

A Disequilibrium Model of the Housing Market: Implicit Selling Time as a Signal of Optimal Holding Periods and Buyer Valuation

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Introduction

Why does the house market cycle display a higher sales volume and a shorter time on the market (TOM) from listing to sale during the price boom phase of the cycle? Houses sell quickly with selling prices high relative to asking price during a boom, but sit on the market unsold for long periods of time with selling price falling relative to asking price during the bust.

Genesove and Mayer (2001) invoke Tversky and Kahneman's (1991) prospect theory in order to explain the transactions volume asymmetry during the bust compared with the boom by loss aversion. That is, after a boom, the market values of houses fall below the prices that the current owners paid for them. Loss averse owners attempt to attenuate their losses by setting higher reservation prices that exceeds the asking prices they would have set in the absence of a loss. Consequently these houses spend a longer time on the market and also receive a higher transaction price when sold. Genesove and Mayer (2001) provide empirical evidence that substantiates the hypothesis.

Stein (1995) and Genesove and Mayer (1997) provide an alternative explanation for the house market asymmetries between boom and bust that arises from the typical seller's reliance on the proceeds from the sale of his existing house to

provide the down payment required for the next home. The owner of a property with a high loan-to-value ratio sets a higher asking price, has a longer time on the market and receives a higher price than an owner with proportionately less debt. A financially constrained seller chooses a higher reservation price in order to fund the minimum down payment required for the replacement home and to cover the transaction costs of moving house. Thus falling real estate prices bring in their wake a large increase in the inventory of unsold homes and an accompanying decline in sales volume.

Novy-Marx (2009) develops a two-sided search model with the transactions surplus split according to Nash bargaining that explains how costly search mechanisms magnify the impact of fundamental shocks. A positive demand shock brings more buyers into the market. This improves the bargaining position of sellers who then sell more quickly, decreasing the stock of sellers in the market. This further increases the relative number of buyers to sellers, amplifying the initial shock. The self-reinforcing feedback loop can be used to explain why houses can sell in a weekend in a hot market but sit for months or years in cold markets.

The analysis in the present paper proposes a parsimonious explanation for this phenomenon that requires only the minimal assumption of a distribution of valuations for potential buyers and sellers that is not directly observable by house market participants. The analysis does not seek to replace the prospect theory, credit constraint or bilateral bargaining explanations given above but rather might be regarded as a basis to which the more complex explanatory mechanisms might be added. Our approach synthesises the extreme bids analysis of Levin and Pryce (2007) with the stock market inventory adjustment models of Glosten and Harris (1988), Hasbrouk (1991), Levin and Wright (2002). The Levin and Pryce (2007) analysis is extended to incorporate the effect of extreme bids in a complete model of the housing

market rather than assuming the number of bids and the distribution of bids to be exogenous. And the stock adjustment models are developed to explain how prices and liquidity are determined when there are no market makers and where market agents cannot directly observe the inventory of unsold items (in our model, selling times act as the signal of inventory accumulation). Our approach differs from the Haurin (1988) approach by making the distribution of bids endogenous, thereby capturing the interdependent nature of selling price, time on the market, number of bids and distribution of bids.

The remainder of the paper is structured as follows. First, we set out an intuitive summary of our model using a graphical representation of Monte Carlo simulations that shows how selling prices rise with the number of bids, all other things being equal. This summary is developed in three stages: (i) we consider individual seller profit maximisation assuming static cost and price functions; (ii) we allow the cost function to become endogenous; and (iii) we allow the distribution of bids itself to become endogenous. Our heuristic summary illustrates how, in the absence of market makers, time on the market becomes a crucial signal to buyers and sellers. The second section develops the formal algebraic model which forms the basis of the empirical application in section three. We conclude in section 4 with a discussion of our results and avenues for future research.

1. Intuitive Summary of the Model

House markets operate within an institutional framework whereby the seller typically posts a list price and then waits for potential buyers to bid for the house. “Time on the market” is the time that elapses between the date that a house is placed on the market and the date when it is sold. This study seeks to explain the wide

swings in time on the market observed across house market booms and slumps using a set of disequilibrium relationships between the house sellers' profit maximising time on the market, time on the market implied by the stock of unsold houses for sale relative to the rate at which houses are being sold, and the long run equilibrium zero excess demand time on the market.

Our analysis models dynamic interactions between these variables in order to identify deviations from the unobservable equilibrium price and time on the market within a general framework that should have relevance for any non-liquid market. In liquid markets, prices are determined by marginal buyers and sellers. However, in non-liquid markets the distribution of valuations within the population of potential buyers and sellers takes centre stage, and intra-marginal valuations determine both price and time on the market.

