

# A Game-Theoretic Approach to Hedonic Housing Prices

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**Abstract**—A property's selling price is described as the result of sequential bargaining between a buyer and a seller in an environment of asymmetric information. Hedonic housing prices are estimated based upon 17,333 records of New Zealand residential properties sold during the years 2006 and 2007.

**Keywords**—Housing demand, hedonics and valuation, residential markets.

## I. INTRODUCTION

THE demand for housing is commonly described as arising from a potential buyer's desire to maximize utility over desirable housing characteristics [1]-[3]. This approach follows the hedonic pricing models of Lancaster [4] and Rosen [5]. The empirical estimation of such models has subsequently been criticised for creating a simultaneity problem between preferences and a characteristic whenever any attempt is made to recover a demand function [6]-[8]. Since then, remedies have been proposed to ensure that the estimates are consistent [9]-[10].

This paper proposes instead to remodel the underlying behavioral assumptions. Instead of deriving hedonic prices from utility-maximization, it describes how such prices may instead arise from a sequential type of bargaining between the buyer and the seller of a product with desirable characteristics. The problem of simultaneity is potentially avoided because the equilibrium of the game is independent of preferences. Furthermore, the description is more intuitively appealing because utility-maximization, even with production, fails to capture the typical haggling that takes place between a buyer and a seller before a product is sold. The model is applied to obtain hedonic prices for New Zealand residential properties that were sold during the years 2006 and 2007.

## II. THE MODEL

The model is a version of a two-period game with asymmetric information proposed by Rubinstein [11] and by

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Ben-Ner and Jun [12]. In the first period, the seller offers a property selling price,  $p_1$  that the buyer decides either to accept or reject. If the offer is accepted, the game ends. If the offer is rejected, the seller makes a second-period offer,  $p_2$ , which again the buyer either accepts or rejects. The game ends after a decision on  $p_2$  is made.

The buyer derives a benefit from the property,  $b$  that depends upon the property's hedonic characteristics. There is a one-period discount factor,  $\delta$ , so that any second-period payoffs in either the selling price or the benefit is to be discounted by  $\delta$ . Information is asymmetric in that the benefit is known to the buyer but not to the seller. All that the seller knows is that  $b$  is randomly distributed according to some probability distribution. For simplicity, the distribution is assumed to be uniform with a range of from between a minimum value of 0 and a maximum of  $b_H$ . The maximum  $b_H$  can be interpreted as a vector of parameters from hedonic characteristics that yields the highest possible benefit to the buyer.

A possible equilibrium that results in a property being sold is that the seller makes a first-period offer which the buyer rejects, after which the seller makes a second-period offer which the buyer accepts. For such an equilibrium, there is an optimal first-period offer  $p_1^*$  made by seller. Corresponding to this offer is an optimal critical benefit to the buyer,  $b_1^*$ , for which  $p_1^*$  will be accepted if the benefit of the property is anywhere higher, and for which  $p_1^*$  will be rejected if the benefit is anywhere lower. Finally there is an optimal second-period offer  $p_2^*$ , that the buyer will accept. These solutions are found by analyzing the strategies and the payoffs below.

First, the critical benefit to the buyer can be derived as  $b_1 = (p_1 - \delta p_2) / (1 - \delta)$ . The reason is as follows. If the first-period offer were accepted, the buyer's payoff will be  $(b - p_1)$ . If it were rejected and the second-period offer were accepted, it will instead be  $\delta (b - p_2)$ . If both offers were rejected, the buyer's payoff will be 0. From these it follows that the first-period offer will be accepted if  $b$  were to be greater than the maximum of either  $p_1$  or  $(p_1 - \delta p_2) / (1 - \delta)$ . Suppose that the higher of these two were  $b_1$ . If  $b_1$  were  $p_1$ , then the buyer is better off by rejecting both offers, with the result that the equilibrium of the game is uninteresting. If instead  $b_1$  were  $(p_1 - \delta p_2) / (1 - \delta)$ , then the first-period offer is rejected and the second period offer is accepted. Thus if the game were to proceed to the second period and the second-period offer were to be accepted,  $b_1$  must be equal to  $(p_1 - \delta p_2) / (1 - \delta)$ .

