INTERNATIONAL REAL ESTATE REVIEW

2013 Vol. 16 No. 2: pp. 189 – 207

On the Functional Form of the Hedonic Price Function: A Matching-theoretic Model and Empirical Evidence

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The key issue in the hedonic price theory is that although the literature emphasises intrinsic nonlinearity in the relationship between house prices and housing characteristics, very little theoretical guidance is provided with regards to a more appropriate mathematical specification for the hedonic price function. Thus, most empirical studies make use of flexible functional forms or simple linear models which possess a direct economic meaningfulness. This theoretical paper attempts to fill this gap by using the Mortensen-Pissarides matching model to show the nonlinearity of the hedonic price function and provide insights on the more appropriate functional relationship between prices and attributes.

Keywords
Hedonic price theory; Hedonic price function; Search and matching models

1. Introduction

Although the economic theory of hedonic prices (Lancaster, 1966; Rosen, 1974) is well known and not in question,[1] it provides very little theoretical guidance on the appropriate functional relationship between prices and attributes in the hedonic price function (Malpezzi, 2003; Taylor, 2003), and thus in empirical studies, researchers have used flexible functional forms, such as Box-Cox functions, or simple parametric models (Anglin and Gençay, 1996).[2]

The hedonic price literature almost unanimously underlines the intrinsic nonlinearity in the relationship between house prices and housing characteristics, though nothing is known a priori about a specific functional form (Anglin and Gençay, 1996; Ekeland, Heckman and Nesheim, 2002, 2004; Parmeter, Henderson and Kumbhakar, 2007; Haupt, Schnurbus and Tschernig, 2010). Nevertheless, while the literature suggests that the equilibrium price function is nonlinear, most empirical studies make use of linear models, thus relying on an influential simulation study by Cropper, Deck and McConnell (1988).[3] This "puzzle" is due to the absence of theoretical groundwork with regards to the more appropriate functional form to use in the hedonic price models (see for e.g., Anglin and Gençay, 1996; Malpezzi, 2003). According to Rosen (1974), there is no reason for the hedonic price function to be linear; in fact, the linearity of the hedonic price function is unlikely as long as the marginal cost of attributes increases for sellers and it is not possible to untie packages. Indeed, Ekeland, Heckman and Nesheim (2002, 2004) demonstrate that nonlinearity is a generic property of the hedonic price function. Hence, a linear model would be a special case for the hedonic price function (Kuminoff, Parmeter and Pope, 2008, 2009). However, the nonlinearity is basically a general concept and may imply the use of several kinds of empirical models.

As a rule, the use of a particular empirical model rather than another should be indicated by the economic theory (Stock and Watson, 2003). Indeed, theoretical models are critical in determining an accurate and consistent econometric model: empirical analysis alone cannot replace conceptual reasoning when estimating the relationships of most economic phenomena (Can, 1992; Brown and Ethridge, 1995).

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[1] For an exhaustive overview see Sheppard (1999) and Malpezzi (2003).

[2] Often linear, semi-logarithmic or log-log models are chosen. These are characterised as being easily interpretable, and the estimated parameters possess a direct economic meaningfulness (Maurer, Pitzer, and Sebastian, 2004). In particular, in the linear model, the parameters give absolute prices for the unit of the attributes.

[3] Cropper, Deck and McConnell (1988) have found that when all attributes are observed, linear and quadratic Box-Cox forms produce the most accurate estimates of marginal attribute prices; whereas, when some attributes are unobserved or are replaced by proxies, linear and linear Box-Cox functions perform best.

In order to build a theoretical foundation for empirical models, this paper develops a matching model *à la* Mortensen-Pissarides (see for e.g., the textbook by Pissarides, 2000) and shows that the hedonic pricing equation is nonlinear. In particular, under the realistic assumption of decentralised housing markets with important search and matching frictions (Leung and Zhang, 2011), in this model, the equilibrium price function is nonlinear with a closed-form solution. Furthermore, this paper provides empirical evidence for the non-linear effect of housing characteristics on selling price.