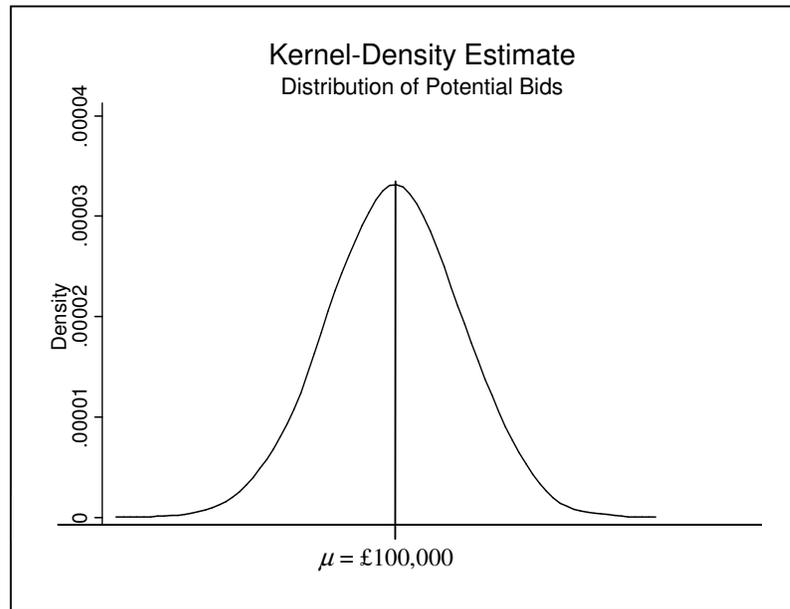
The source of the problem is that valuation varies between individuals. This is not important as long as a mechanism exists for establishing the market clearing price at which the quantity supplied is equal to the quantity demanded. For example the market clearing price for oranges is determined in the vegetable auction market by the lowest buyer's valuation and the highest seller's valuation. The market clearing price of M&S shares is likewise determined by the lowest buyer's valuation and the highest seller's valuation, not by an auction but via market-makers who stand ready to act as counter-party principals for anyone wishing to buy or sell named stocks during trading hours in return for a bid-ask spread.

Market-makers carry inventories of stocks. They interpret unexpected movements in their inventory for a given stock as "excess demand" i.e. a signal that the demand and/or supply curve has shifted and that the market is no longer clearing at the current price. They respond to unanticipated inventory movements by adjusting

their buying and selling prices until the desired inventory levels are re-established at the new market-clearing equilibrium prices. However, the market-clearing mechanism for the housing market is very different. There is no institutional mechanism that directly reveals market-clearing prices in the house market because each house is unique with respect to location and characteristics. This is the origin of the exceptionally large swings in unsold inventories of unsold houses over the cycle. The central role of the distribution of intra-marginal valuations in explaining price, time on the market and the backlog of unsold inventory is explained in three stages.

The first stage considers short run equilibrium price and time on the market using the example of a hypothetical database of 50,000 individuals' valuations for a particular type of house k , with a mean of £100,000 and standard deviation of £10,000 that represents the population of *potential* bids where the population of potential buyers and sellers know the mean and standard deviation of the valuation distribution. From this distribution of 50,000 valuations (*potential* bids for house k), depicted in Figure 1, *actual* bids are randomly drawn in time period t .

Figure 1 Distribution of Potential Bids for House k



As the number of actual bids per house sale rises, the average value of the *mean* actual bid for house *k* converges towards £100,000 (the Law of Large Numbers), but the average value of the *maximum* actual bid rises steadily with the number of bids. This relationship is illustrated by the solid line in Figure 2 which shows the how the average value of the maximum bid rises (to over £115,000 at ten bids) as a function of the number of bids for a given valuation distribution. Note that this is a purely statistical phenomenon that arises from the fact that the Law of Large Numbers applies to the sample mean but not to the sample maximum. The results plotted in Figure 2 were derived from a Monte Carlo simulation assuming: (i) sampling with replacement from a normally distributed set of 50,000 potential valuations for house *k*, (ii) that there is no strategic element to bidding and (iii) that bids, once offered, cannot be withdrawn.

Figure 2 Monte Carlo Simulation of the Effect of Number of Bids on the Average



Figure 2 also shows that the waiting cost of selling the house rises with the number of bids, represented by the linear dotted line. Waiting for an extra bid requires longer time on the market which raises the expected sale price as more potential buyers become aware of the property for sale. But increasing the holding period also raises the cost of financing and depreciation (maintenance). Diminishing returns set in for waiting for an extra bid with respect to the sale price (because of the concave shape of the maximum bid price line estimated from Monte Carlo simulations) but not with respect to costs, and this ensures a unique optimal combination of price and time on the market (P^*, T^*) that maximises the gain net of financing and maintenance costs to the seller.