Second, the solution for the second-period offer can be derived as  $p_2 = b_1 / 2$ . This is because having been rejected for the first offer, the seller forms an updated belief concerning the range of the buyer's benefits. This range is now thought of as between 0 and  $b_1$ . For a uniform distribution, the conditional probability that the buyer will accept the second-period offer is thus  $(b_1 - p_2) / b_1$ , an area corresponding to the range between  $p_2$  and  $b_1$ . The conditional probability that the buyer will reject the offer is  $p_2 / b_1$ . The seller's goal is thus to choose  $p_2$  so as to maximize the expected value function:  $\{(b_1 - p_2) / b_1\} p_2 + (p_2 / b_1) 0$ . The solution to this problem is  $p_2 = b_1 / 2$ .

Finally, the solution for the first-period offer  $p_1$  is obtained by assuming that the seller shall have formed all beliefs early on in the game. The seller knows that  $(b_h - b_l) / b_h$  is the probability that the buyer will accept the first-period offer and, also, that  $b_l = (p_1 - \delta p_2) / (1 - \delta)$  is the critical benefit to the buyer. Armed with this foresight, the seller's problem is thus to choose  $p_1$  in order to maximize the following expected payoff from every possible contingency:  $\{(b_h - b_l) / b_h\} p_1 + (\delta (b_1 - p_2) / b_h) p_2 + \delta (p_2 / b_h) 0$ . In their reduced forms, the resulting solutions for  $p_2^*$ ,  $b_1^*$  and  $p_1^*$  are therefore:

$$p_2^* = (2 - d) b_h / 2(4 - 3d) \quad (1)$$

$$b_1^* = (2 - d) b_h / (4 - 3d) \quad (2)$$

$$p_1^* = (2 - d)^2 b_h / 2(4 - 3d) \quad (3)$$

The solution for  $p_2^*$  indicates the main testable proposition of the model: that if a property were successfully sold, the selling price will in general be a positive function of the buyer's maximum benefit, which in turn is a vector of hedonic parameters. The solution for  $b_1^*$  indicates that the buyer forms an optimal benefit and it is on this basis that the first-period offer (the solution for  $p_1^*$ ) is rejected.

The solutions in (1) to (3) can be generalized if the assumed probability distribution is not uniform. If the underlying distribution continues to be bounded by a minimum value of 0 and a maximum value of  $b_h$ , the solutions can each be shown as continuing to be a positive function of  $\delta$  and  $b_h$ . If instead the underlying distribution were to be unbounded from either side, an additional assumption is required regarding what the seller is supposed to know. This additional assumption is that the seller must know the probability of the benefit falling within the range of 0 and  $b_h$ . This probability can then be used as a weight to obtain closed-form solutions that are similar to those in (1) to (3).

### III. EMPIRICAL IMPLEMENTATION

Econometrically, the benefit of a property can be estimated by valuing the impact of favorable housing characteristics upon the property's selling price. Such an investigation was made possible by the records of Land Information New Zealand (LINZ) concerning 17,333 residential properties sold

between July 1, 2006 and August 20, 2007. To control for market appreciation, four dummy variables were created to represent the quarterly lag at which the properties were sold. The first, for a one-quarter lag, was for sales dates between September 1, 2006 and November 30, 2006. The fourth, for a four-quarter lag, was for sales dates between June 1, 2007 and August 20, 2007. Thus, the base dates for gauging market appreciation were properties sold between July 1, 2006 and August 31, 2006, and these accounted for 878 of the observations.

Estimates for the benefit are shown in Table 1. Numbers in parentheses are for corresponding t-statistics. The dependent variable is the property's selling price in New Zealand dollars. The first-column results are from an ordinary-least squares regression that does not consider the market-appreciation dummy variables. The second and third regressions are from fixed and random-effects linear-regressions that consider them. These additional ones were necessary because the observations were grouped according to twelve territorial areas spread across New Zealand. The fixed effects regression assumed that the group-specific residual was constant within each territorial area.