Several papers have examined the widely used hedonic pricing equation (see for e.g., Epple, 1987; Bartik, 1987; Kahn and Lang, 1988; Palmquist, 1988; Brachinger, 2003; Ekeland, Heckman and Nesheim, 2002, 2004). Moreover, there have been attempts to develop a dynamic theory of hedonic prices (Kwong and Leung, 2000; Kan, Kwong and Leung, 2004; Leung, Wong and Cheung, 2007).[4] However, these important contributions did not consider the search and matching frictions. In fact, what distinguishes my paper from previous efforts is that it is based on a search-matching model, arguably more appropriate for a "matching market" like the housing market.[5]

Also, the proposed housing market matching model allows a major drawback of the standard hedonic pricing theory to be overcome: the assumption of competitive markets. Indeed, in the standard hedonic pricing theory, markets are assumed to be sufficiently thick (i.e. markets with a large amount of trading) so that implicit or hedonic prices, i.e. the shadow prices of the characteristics, are revealed to economic agents through trades that differ only in terms of a single attribute. However, this is hardly true: markets become increasingly thin when traded goods are increasingly heterogeneous, and the implicit or hedonic prices as well as the "true" market value of the good are not known (Harding, Rosenthal and Sirmans, 2003; Harding, Knight and Sirmans, 2003; Cotteleer and Gardebroek, 2006).[6] In fact, the house price

[4] In particular, Leung, Wong and Cheung (2007) have developed a dynamic theory of hedonic prices based on the general equilibrium asset pricing model *à la* Lucas which holds not only at the steady state, but in principle at any point in time.

[5] Peters (2007) has developed a suitably modified version of hedonic equilibrium by using the limits of the Bayesian Nash equilibrium from finite versions of the game to determine the out of equilibrium payoffs. The goal of this paper is to address a realistic situation in which characteristics of traders on both sides of the market are endogenous. This formalisation can be applied to any matching markets (labour, marriage and housing).

[6] According to Arnott (1989), the real estate market is thin because of the indivisibility and multi-dimensional heterogeneity of housing units. Although the model is extended to treat costly search, central in Arnott's (1989) modelling framework is the analysis of tenant search and landlord behaviour in a (rental) market with tenant idiosyncratic tastes. Thin (rental) markets are in fact modelled by assuming an idiosyncratic component to the tastes of households over housing units. Given such idiosyncratic tastes, tenants search for their preferred unit and are willing to pay a premium for it. This confers monopoly power on landlords, which they exploit by setting rents above

realistically depends not only on the housing characteristics but also the search and matching frictions and bargaining power of the parties. Indeed, several recent papers have just used the search-matching models to study the housing market (among others, Diaz and Jerez, 2009; Novy-Marx, 2009; Piazzesi and Schneider, 2009; Genesove and Han, 2010; Leung and Zhang, 2011; Peterson, 2012). However, none of these existing works of research have considered how to take advantage of this approach to derive an appropriate functional form for the hedonic price equation.[7]

The rest of the paper is organised as follows: Section 2 presents the housing market matching model; Section 3 gives insights on a more appropriate functional form to use in the hedonic price models, while Section 4 shows the empirical plausibility of the theoretical result; and finally, Section 5 concludes the work.

2. A Baseline Matching Model of Housing Market

I have adopted a standard matching framework *à la* Mortensen-Pissarides (see for e.g., Pissarides, 2000) with random search and prices determined by Nash bargaining. I believe that the behaviour of the housing market can be properly formalised by the Mortensen-Pissarides matching model. Indeed, the random matching assumption is absolutely compatible with a market where the formal distinction between the demand and supply side is very subtle; whereas, bargaining is a natural outcome of thin, local and decentralised markets for heterogeneous goods.

Since I am interested in selling price, the market of reference is the homeownership market rather than the rental market. In this market, if a contract is legally binding (as hypothesised) it is no longer possible to return to the circumstances that preceded the bill of sale, unless a new and distinct contractual relationship is set up. In matching model jargon, this means that the destruction rate of a specific buyer-seller match does not exist and the value of an occupied home for a seller is simply given by the selling price.

Buyers (*b*) expend costly search efforts to find a (new or better) house, while sellers (*s*) hold $h \geq 2$ houses of which $h-1$ are on the market, i.e. vacancies (v) are simply given by $v = (h-1) \cdot s > 0$.[8] It is therefore possible that a

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costs. In the long run, however, free entry and exit lead to zero profits, with vacancies as the equilibrating mechanism.

[7] Unlike the quoted studies, I have followed the standard matching framework *à la* Mortensen-Pissarides without any deviation from the baseline model.