The house seller's net gain is maximised at that time on the market beyond which the expected incremental gain in the expected sale price from waiting for another bid is outweighed by the incremental cost of financing and maintenance. In the example of Figure 2, based on a hypothetical normal distribution of potential

valuations with a mean of £100,000, a standard deviation of £10,000, an assumed expected wait of one month per bid, and a waiting cost of 1.5% of the expected sale price per month, the seller's net gain is maximised by setting a reservation price of £110,227 with the expectation of four bids and an optimal the holding period (time on the market) of four months ($T^* = 4$ months).

More generally, a unique expected selling price and time on the market combination (P^*, T^*) maximises profit to the seller for given values of the mean and standard deviation of the valuation distribution, the interest rate and the expected waiting time per bid.¹ The first stage of the analysis concludes that a unique time on the market T^* exists for a given coefficient of variation for the distribution of valuations and selling cost interest rate. However, this stage of the analysis is limited by the assumptions that the waiting time per bid is exogenously given and that the population of potential buyers and sellers are informed about the mean and standard deviation of the valuation distribution.

The second stage of the analysis continues with the assumption that the population of potential buyers and sellers know the mean and standard deviation of the valuation distribution but that the time per bid becomes endogenous. Time per bid (or number of bids per period) varies with the available stock of houses relative to the pressure of demand, that is, on the stock of unsold houses for sale at time t relative to the number of houses being sold per period at time t . This relationship also represents a second definition of implied time on the market ($T^\#$), calculated as the number of unsold houses for sale at time t divided by the rate at which houses are actually being

¹ A given coefficient of variation for the distribution of valuations, interest rate, and waiting time per bid is sufficient to define the profit-maximising expected time on the market T^* . We cannot prove this analytically because we have no analytical formula for the maximum bids function. However, repeated simulations provide strong empirical evidence that this is the case. For example, a valuation distribution with a mean valuation of £200,000, a standard deviation of £20,000, and an interest rate of 1.5% of the expected selling price per month also maximises the net gain to the seller with an expected

sold per period at time t . $T^\#$ is determined by the overhang of the unsold stock of houses on the market relative to the rate that houses are being sold.

The profit-maximising time on the market T^* in Figure 1 varies with $T^\#$ because the incremental cost of waiting for another bid, the slope of cost function in Figure 2, rises with waiting time per bid. $T^\#$ reflects the cumulative effect of past pricing errors on the current stock of unsold houses resulting in either a shortage or a glut of unsold properties “currently” on the market at time t . For example, a glut of properties on the market relative to the rate of sales, a high implied time on the market $T^\#$, raises the wait per bid, increases the slope of the cost per bid function in Figure 2, lowers the profit-maximising number of bids and the lowers the expected profit-maximising price P^* . It is important to note that this lower profit-maximising price also creates increases demand which eventually eliminates the excess overhang of unsold houses. This second stage of the analysis concludes that the optimal T^* depends on $T^\#$, and that any deviation between T^* and $T^\#$ at time t creates a feedback response over subsequent periods towards a long run equilibrium where $T^* = T^\#$. That is, there is a long run equilibrium value for $T^\#$ with no positive or negative excess unsold overhang, henceforth referred to as T^e .

The third stage of the analysis discontinues the assumption that the population of potential buyers and sellers know the mean and standard deviation of the valuation distribution. Potential buyers and sellers cannot directly observe the distribution of valuations. They resolve the problem of unobservable shifts in the distribution of valuations over time by interpreting observable systematic deviations between actual and expected times on the market as indicating shifts in the distribution of valuations. For example, if the unsold stock of houses rises relative to the rate of house sales, this

TOM of T^* equal to four months waiting for four bids, because the coefficient of variation is the same as the earlier example.

rise in $T^\#$ is regarded as evidence that the distribution of valuations has shifted to the left. $T^\#$ information provides estate agents and property valuers with indirect knowledge about change in the valuation distribution over time. Shortening (lengthening) waiting time per bid reveals a shrinking (growing) overhang of unsold houses for sale, implying excess demand (negative excess demand) at current seller reservation prices.

A third definition of time on the market, that is in addition to T^* and $T^\#$, refers to the unobservable long run equilibrium time on the market (T^e) for which there is a corresponding zero excess demand price (P^e). The house market is typically observed during periods of positive or negative excess demand with dynamic relationships between P^*T^* , $P^\#T^\#$ and P^eT^e . When the market is not in long run equilibrium, these dynamic feedback processes adjust the implied time on the market $T^\#$ and the profit maximising time on the market T^* over subsequent periods. Absent external shocks, this process leads to a long run zero excess demand equilibrium time on the market T^e that is equal to the profit maximising time on the market with $T^*=T^\#=T^e$. However, long run equilibrium is never attained because the zero-excess demand price itself changes over time.

