre-packaged bundles of attributes with asset value measured by the product of each attribute and its implicit market price (Rosen, 1974).[1] Rosen's theory has spawned an immense literature aimed at estimating those attribute prices for a variety of goods or services such as the supply of labor, automobiles, art objects, municipal bonds and real estate (see for example, Ekeland et al., 2003; Arguea and Hsiao, 1993; Gunnelin and Soderberg, 2003). In general, this literature uses a sample of market sales where one observes the sale price of the asset (the market value of the full bundle) and a vector, q of attributes for each transaction. Given these data, the analyst regresses the bundle price (or the natural log of price) on attributes q_j, ($j = 1, \ldots, n$) as indicated in Eq. (1)

$$P_i = v' q_i^0 + \varepsilon_i \tag{1}$$

where i indexes M individual property sales in cross-section, each with n hedonic characteristics; $v\ (q_i^0)$ is an n-dimensional column vector of implicit market prices (property characteristics) as of time 0. The disturbance term arises from negotiations between buyers and sellers who have idiosyncratic characteristics. Thus, ε_i is typically assumed to be iid. Rosen (1974) derived conditions for v_j to measure implicit market price.

How does this model change if we allow the owner of the durable asset to alter the characteristic vector (i.e., redevelop the asset) at some cost, where cost is assumed to be strictly positive? In this case, any changes to price, random or deterministic, or depreciation of quantity may be associated with redevelopment of q_i^0 to a different level.[2] We motivate the addition of another term to Eq. (1) for the value of this option, the right but not the obligation to change the characteristic vector. Option value includes the expected net present value (possibly zero, but necessarily non-negative) of the asset as reconfigured at the time the redevelopment option is

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[1] One of the more restrictive assumptions is that markets for each attribute are sufficiently deep to allow implicit equilibrium prices to be determined: i.e., many buyers and sellers are present for each possible vector. This assumption has been relaxed by Harding et al. (2003).

[2] Depreciation makes investment partially reversible. The value of the option to redevelop follows from partial or total irreversibility: it is costly to change the characteristic vector.

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exercised. For example, it is common in some housing markets to see demolition of smaller older houses and reconstruction of "McMansions" at a much higher intensity, the exercise of a call option.

Because of our focus on teardowns or substantial renovations we define the "intensity" of existing characteristics as a scalar aggregation index for the amount of structure per unit land value. The aggregator variable increases with interior square footage and other amenities (e.g., bathrooms, fireplaces or a pool) and decreases with building age and with land value.[3] Theory demonstrates that use value (i.e., standard hedonic value when option value is near zero) increases and option value decreases with the aggregator variable.

The purpose of this study is to provide empirical evidence that, in the absence of correctly-specified variables for option value, hedonic estimates of implicit market prices will be biased. Specifically, variables such as building age and lot size are likely to capture some of the omitted option value; the direction of bias will be analyzed here. Intuitively, the coefficient on age measures depreciation (i.e., reduced asset value due to aging) for new structures that are near optimal size (see Malpezzi et al., 1987). But the depreciation rate is smaller for an older structure or for any property with substantial option value, and it is irrelevant near the redevelopment time. Moreover, in the absence of a correctly specified option value term in the hedonic regression, the age variable may capture option value, so the hedonic regression may indicate that property value increases with age for older houses.[4]

Malpezzi et al. (1987) identify three problems with using the coefficient on building age to measure depreciation: (1) age is correlated with omitted location variables; (2) construction quality varies with age and older better quality units are more likely to survive; and (3) land does not depreciate, and newer houses are built on land with higher value. In response, we use geocoded transactions to include numerous location variables in the regression, and we introduce land value explicitly into the option value term of our regression.[5] It is our treatment of land value as part of the option value term that is our greatest departure from previous hedonic literature.

We use a certainty model with constant exponential depreciation to motivate the addition of an option value term to the standard hedonic regression, Eq. (1). In our model, depreciation, together with constant or increasing land value implies an optimal time for redevelopment to a new, higher level of intensity. Our model is closest to that of Wheaton (1982), who allows durable capital to be replaced by newer, larger structure yielding higher rent.[6]

Any empirical test of hedonic theory with option value must deal with two major issues:

(1) Appropriate measurement of the intensity of the existing vector.
(2) How to specify a nonlinear regression so as to correctly identify use value and option value.