[8] Since there is no rental market, this is a reasonable assumption. Alternatively, one could assume that the sellers hold $h \geq 1$ houses of which h are on the market, and that the buyers are the homeless. This case would not change the results of the analysis.

buyer can become a seller, and that a seller can become a buyer. Indeed, buyers today are in fact potential sellers tomorrow (Leung, Leong and Wong, 2006).

The expected values of a vacant house (V) and of buying a house (H) are given by:[9]

$$rV = -c + q(\vartheta)\cdot[P - V] \quad (1)$$

$$rH = -e + g(\vartheta)\cdot[x - H - P] \quad (2)$$

where $\vartheta \equiv v / b$ is the housing market tightness from the standpoint of sellers, while $q(\vartheta)$ and $g(\vartheta)$ are, respectively, the (instantaneous) probability of filling a vacant house and of buying a home. The standard hypothesis of constant returns to scale in the matching function, $m = m\{v,b\}$, is adopted (see Pissarides, 2000; Petrongolo and Pissarides, 2001), since it is also used in (recent) search models of the housing market (Diaz and Jerez, 2009; Novy-Marx, 2009; Piazzesi and Schneider, 2009; Genesove and Han, 2010; Leung and Zhang, 2011; Peterson, 2012). Hence, the properties of these functions are straightforward: $q'(\vartheta) < 0$ and $g'(\vartheta) > 0$.[10] The terms c and e represent, respectively, the costs sustained by sellers for the advertisement of vacancies and the effort (in monetary terms) made by buyers to find and visit the largest possible number of houses. If a contract is stipulated, the risk neutral buyer gets a linear benefit x from the property, which coincides with the value of the house (abandoning the home searching value) and pays the sale price P to the seller (who abandons the value of finding another buyer). Intuitively, the value of the house, and thus the buyer's benefit, can be higher or lower according to the mix of desired and undesidered housing characteristics (not all characteristics are in fact desired).[11] For the sake of simplicity, I assume that all characteristics are desired. Hence, more housing characteristics mean higher house value (i.e. the buyer's benefit).

The endogenous variables that are simultaneously determined at equilibrium are market tightness (ϑ) and sale price (P). The "zero-profit" or "free-entry" condition normally used by matching models (see Pissarides, 2000) yields the first key relationship of the model, in which market tensions are a positive

[9] Time is continuous and individuals are risk neutral, live infinitely and discount the future at an exogenous interest rate $r > 0$. As usual in matching-type models, the analysis is restricted to a stationary state.

[10] Standard technical assumptions are postulated: $lim_{\vartheta \to 0} q(\vartheta) = lim_{\vartheta \to \infty} g(\vartheta) = \infty$, and $lim_{\vartheta \to 0} g(\vartheta) = lim_{\vartheta \to \infty} q(\vartheta) = 0$. By definition, markets with frictions require positive and finite tightness, i.e. $0 < \vartheta < \infty$, since for $\vartheta = 0$ the vacancies are always filled, whereas for $\vartheta = \infty$ the home-seekers immediately find a vacant house.

[11] Air and noise pollution, bad neighbourhoods are examples of "undesidered" housing characteristics which decrease the value of the house.

function of price. By using the equilibrium condition $V=0$ in (1), the following is obtained:

$$\frac{1}{q(\vartheta)} \equiv q(\vartheta)^{-1} = \frac{P}{c} \tag{3}$$

with $\partial\vartheta / \partial P > 0$. This positive relationship is very intuitive (recall that $q'(\vartheta) < 0$): in fact, if the price increases, more vacancies will be on the market.

Since vacancies depend on the number of sellers, which in turn depend on market tightness (as will be made clear later), the zero-profit condition is reformulated to find the share of sellers (and buyers) in equilibrium. Precisely, the transition process from seller (buyer) to buyer (seller) comes to an end when the value of being a seller is equal to zero. In this case, in fact, no one will be willing to become a seller and thus matching no longer occurs. Note that the value of being a seller is nothing but the value of a vacant house.