The three stages of the analysis are integrated into a model that examines the processes by which the time that a house is on the market for sale both determines and is determined by its selling price. In this model, the observable transaction price maximises expected gain to the seller but this need not correspond to the long run market-clearing zero excess demand price (P^e). The model incorporates dynamic causal feedbacks between T^* the profit maximising time on the market, $T^\#$ the implied time on the market and T^e the long run zero excess demand market-clearing time on the market and their corresponding prices. The dynamic system explains why time on

the market shortens as house prices rise during boom periods of the house price cycle, and lengthens as house prices fall during house market slumps. This house market model could be applied to any illiquid durables market that involves waiting, for example, the market for second-hand cars but would not apply to a liquid market such as a stock market in which market-makers stand ready to provide immediacy by acting as counterparties for buyers and sellers in return for a bid-ask spread.

2. The model

Levin and Pryce (2007) note that the phenomenon of extreme bids observed during house price booms is an inevitable statistical outcome of multiple bids that occur during periods of high demand². A normal distribution $N(\mu, \sigma)$ of valuations for a representative house implies that the expected sale price is the mean of the maximum bid, which rises at a decreasing rate with the number of bids. As the number of bids per auction rises, the average value of the mean bid tends to μ , but the average value of the maximum bid rises with the number of bids. That is,

$$P = f(B, \mu, \sigma), \quad \frac{\partial P}{\partial B} > 0, \quad \frac{\partial^2 P}{\partial B^2} < 0 \quad (1)$$

where P is the price at which the house is sold, B is the number of bids, μ is the mean and σ is the standard deviation of the valuation distribution.

The number of bids and selling time are in fact connected. The number of bids for a house is, by definition, the time that the house is on the market divided by the average time interval between bids,

$$B = \frac{T}{\tau}, \quad (2)$$

where T is the time on the market and τ is the time interval between bids. (If bids are submitted in rapid succession, τ will be small, whereas if there are long time lapses between the submission of bids for house k , then τ will be large.) Substituting (2) into (1) gives selling price entirely as a function of time on the market, time lapse between bids, and the mean and variance of the distribution of potential bids:

$$P = f\left(\frac{T}{\tau}, \mu, \sigma\right), \quad \frac{\partial P}{\partial T} > 0, \quad \frac{\partial^2 P}{\partial T^2} < 0 \quad (3)$$

The cost of keeping a house on the market C includes maintenance (or depreciation) and a financing cost for the length of time that the house lies on the market. This can be expressed as:

$$C = g(T), \quad \frac{\partial C}{\partial T} > 0 \quad (4)$$

Short Run Equilibrium

The seller's profit π is the sale price minus the costs of T . That is,

$$\pi = P - C \quad (5)$$

² That analysis did not, however, explain what determines the number of bids.

The seller's profit at time t is maximised by substituting (3) and (4) into (5), giving

$$\pi_t = f\left(\frac{T_t}{\tau_t}, \mu_t, \sigma_t\right) - g(T_t) \quad (6)$$

which is the algebraic expression of Figure 2. The profit maximising equilibrium price P_t^* and time on the market T_t^* at time t is given by differentiating π with respect to T , setting this expression equal to zero, solving for T^* , and substituting this value into (3) to solve for P_t^* . The equilibrium values P_t^* and T_t^* for any given μ and σ depend on the particular value for τ ruling at time t . The waiting time per bid in turn depends on whether the house market is in a boom or a slump at time t . That is, τ_t depends on the state of the house market at time t .

Long Run Equilibrium

The house market is in long run equilibrium at the zero excess demand price (P^e) and time on the market (T^e). However, this long run equilibrium state (P^e, T^e) is unobservable. House markets are seldom in long run equilibrium. Prices and time on the market are typically in a disequilibrium state of positive or negative excess demand. There are two dynamic processes that generate continuous adjustments between long run equilibrium and observed price and time on the market.

The first process is caused by a legacy deficit or surplus of unsold houses for sale caused by past pricing errors. At any given time there is a shortage (glut) of unsold houses for sale on the market relative to the rate at which they are being sold, caused by historical prices having been set too low (high). A shortage of unsold

houses on the market causes time per bid, τ , to fall, which causes the observable profit maximising price P^* to rise. This same unsold inventory correction process would likewise help eliminate any legacy overhang of excess unsold houses effect of past pricing errors (this is analogous to the stock market inventory adjustment process described in Glosten and Harris (1988), Hasbrouk (1991), and Levin and Wright (2002) except that it operates without a market maker).

The second process concerns the mean of the valuation distribution μ in (1) changing over time. That is, the zero excess demand market clearing price itself changes over time as circumstances change. In some cases the new circumstances that raise the zero excess demand market clearing price are public knowledge; both buyers and sellers revise their house price valuations without any impact on the stock of unsold houses for sale. In other cases, when the new circumstances are not known to everybody, informed trading impacts on the unsold stock of houses for sale. Once again this alters time per bid, τ , the profit maximising price P^* , and this causes an *ex post* revision of house price valuations towards the new long run equilibrium T^e, P^e .