The average selling price of a residential property was found to be NZ\$389,816, and this price had a standard deviation of NZ\$356,263. One of the most important influences upon it was market appreciation. This ranged from between a one-quarter effect of NZ\$8,929 (2.3% of the average selling price) to a four-quarter effect of NZ\$48,414 (12.4% of the selling price). Also statistically significant was the size of the property, measured either in land area, in building area, or in living area. For instance, an additional square meter of living space was estimated to convey a price effect of between NZ\$1054 to NZ\$1174.

Building condition was also highly valued. A top ranking of "good" by inspectors (as opposed to average, fair or poor) conveyed a price effect of between NZ\$12,341 to \$16,835. A large improvement such as a swimming pool, a glass house or a tennis court also added anywhere between NZ\$38,042 to NZ\$50,730 to the selling price. Having either a landscape or water view was estimated to increase the price by between NZ\$162,341 to NZ\$194,014.

Of some surprise was the negative and statistically-significant effect of a property being built on land that was leveled rather than sloped. The theoretical expectation was that leveled properties would have been the ones favored. Also of some surprise was the statistical insignificance of having access to parking, to a roofed garage or a deck, or to the lack of privacy from having units located on the same property.

TABLE 1  
SUMMARY STATISTICS AND REGRESSION COEFFICIENTS OF HOUSING CHARACTERISTICS UPON PROPERTY SELLING PRICES AS THE DEPENDENT VARIABLE

Variable	Mean	Standard Deviation	Least Squares (1)	Fixed Effects (2)	Random Effects (3)
Property selling price (in dollars).....	389816.40	356262.80	. ----	. ----	. ----
Land area (in square meters).....	115.72	1139.43	34.57 (9.63)	24.81 (6.42)	28.36 (7.83)
Number of units on the same property.....	1.15	1.79	753.58 (1.28)	802.23 (1.51)	631.35 (1.08)
Parking units available.....	1.47	4.29	-196.73 (-0.56)	575.69 (1.80)	-145.99 (-0.41)
Building condition (1=good, 0 if average, fair or poor.).....	0.48	0.50	16835.76 (6.54)	12341.23 (5.19)	15483.84 (6.03)
Building area (in square meters).....	145.86	198.36	719.66 (21.67)	747.32 (24.72)	725.93 (21.92)
Levelled location rather than sloped (1=yes).....	0.56	0.50	-35284.95 (-14.45)	3615.80 (1.55)	-33482.90 (-13.73)
Some view available of landscape or water (1=yes).....	0.06	0.24	194014.20 (41.40)	162341.60 (37.82)	191780.30 (41.04)
Living area (in square meters).....	119.43	50.83	1174.45 (27.94)	1054.81 (27.40)	1163.82 (27.75)
Deck available (1=yes).....	0.48	0.50	-132.15 (-0.05)	2486.35 (1.10)	973.56 (0.40)
Large improvements, e.g. swimming pool. (1=yes).....	0.02	0.16	38042.10 (5.29)	50731.80 (7.77)	38522.75 (5.38)
Roofed garage (1=yes).....	0.57	0.88	-444.70 (-0.28)	-747.83 (-0.51)	138.42 (0.09)
Sold first quarter (1=yes).....	0.28	0.45	----	8928.55 (1.76)	2818.11 (0.53)
Sold second quarter (1=yes).....	0.30	0.46	----	20619.97 (4.07)	14158.01 (2.68)
Sold third quarter (1=yes).....	0.27	0.45	----	25854.97 (5.06)	27914.65 (5.23)
Sold fourth quarter (1=yes).....	0.09	0.29	----	22655.82 (3.72)	48414.04 (7.75)
Constant of the regression.....	----	----	121810.80 (35.49)	93574.18 (16.80)	104573.10 (18.01)

#### IV. CONCLUDING REMARKS

The model and findings can be regarded as adding to the literature on uncovering the hedonic benefits of housing characteristics. Nonetheless, the model is not derived from utility-maximization. Its testable proposition arises from the much more common experience of haggling in property markets. The model also adds to other theories of property decision-making such as to one where buyers or tenants are instead interested in minimizing their search and moving costs [13]. One area for future research is the inclusion in the regressions of demographic variables to help explain why some hedonics matter more than others.

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