Instead, the selling price is obtained by solving the following optimisation condition, the so-called Nash bargaining solution usually used for decentralised markets (recall that in equilibrium $V=0$):

$$P = argmax\left\{(P-V)^{\gamma} \cdot (x-H-P)^{1-\gamma}\right\}$$

$$\Rightarrow P = \frac{\gamma}{(1-\gamma)} \cdot (x-H-P) \Rightarrow P = \gamma \cdot (x-H)$$

where $0<\gamma<1$ is the share of bargaining power of sellers. Entering into a contractual agreement obviously implies that $x>H$, $\forall\vartheta$ for the buyer. Hence, the selling price is always positive. By using the previous result, i.e. $(x-H-P) = \frac{(1-\gamma)}{\gamma} \cdot P$, in Equation (2), eventually we get an explicit expression for the selling price:

$$P = \frac{\gamma \cdot (rx+e)}{r+g(\vartheta) \cdot (1-\gamma)} \tag{4}$$

with $\partial P / \partial\vartheta < 0$. With regards to the economic meaning of Equation (4), if the market tightness increases, the effect of the well-known congestion externalities on the sellers' side (see Pissarides, 2000) will lower the price (recall that $g'(\vartheta) > 0$).

This simple model is able to reproduce the observed joint behaviour of prices and time-on-the-market (see for e.g., Leung, Leong, and Chan, 2002). In fact, with a probability of filling a vacant house of $q(\vartheta)$, the (expected) time-on-the-market is $q(\vartheta)^{-1}$. Hence, from Equation (3), the house with a higher selling price has a longer time on the market (since $q(\vartheta)^{-1}$ is increasing in ϑ); whereas, from Equation (4), a longer the time-on-the-market (i.e. higher market tightness) means a lower sale price.

It is straightforward to obtain from (3) that when P tends to zero (infinity), ϑ tends to zero (infinity), as $q(\vartheta)$ tends to infinity (zero). Consequently, given the negative slope of (4) and the fact that price is always positive, only one long-term equilibrium derived from the intersection of the two curves exists in the model. Finally, by normalising the population in the housing market to the unit, $1 = b + s$, and using both the definition of vacancies, $v = (h-1)\cdot s$, and the value of equilibrium tightness ($\vartheta \equiv \vartheta^* = v / b$), the model is closed in a very simple manner.[12]

3. Hedonic Price and Functional Form Specification

The two key equations of the model are the free-entry condition, i.e. Equation (3), and the Nash bargaining solution, i.e. Equation (4). Indeed, the latter is none other than the hedonic price function of the model, where the selling price is a positive function of housing characteristics. From (4), in fact, P depends positively on the value of the house, *x*, which in turn, positively depends on the housing characteristics. Hence, the hedonic or implicit price is positive and the equilibrium hedonic price function has a closed-form solution.

However, unlike the standard hedonic price theory, the sale price of this model not only depends on the housing characteristics but also on the market tensions, bargaining power of the parties and search costs. In particular, market tensions are an endogenous variable of the model. Hence, in order to express the hedonic price function only in terms of exogenous variables, Equations (3) and (4) need to be combined. By using the popular Cobb-Douglas functional form (also used by Novy-Marx, 2009; Piazzesi and Schneider, 2009; Peterson, 2012), i.e. $m = v^{1-\alpha} \cdot b^{\alpha}$, where α is the elasticity of the matching function with respect to the share of buyers, the following implicit function is obtained for selling price:

$$r \cdot P + \left(\frac{P}{c}\right)^{\frac{1-\alpha}{\alpha}} \cdot (1-\gamma) \cdot P = \gamma r x + \gamma e$$

$$\Rightarrow r \cdot P + \left(\frac{1}{c}\right)^{\frac{1-\alpha}{\alpha}} \cdot (P)^{\frac{1}{\alpha}} \cdot (1-\gamma) = \gamma r x + \gamma e \qquad (5)$$

[12] Given the equilibrium value of market tightness, it is in fact straightforward to solve this system of three equations with three unknowns (*v*, *b*, *s*).

with $q(\vartheta)=\dfrac{v^{1-\alpha}\cdot b^{\alpha}}{v}=\vartheta^{-\alpha}$, $g(\vartheta)=\dfrac{v^{1-\alpha}\cdot b^{\alpha}}{b}=\vartheta^{1-\alpha}$, and $\vartheta=\left(\dfrac{P}{c}\right)^{\frac{1}{\alpha}}$ from (3).