These relationships may be described more formally. The time interval between the receipt of bids, τ_t , depends on the state of the house market at time t . The state of the house market can be expressed as the ratio of unsold house to house sales $\frac{H_t}{S_t}$ where H_t is the number of unsold houses on the market for sale at time t , and S_t is the sales rate at time t expressed as the number of house sold during the most recent period. The state of the house market at time t by definition implies an average time on the market, $T_t^\#$:

$$T_t^\# = \frac{H_t}{S_t}, \quad (7)$$

The distinction between T^* and the implicit time on the market $T^\#$ is that T^* is a decision variable whereas $T^\#$ is a state variable. T^* can be altered by a decision to sell at a higher or lower price. $T^\#$ expresses the existing state of the house market as the relationship between the number of houses for sale and the rate at which houses have been selling.

Crucially, these variables are not independent, however. There is a dynamic relationship between T^* , $T^\#$ and T^e . Time per bid τ_i depends on the number of houses on the market for sale relative to the rate at which houses are selling. That is,

$$\tau_i = f(T_i^\#) \quad \frac{\partial \tau}{\partial T^\#} > 0 \quad (8)$$

Substituting (8) into (6), the profit maximising seller price P^* rises when $T^\#$ is low.

That is,

$$P^* = f(T^\#), \quad \frac{\partial P^*}{\partial T^\#} < 0 \quad (9)$$

$T^\# < T^e$ implies a shortage of houses on the market for sale relative to the rate at which houses are currently being sold. This shortage may either be caused by past prices being too low, or because of informed trading when the zero excess demand price rose without public knowledge. In either case the low inventory of unsold houses reduces $T^\#$, which lowers the time per bid τ , which in turn raises the seller's profit maximising selling price P^* . The perception of low $T^\#$ feeds back to raise the distribution of valuations, and this in turn raises $T^\#$ by increasing the number of new

houses coming on the market and reducing the number of houses being sold. In the absence of any further disturbance, this dynamic process continues until there is convergence of selling times and prices towards their long run house market equilibrium values: $T^* = T^\# = T^e$, and $P^* = P^\# = P^e$.

3. Empirical Model

An empirical model is developed to explore these dynamic relationships between time on the market and house prices. This model is based on the assumption that observable implied time on the market (stock of houses for sale to monthly sales ratio) provides a signal to house market participants of excess demand caused by informed trading that the demand and/or supply curve has shifted and that the market is not clearing at the current price. House market participants adjust their perception of the zero excess demand price in response to unanticipated observed excess demand.

The observed selling price for a representative house at the beginning of period t , P_t^* , consists of two components. The first component, P_t^e , is the perceived zero excess demand selling price in that area. The second component, θ_t , is an adjustment caused by sellers adjusting their profit maximising P^*T^* to take advantage of deviations in observed $T^\#$ from the optimal T^e caused by past pricing errors. That is:

$$P_t^* = P_t^e + \theta(T_t^\# - T^e) \quad (10)$$

The price adjustment term $\theta(T_t^\# - T^e)$ shows the seller's response to a glut or shortage of unsold houses on the market, the deviation of the unsold houses overhang ratio $T^\#$ at time t from the long run equilibrium T^e . This adjustment occurs during booms

or slumps that make it profitable for sellers to adjust the profit-maximising time waiting for bids by raising or lowering their reservation price above or below the zero excess demand price. This is revealed by the deviation between the actual $T^\#$ and long run T^e at time t , and θ that shows $\frac{\Delta P^*}{\Delta T^\#}$, the change in the seller's profit maximising price for a change in the unsold houses overhang ratio $T^\#$. T^e is the long run optimal time on the market; $T_t^\#$ is implied time on the market at the beginning of period t ; θ shows $\frac{\Delta P^*}{\Delta T^\#}$ as sellers raise price to take advantage of a shortage of houses on the market caused by past pricing errors.

The valuation distribution μ in (1) also changes over time. Changes in the zero excess demand price P^e over time consists of two components. The first component is publicly available new information that alters expectations about future house prices. The second component is the perception of new private information. Private information is defined as information that is known to informed market participants but is not generally available to sellers and estate agents. Estate agents cannot directly observe the private information component, but they are able to observe its effect on unanticipated movements in $T_t^\#$. More formally:

$$P_t^e = P_{t-1}^e + \eta(T_t^\# - T^e) + \varepsilon_t \quad (11)$$

where: $\eta(T_t^\# - T^e)$ is the change in the zero excess demand price between the beginning of period $t-1$ and the beginning of period t attributable to private information; and ε_t is the shift in the zero excess demand market price attributable to public news incorporated into the price since the last period.