Functional form is highly relevant to model identification because option value depends negatively on the structure size and other desirable characteristics whereas these same variables enter positively into the use value portion of the model.

Our empirical results suggest that, in a market with only 1–3% option value for the median property, the bias in the age coefficient is substantial. Cumulative depreciation effects for a 20 year old property without much option value are underestimated by about 3% points whereas those for a property with a lot of redevelopment potential are overestimated by about 6% points. On the other hand, coefficients on lot size and interior area are not biased by economically significant amounts. In markets with more option value, one can expect to observe more bias in the coefficients.[7]

The next section develops theory for the value of an embedded option to redevelop the vector of hedonic characteristics in Eq. (1). Section 3 analyzes the implications of the redevelopment option for the standard hedonic regression; it specifies a nonlinear hedonic valuation model. The data and empirical results are described in Section 4. Section 5 concludes.

2. The option to redevelop and structure depreciation

This section develops a simple theoretical framework motivating the importance of real option theory for the hedonic pricing model. In this framework, prices and interest rates are fixed – option value derives entirely from depreciation. In the model, the entire vector of hedonic characteristics depreciates at a constant rate $\delta \geqslant 0$: i.e., we consider functional obsolescence and we abstract from different rates of depreciation for individual structural components. Building age enters our model in two ways: (1) in the standard hedonic regression where age is intended to capture depreciation and (2) in an additional variable for the option term, where option value increases with age.

Eq. (1) is a cross-sectional hedonic regression, whereas real option theory is based on the present value of the future costs and benefits associated with redevelopment. Therefore, our first task is to show how the implicit prices in Eq. (1) are related to discounted present values.

The asset value of the vector of depreciating characteristics can be represented by the present value of the service flows discounted at constant rate $\rho > 0$:[8]

$$PV(q_i^0) = \int_0^\infty p' q_i^0 e^{-(\delta+\rho)s} ds. \tag{2}$$

Time is indexed by s; the n-dimensional column vector of implicit spot rental rates per unit time is p which is assumed constant, and the vector of hedonic characteristic at time 0 is q_i^0 $(\geqslant 0)$.[9] We can now derive the vector of implicit market prices, v:

$$v = p(\delta+\rho)^{-1} \tag{3}$$

Property characteristics q_i^0 change only by depreciation until the owner decides to redevelop – i.e., exercise a one-time call option at cost k. This is an exchange option: at time T, the depreciated vector $q_i^0 e^{-\delta T}$ is exchanged for a new larger structure characterized

[3] Capozza and Li (1994) show that location is an important determinant of the value of the development option. In their monocentric model, development takes place on the urban fringe. One contribution of our paper is to construct a measure of intensity that includes location value, and to show that low intensity (e.g., an older, centrally located structure) may trigger redevelopment.

[4] Increasing value for older properties is typical of hedonic studies: see Coulson and McMillen (2008) and Goodman and Thibodeau (1995). The results of Malpezzi et al. (1987) are consistent with increases in option value for older houses: for renter (owner) regressions, 5 of 59 (9 of 59) metropolitan areas have non-negative "depreciation" at 10 years of age. They point out that positive age effects may be explained because "the market may have been adjusting to shifts in households' demands" or to changes in supply (p. 384). Clapp and Giaccotto (1998) use a rational expectations framework to allow the age coefficient to change with shifts in supply and demand over time.

[5] The variation in construction quality with age is a measurement problem because older houses have often been substantially renovated, but their original construction date is the only one observed by the econometrician. Our empirical estimates use assessed structure value, which includes the assessor's estimates of property condition.

[6] Wheaton's model does not include depreciation, but new properties can have higher rent than old. When rent on new structures increases enough to compensate for construction costs, structures that were optimal under a previous rental regime will be replaced with higher amounts of capital per unit land.

[7] This conclusion follows from standard results for omitted regressor bias.

[8] Poterba (1984) exploits Eq. (2) in his study of taxes on owner occupied housing. Dreyfus and Viscusi (1995) allow for a finite life for hedonic characteristics.

[9] Since quantity is measured as a stock, rental rates implicitly include the rate of service flow as well as rents per unit flow.