The total differentiation of Equation (5) with respect to P and x thus yields:

$$r\cdot dP+\left(\frac{1}{\alpha}\right)\cdot(P)^{\frac{1}{\alpha}-1}\cdot\left(\frac{1}{c}\right)^{\frac{1-\alpha}{\alpha}}\cdot(1-\gamma)\cdot dP=\gamma r\cdot dx$$

$$\Rightarrow\frac{dP}{dx}\equiv p=\frac{\gamma r}{r+\left(\frac{1}{\alpha}\right)\cdot\left(\frac{P}{c}\right)^{\frac{1-\alpha}{\alpha}}\cdot(1-\gamma)}>0 \tag{6}$$

As a result, the hedonic price function is non-linear even if the buyer is risk neutral and acquires a linear benefit from the property: in fact, the implicit or hedonic price p depends on x, since $p=f(P)$ and $P=f(x)$. This is in line with the hedonic price literature which suggests that the equilibrium price function should be nonlinear.

The key role of market tightness on the shape of the hedonic price function is straightforward: in fact, the selling price depends on the matching probabilities between seller and buyer which are, intuitively non-linear (for example, an increase in tightness increases at decreasing rates the probability of finding a home). Also, the equilibrium market tightness depends on housing characteristics through the selling price (see Equation 3). In short, housing characteristics affect the selling price, which in turn, influences market tightness; eventually, the variation of market tightness causes a further change in the selling price. Thus, the combination of these effects leads to the non-linear effect of housing characteristics on house price. Precisely, the positive effect of an increase in housing characteristics is subsequently mitigated by market tightness. Indeed, since the selling price is increasing in the house value (namely, the hedonic price is positive), it may also be stated that $d^2P/dx^2\equiv p'(x)<0$. Hence, this theoretical model also gives a precise statement about the form of the hedonic price function: in fact, it suggests an increasing relationship at decreasing rates between selling price and housing characteristics. [13]

4. Empirical Testing

In order to test the empirical plausibility of an increasing relationship at decreasing rates between selling price and housing characteristics, the benchmark parametric econometric model proposed by Anglin and Gençay

[13] Note that the search effort of the buyer also affects the hedonic price, since P depends on *e*.

(1996) is used, and also considered by Parmeter, Henderson and Kumbhakar (2007), and Haupt, Schnurbus and Tschernig (2010).[14]

The Anglin-Gençay benchmark parametric model is characterised by many binary variables and the relationship between the dependent variable (selling price), the continuous regressor (the lot size) and the discrete variables is represented in terms of relative changes (elasticity).[15] In this empirical analysis, data from their study are employed. Details about this dataset are reported in the Appendix – Part I (at the end).

By following the benchmark parametric model by Anglin and Gencay (1996), all the quantitative variables (*lot size, bedrooms, bathrooms, stories*) are transformed into natural logarithms;[16] whereas, the dummy variables, by definition, cannot be transformed (Maurer, Pitzer and Sebastian, 2004). The econometric model is thus the following:

$$ln(P_i) = \beta_0 + \beta_1 \cdot ln(LOT_i) + \beta_2 \cdot ln(BED_i) + \beta_3 \cdot ln(BATH_i) + \beta_4 \cdot ln(STO_i) + \beta_5 \cdot DRI_i + \beta_6 \cdot RER_i + \beta_7 \cdot FIB_i + \beta_8 \cdot GWH_i + \beta_9 \cdot CAC_i + \beta_{10} \cdot PRN_i + \beta_{11} \cdot GAR_i + \varepsilon_i \quad (7)$$

where P_i is the selling price of the house i; *DRI*, *RER*, *FIB*, *GWH*, *CAC* and *PRN* are dummy variables for driveway, recreational room, finished basement, gas water heating, central air conditioning and preferred neighbourhood, respectively; *GAR*, *BED*, *BATH* and *STO* are the number of garages, bedrooms, full bathrooms and stories, respectively; and *LOT* is the lot size (in square feet). Finally, ε_i is the stochastic error term.

By neglecting the binary variables,[17] I focus on β_i, with $i = 1, 2, 3, 4$. It follows that with $0 < \beta_i < 1$ the relationship is increasing at decreasing rates,

[14] Indeed, Haupt, Schnurbus and Tschernig (2010) show that the null hypothesis of the correct specification of the linear parametric model proposed by Anglin and Gençay (1996), against the alternative of parametric misspecification, cannot be rejected at any reasonable significance level. Also, they show that the parametric model predicts better than the nonparametric specification proposed by Parmeter, Henderson and Kumbhakar (2007).