Private information causes an unexpected shift in the demand for houses that is initially observed as an unexpected change in $T_t^\#$ the current price. Sellers, guided by estate agents, attribute the deviation in $T_t^\#$ from T^e as unanticipated excess demand caused by the activities of informed buyers and sellers. Buyers, sellers and estate agents respond to observable deviation of $T_t^\#$ from T^e by adjusting their perception of the zero excess demand price at time t by an amount equal to the product of the observed unanticipated excess demand and the slope of the excess demand curve required to eliminate it. Therefore, the change in price necessary to eliminate the deviation between $T_t^\#$ and T^e defines the slope of the excess demand curve $\eta = dP/dT^\#$ facing sellers.

Substituting (11) into (10) gives:

$$P_t^* = P_{t-1}^e + \eta(T_t^\# - T^e) + \theta(T_t^\# - T^e) + \varepsilon_t \quad (12)$$

The unobservable zero excess demand price, P_{t-1}^e , can be eliminated by subtracting (10) lagged one period from (12) which gives the first difference of the observed price, P_t^* :

$$P_t^* - P_{t-1}^* = P_{t-1}^e + \eta(T_t^\# - T^e) + \theta(T_t^\# - T^e) + \varepsilon_t - P_{t-1}^e - \theta(T_{t-1}^\# - T^e) \quad (13)$$

which eliminates P_{t-1}^e from the equation.

Equation (13) can be written as a regression equation of the form:

$$P_t^* - P_{t-1}^* = a + bT_t^\# + cT_{t-1}^\# + \mu_t \quad (14)$$

where :

$$\begin{aligned} a &= -\eta T^e \\ b &= \eta + \theta \\ c &= -\theta \end{aligned} \tag{15}$$

and μ is a well-behaved error term. The estimates of the parameters a , b and c can be used to derive estimates of η , θ and T^e by solving these three equations for the unknowns. The parameter estimate of " c " = $-\theta = \frac{-\partial P^*}{\partial T^\#}$ summarises the change in price for a deviation in $T_t^\#$ from the long run equilibrium T^e that maximises the seller's profit.

One way to interpret the method applied here is as an application of Indirect Least Squares, a well-established way of dealing with a system of endogenous variables (see Maddala 1992 p.358-360 for a discussion of the method in general). The method involves substituting the simultaneous equations into each other in order to arrive at the reduced form, which can then be directly estimated in a single regression. The coefficients of the reduced form relate to combinations of the parameters of the original simultaneous equations. Because some of the original parameters can contribute to more than one of the estimated reduced form coefficients, it is often difficult to disentangle the different effects, leading to the *identification problem* and the need for an econometric alternative to Indirect Least Squares (such as Two Stage Least Squares -- Maddala 1992 p.373). However, sometimes, an algebraic solution can be found that allows the researcher to make sense of the estimated reduced form coefficients, or at least the ones of greatest interest, so that estimation of the reduced form is all that is required. This is what we have achieved by transforming equations (10) and (11) into (14) and (15). (See

Malpezzi and Maclennan 2001 for an example of an Indirect Least Squares algebraic approach to the demand for and supply of housing).

Data

The source of our house price and selling time data was The Glasgow Solicitors Property Centre (GSPC), a consortium of estate agents in the Strathclyde region of Scotland for the period 1999–2007. GSPC data have been used in a number of published studies (Pryce and Gibb 2007; Pryce and Oates 2008) and, by UK standards at least, is a relatively clean and detailed geo-coded dataset. We attempt to control for sales heterogeneity by measuring house prices as the average price per room for properties sold on the second Thursday of each month. However we are unable to control for stock heterogeneity. This represents a potential weakness for the analysis if stock heterogeneity is not a random error and varies systematically over time.

Table 1 Data Summary

	$T^{\#} = H_t / S_t$	Price per room
Mean	2.29	£25,868
Standard deviation	1.18	£8,933
Number of months	105	107

Monthly Change in House Prices

The monthly change in price is calculated as $(avP_t - avP_{t-1})/avP_{t-1}$ where avP_t is the average GSPC sale price per room over the last three months.

Time on the Market $T^\#$

GSPC also provided sales per month and the number of unsold houses for sale on the second Thursday of each month between 1999 and 2007. $T^\#$ for each month was calculated using equation (7) as the average number of unsold houses for sale divided by the number of sales over the last three months.

Results

The regression estimation equation differs from (14). The dependent variable was expressed as a proportional change rather than an absolute change in order to eliminate bias caused by effects of inflation over the sample period, and moving average error correction terms were added. The parameters of interest in (14) were estimated by fitting the following model for the monthly data set 1999:2 to 2007:11

$$\frac{P_t^* - P_{t-1}^*}{P_{t-1}^*} = a + b \cdot T_t^\# + c \cdot T_{t-1}^\# + d \cdot MA(1) + e \cdot MA(2) + f \cdot MA(3) + \varepsilon_{it} \quad (16)$$

where $\frac{P_t^* - P_{t-1}^*}{P_{t-1}^*}$ is the growth in the price of houses in Glasgow in month t , a is a constant, $MA()$ are moving average terms and ε_{it} is a random error term. The estimates of (16) are shown in Table 2.