[15] Data on housing characteristics, in fact, typically consists of one continuous regressor (the lot size) and many ordered and unordered categorical variables (Parmeter, Henderson and Kumbhakar, 2007; Haupt, Schnurbus and Tschernig, 2010).

[16] The Box-Cox regression also suggests a logarithmic transformation for the quantitative variables. Because of the presence of the value 0, the natural logarithm is not used for the variable number of garage places.

[17] The coefficients for the binary variables give the surcharge which is to be paid relative to a property without those attributes. For more details about the economic interpretation of the effect of dummy variables on the dependent variable in natural logarithmic form see Halvorsen and Palmquist (1980).

while with $\beta_i > 1$, the relationship is increasing at increasing rates, and finally with $\beta_i = 1$, the relationship is linear.

The ordinary least squares (OLS) results show that the coefficients β_i have positive signs and are statistically significant, i.e. $\beta_i \neq 0$. Furthermore, the coefficients β_i range between 0.089 (*number of bedrooms*) and 0.313 (*lot size*), i.e. $0 < \beta_i < 1$, and the null hypothesis of $\beta_i = 1$ is rejected at any reasonable significance level, thus confirming the nonlinearity of the hedonic price function. Finally, not surprisingly, the econometric model is statistically correct (for details about the estimation results, see Appendix – Part II, at the end).[18] Hence, an increasing relationship at decreasing rates may be the most appropriate functional form for the hedonic price function (as suggested by the theoretical model).

Finally, this theoretical framework may also be used to study how errors in measuring marginal attribute prices vary with the form of the hedonic price function; in this way, the simulation strategy developed by Cropper, Deck and McConnell (1988), and updated by Kuminoff, Parmeter and Pope (2008, 2009), may take the (equilibria of the) housing market with search and matching frictions into account, thus relaxing the unrealistic assumption of competitive housing markets.[19]

5. Conclusion

The nonlinearity in the relationship between house price and housing characteristics is a recognised starting point for the hedonic price literature, although nothing is known a priori about a specific functional form. Indeed, the economic theory of hedonic prices provides very little theoretical guidance on the appropriate functional relationship between prices and attributes in the hedonic price function. This is a very significant shortcoming for empirical studies, since theoretical models are critical in determining accurate and consistent econometric models and the use of a particular empirical model rather than another should be indicated by the economic theory. As a consequence, most empirical studies make use of flexible functional forms or simple models which possess a direct economic meaningfulness. This paper

[18] On the shape of the hedonic price function (precisely, on the estimate of the marginal price of floor space) see the interesting discussion between Coulson (1992, 1993) and Colwell (1993).

[19] In the quoted studies, the marginal bid of consumers (namely, the "true" marginal price paid) for each attribute is obtained by simulations of housing market equilibria. Subsequently, equilibrium housing prices, together with housing attributes, provide the data used to estimate various functional forms for the hedonic price function. Finally, errors in estimating marginal prices are calculated by comparing the consumer's equilibrium marginal bid with the gradient of the hedonic price function.

develops a baseline matching model in which the nonlinearity of the hedonic price function emerges as an equilibrium outcome in a market with search and matching frictions. Furthermore, it provides empirical evidence for the non-linear effect of housing characteristics on selling price.

A drawback of this analysis, however, must be acknowledged: there is a “gap” between the theoretical model (which derives a complicated non-linear function) and its empirical counterpart (in which many binary regressors are used). It follows that the theoretical model introduces a number of parameters which cannot be tested for (above all, the bargaining power of the parties).[20] The explanation (justification) for this difference is that the aim of the empirical part of the paper is to offer clear evidence for the particular shape of the hedonic price function derived from the theoretical model. The empirical model used is in fact, a very popular econometric specification. Nevertheless, it would be desirable to verify these results by using another dataset and/or a more complex empirical model.

Acknowledgment

The author wishes to thank the two anonymous referees for their many helpful comments and suggestions. The usual disclaimer applies.

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[20] However, a simple way to measure the important effect of bargaining power with dummy variables can be found in Iacobini and Lisi (2012).

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Appendix

I) Data

The dataset contains 546 observations on the sales prices of houses sold during July, August and September (1987) in the city of Windsor, Canada (*source:* Anglin and Gencay, 1996). The following variables are available:

price (P): sale price of a house
lotsize (LOT): the lot size of a property in square feet
bedrooms (BED): number of bedrooms
bathrms (BATH): number of full bathrooms
stories (STO): number of stories excluding basement
driveway (DRI): dummy, 1 if the house has a driveway
recroom (RER): dummy, 1 if the house has a recreational room
fullbase (FIB): dummy, 1 if the house has a full finished basement
gashw (GWH): dummy, 1 if the house uses gas for hot water heating
airco (CAC): dummy, 1 if there is central air conditioning
garagepl (GAR): number of garage places
prefarea (PRN): dummy, 1 if located in preferred neighbourhood of the city

Summary statistics:

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
price	546	68121.6	26702.67	25000	190000
lotsize	546	5150.266	2168.159	1650	16200
bedrooms	546	2.965201	.7373879	1	6
bathrms	546	1.285714	.5021579	1	4
stories	546	1.807692	.8682025	1	4
driveway	546	.8589744	.3483672	0	1
recroom	546	.1776557	.3825731	0	1
fullbase	546	.3498168	.4773493	0	1
gashw	546	.0457875	.2092157	0	1
airco	546	.3168498	.4656750	0	1
garagepl	546	.6923077	.8613066	0	3
prefarea	546	.2344322	.4240319	0	1

II) Estimation Results

Source	SS	df	MS			
Model	51.5755541	11	4.68868673	Number of obs	=	546
Residual	23.8376161	534	.044639731	F(11, 534)	=	105.03
				Prob > F	=	0.0000
				R-squared	=	0.6839
				Adj R-squared	=	0.6774
Total	75.4131702	545	.138372789	Root MSE	=	0.21128

ln_price	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
ln_lotsize	.3129159	.0269214	11.62	0.000	.260031	.3658007
ln_bedrooms	.0887915	.0437256	2.03	0.043	.0028962	.1746868
ln_bathrms	.2637722	.0312154	8.45	0.000	.2024521	.3250923
ln_stories	.1652339	.024935	6.63	0.000	.1162513	.2142166
driveway	.1095447	.0283597	3.86	0.000	.0538344	.165255
recroom	.059703	.0261513	2.28	0.023	.0083309	.1110751
fullbase	.0956443	.0216553	4.42	0.000	.0531043	.1381843
gashw	.1733505	.044116	3.93	0.000	.0866883	.2600126
airco	.1707837	.0212669	8.03	0.000	.1290066	.2125608
garagepl	.048916	.0115416	4.24	0.000	.0262436	.0715884
prefarea	.1296759	.0227795	5.69	0.000	.0849275	.1744243
_cons	7.920482	.2191781	36.14	0.000	7.489925	8.351039

Ramsey RESET test by using powers of the fitted values of *ln_price*

Ho: model has no omitted variables
F(3, 531) = 0.76
Prob > F = 0.5184

test ln_lotsize = 1

F(1, 534) = 651.36
Prob > F = 0.0000

test ln_bedrooms = 1

F(1, 534) = 434.27
Prob > F = 0.0000

test ln_bathrms = 1

F(1, 534) = 556.27
Prob > F = 0.0000

test ln_stories = 1

F(1, 534) = 1120.76
Prob > F = 0.0000

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance
Variables: fitted values of ln_price
chi2(1) = 0.51
Prob > chi2 = 0.4761

Variable	**VIF**	**1/VIF**
ln_stories	1.56	0.640629
ln_bedrooms	1.51	0.663440
ln_lotsize	1.40	0.713723
fullbase	1.30	0.766523
ln_bathrms	1.26	0.791675
recroom	1.22	0.818292
garagepl	1.21	0.828859
airco	1.20	0.835121
driveway	1.19	0.839165
prefarea	1.14	0.877891
gashw	1.04	0.961490
Mean VIF	1.28	

Furthermore, by deleting four severe outliers (where the studentized residuals in absolute value were higher than 3), the model also overcomes the test for the normal distribution of residuals:

Skewness/Kurtosis tests for Normality					
				------- joint ------	
Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
Residuals	542	0.1020	0.3541	3.53	0.1708