Table 2**House Price Growth - Model Estimates**

Model	House price growth (quarterly)	
	Parameter	t-Statistic
Constant	0.016846	2.7
T_t[#]	-0.023950	4.4
T_{t-1}[#]	0.020426	4.1
MA(1)	0.654227	6.8
MA(2)	0.640025	6.7
MA(3)	-0.336913	3.5
N. Observations	103	
R²	0.64	
DW	2.02	
LM	4.13	[p=0.02]
ARCH LM	0.73	[p=0.73]
White	0.32	[p=0.32]
Ramsay Reset Test	1.51	[p=0.23]

Substituting the estimated parameter values into (15) gives

$$\theta = -c = -0.020426$$

θ measures the price response to the unsold houses overhang that occur during booms or slumps that make it profitable for sellers to adjust the profit-maximising time waiting for bids by raising or lowering their reservation price above or below the zero excess demand price. The profit maximising price P^* is 2% higher when the unsold houses for sales to sales ratio falls by unity. The empirical specification of the regression equation contains the assumption of a constant percentage change in price for a unit fall in the ratio of unsold houses to sales. We tried a number of alternative functional specifications of the model but these were unable to detect statistically significant deviations from this assumption when the ratio of unsold houses to sales takes extreme values during periods of apparent market frenzy or despair.

Turning to the excess demand price adjustment, η defines the slope of the long run excess demand curve $dP^e/d T^\#$.

$$b = \eta + \theta = -0.023950$$

$$\therefore \eta = -0.023950 + 0.020426 = -0.00352$$

A third of one percent price rise is required to eliminate excess demand when the implied time on the market (ratio of unsold houses for sale to sales) shortens by unity, for example from the sample mean of 2.3 months to 1.3.

Turning to the long run equilibrium level of $T_i^\#$, the constant term in Table 2 can be substituted into (15) to give

$$a = -\eta \cdot T^e = 0.016846$$

$$\therefore T^e = \frac{0.016846}{0.00352} = 4.8$$

That is, the estimated unobservable long run equilibrium implied time on the market T^e is 4.8 months.

We carried out a number of tests in order to evaluate the suitability of the specification. These test include 1) the Durban-Watson Statistic; 2) a Lagrange multiplier test of residual correlation (see Godfrey 1978a, 1978b); 3) the ARCH LM Test (see Engle, (1982); 4) White's (1980) Heteroskedasticity Test; 5) the Ramsey (1969) RESET test of functional form misspecification. The Durban-Watson Statistic, ARCH LM test, White's Heteroskedasticity Test and the Ramsey RESET correlations were not significant at the five per cent level. However, the Lagrange multiplier test for serial correlation was significant at the five per cent level. The problem here is likely associated with the practical point that the theory cannot provide any basis for deciding the real time it takes for the perception of the distribution of valuations to alter in response to deviations in T^e . This is an empirical matter that warrants further investigation.

4. Discussion

The underlying theme of our model is that the implicit time on the market, $T^\#$, defined as the overhang of unsold houses relative to the rate at which houses are selling, triggers two processes. First, it is used by sellers to gauge how long they should hold out for a better price. Second, $T^\#$ is used by prospective buyers and sellers to adjust their perception of the distribution of valuations (potential bids). The empirical analysis attempted to decompose a time series of house price changes into components that co-exist in dynamic equilibrium. There are two advantages to this approach. First, it should be possible to derive the unobservable equilibrium prices and equilibrium time on the market. The estimates for T^e and θ can be substituted into

(10) for each period to calculate the estimated deviation between the current actual price and the current equilibrium price P^e_t . Second, the parameter estimates of equation (16) shown in Table 2 can be used to calculate a forecast for the next month.

Our simple model of the housing market endogenises movements in selling times, sale prices and the frequency and number of bids. We have demonstrated that complex market adjustments can occur even when the bidding process is assumed to be a simple random statistical draw from a normal distribution of valuations – that is, without strategic bidding, prospect theory or leverage constraints.

The model is intended to capture an essential characteristic of housing markets: that prices and quantities adjust through two inventory adjustment processes driven by movements in excess demand that operate in the absence of a market maker. Supply and demand are not modelled separately because the focus is on excess demand. In the absence of private information there would never be excess demand – prices would simply move in response to new publicly available information without any build-up or run-down of the number of unsold houses for sale. However, the model recognises that private information can create positive or negative excess demand. The valuation distribution may shift in response to private information unknown to either buyers or sellers. The paper models how excess demand caused by private information is revealed by movement in the number of unsold houses on the market relative to the rate at which houses are selling ($T^{\#}$).

How does the model presented in the analysis relate to the extensive housing literature on reservation prices? In the model the seller posts a non-negotiable price and waits for the optimal number of buyer bids drawn from the valuation distribution. These bids lie on the table for the seller's profit-maximising time on the market until the house is sold. The transaction price is the buyer's reservation price. Accordingly,

any surplus between the buyer's reservation price (the maximum price above which the buyer would not buy) and the seller's reservation price (the minimum price below which the seller would not sell) accrues to the seller.

This tautological conclusion is however unlikely to hold true for actual house markets. Arnold (1999) shows how sellers may manipulate list prices as the first step in a bargaining game in order to strengthen their position in order to secure a larger share of the surplus represented by the gap between buyer and seller reservation prices. Sirmans, Turnbull and Dombrow (1995) suggest that principle-agent incentive incompatibility could encourage estate agents to persuade sellers to accept suboptimal offers. Wilhelmsson (2008) notes the importance of failed bids on reservation prices, finding that repeated bidding-and-losing households increase their reservation price and pay a higher overall price compared to other households. Wang and Zions (2008) invoke the principle of opportunity cost in order to analyze the impact of negotiation on reservation prices. A negotiator considers the party's best alternative to a negotiated agreement which provides a reference point that may be used to determine a reservation price for other alternatives.

The seller's reservation price of a house may be influenced by liquidity constraints (Stein, 1995; Ortalo-Magne and Rady, 2006), loan to value ratios (Lamont and Stein, 1999; Genesove and Mayer, 1997) and loss aversion (Engelhardt, 2003; Genesove and Mayer; 2001). Herrin, Knight and Sirmans (2004) and Huang and Palmquist (2001) provide empirical evidence of a negative impact of market duration on reservation prices for disaggregated house sales data, which indicates an updating process during the market process for reservation prices. Glower, Haurin, and Hendershott (1998) explain how seller motivation may generate seller reservation

price heterogeneity. For example, sellers who already have planned dates to move at the time of listing, sell more quickly than those who do not.

The model presented in our analysis could be extended to include many of these features. For example, the cost of waiting function in Figure 2 would have a steeper slope for sellers who already have already purchased their next house and have a planned date to move (see Glower, Haurin, and Hendershott (1998). The continuous updating process expressed by Herrin, Knight and Sirmans (2004) and Huang and Palmquist (2001) is consistent with the model presented where the time between observations is shortened to express the actual perception lag. Liquidity constraints (Stein, 1995; Ortalo-Magne and Rady, 2006), loan to value ratios (Lamont and Stein, 1999; Genesove and Mayer, 1997) and loss aversion (Engelhardt, 2003; Genesove and Mayer; 2001) provide explanations for why valuation distributions shift over time. However, the model does not attempt to explain why the distribution of valuations shift over time, but rather how these shifts in the distribution of valuations are transmitted to the market.

Wilhelmsson's (2008) finding that repeated bidding-and-losing households are more willing to increase their reservation price and pay a higher overall price compared to other households, and Wang and Zions (2008) use of the principle of opportunity cost in the determination of reservation prices are, absent negotiation, consistent with the foregone alternative optimizing principle of our model, expressed in Figure 2 and the subsequent equations that explain how these functions shift. However, our model does not recognize Sirmans, Turnbull and Dombrow (1995) the problem of principle-agent incentive incompatibility.

his model, therefore, provides a simple basis on which to explore the effects of loss aversion, credit rationing, bargaining, and a large number of other complex

phenomena. An obvious extension of the model would be to consider the impact of time-limited bids. The model presented assumes that bids arrive as time elapses, more bids are sitting on the table as more time elapses, and all bids sit on the table until the seller accepts a bid. In reality, buyers would be unwilling to wait forever to discover whether their offer is the winning bid. This complicates the profit function for sellers because waiting incurs the additional risk that existing offers will be withdrawn. It also affects the way in which the maximum “live” bid corresponds to the total number of bids received so far: if bids are perishable then the bidding process amounts to taking repeated small samples of bids (because the initial round of bids left will be withdrawn) rather than an a single, cumulative sample.

Also, we have not modelled the search behaviour of buyers – they face a similar “perishable goods” problem because properties may leave the market before they have had the chance to view them, and viewed properties may sell before they have had chance to bid on them. So the relationship between the rate at which bids are offered on a particular property, and the number properties entering and leaving the market in a given period, may be complex because the time per bid will be partly driven by the search process. There may, for example, be a physical limit on the number of properties a buyer can view in a given period, implying a non-linear relationship between time per bid for a given house and the state of the market. Another clear extension would be to allow for strategic bidding – buyers do not necessarily offer their reservation price for a dwelling but take into account the likely maximum bid from other bidders given the state of the market.

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