Why Do Sellers Hold Out in the Housing Market? An Option-based Explanation

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Abstract

In the residential housing market, home owners are reluctant to sell in a declining market. We build a model which focuses on the embedded call option associated with home ownership that allows owners to delay the (irreversible) sale. When prices are low, the (opportunity) cost of a sale, i.e., a higher implied gain from a future sale, likely exceeds its immediate trade benefit and an owner is better off waiting for market conditions to improve. The model also highlights the importance of supply conditions: a more constrained supply is associated with a longer delay. Using state-level residential housing data, we find evidence consistent with the model. Transaction volume is increasing (decreasing) in the rental growth rate (volatility) in the cross section; their effects are amplified in areas with low supply elasticities, and in times with low market prices. Overall, this paper provides a rational explanation for delayed trading decisions in the housing market.

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1 Introduction

One puzzle in the residential housing market is that owners are reluctant to sell and trading volume is persistently low in a declining market. Existing research has focused on the role of credit market frictions, search costs or sellers’ loss aversion. There is yet another possibility for home owners’ delayed trading decisions. In Case and Shiller (1988)’s survey paper, 70% of the survey respondents in California, and 50% in Boston and Milwaukee, agreed to the statement that the best strategy in a soft market is to “hold on until you get what you want”. One popular interpretation is households’ cognitive bias such as over-optimism or extrapolation based on past information (Lakonishok et al., 1994), given the fact that the U.S. housing price in general has seen an upward trend for the past fifty years.

The objective of this paper is to offer one rational explanation of the “hold-out” phenomenon. Home ownership has an embedded resale (call) option which allows owners to choose the optimal timing of sale. We build a continuous-time model with infinitely-lived risk neutral agents. We show that the decision of sale timing is an optimal stopping problem for owners, which is a function of economic fundamentals as well as the prevalent bargaining powers between trade parties. The benefit associated with waiting (or the opportunity cost of an immediate sale) is a higher price and greater gain from trade from a future transaction. When the current price is low, there is a greater probability that the benefit of an immediate sale is smaller than the opportunity cost, causing potential sellers to delay. Our study thus complements the literature by focusing on discretionary sale timing and rational incentives to delay trading decisions in a context with few market frictions.¹ Furthermore, the model in this paper predicts that transaction volume is a

¹In the 2005 American Housing Survey, for the question on the moving reason, about 10% of the respondents that have moved within the last year quoted “new job or job transfer” as the reason. Another 8% of the respondents reported reasons that are likely to require immediate move, which include private or government displacement, eviction and change in marital status. On the other hand, 8.5% of respondents moved because they wanted to be “closer to school or work” and another 18% of respondents either “needed larger house” or “wanted better home”. This suggests that the mobility decision can be discretionary instead of exogenously and randomly determined. There is also empirical evidence showing
function of the housing market fundamentals, facilitating direct empirical tests. Using a comprehensive national dataset, we find evidence consistent with our option-based explanation.

Agents in our model are characterized by intrinsic housing preference types. Demand for owner-occupied housing is a function of demographic characteristics such as age and marital status. The housing demand types are defined by a random shock upon which agents are motivated to move and become potential buyers and sellers. A potential seller’s reservation price is the total cost of an immediate sale, which is the sum of a fixed monetary transaction cost and the opportunity cost. A potential buyer’s reservation price consists of two components. One is the imputed rental cost she needs to pay during her duration of stay in the house. In the event she needs to move and sell the house, the agent becomes a potential seller and has a reservation price equal to the sum of the transaction cost and the option value of waiting. Thus, the total gain from trade (or total trade surplus), defined as the difference between potential seller’s and buyer’s reservation price, is a function of the imputed rent in the housing market and time-varying. The sharing rule, and thus the transaction price, is determined by a bilateral bargaining game as in Rubinstein and Wolinsky (1985). If the potential seller decides to sell and upon a buyer and seller match, the total trade gain is split according to the relative bargaining power that is based on the population size of the buyer and the seller group.2

Given the pricing rule and the rent process, then the decision on the sale timing becomes an optimal stopping problem for the potential seller by comparing the benefit of waiting versus that of an immediate trade. We obtain a closed-form solution for the resale option value. There is a critical level of the underlying rent such that potential sellers will exercise their resale option only if the market rent is above this threshold.

that residential mobility depends on the local housing market and labor market conditions (Gabriel et al., 1993).

2In order to abstract away from other factors known to affect transaction volume (Stein, 1995; Krainer, 2001), we assume no credit constraints or search frictions, and market clearing occurs immediately once a seller is matched to a buyer after she decides to sell.
Since the equilibrium transaction price is monotonic in rent, there will be an equivalent price threshold below which the gain from an immediate sale is not sufficient enough to offset the value associated with further waiting. In the down market, there is a greater probability that the price is below the optimal option exercise threshold. As a result, owners hold on to their homes and wait until the market conditions improve, leading to a decrease in the trading volume. This key implication is robust when we relax the assumptions of homogeneous buyer or seller type and exogenous market entry.

It is of interest to highlight the role of supply conditions in the resale option exercise. Specifically, we consider a special case where land supply can be competitively added. The added supply will affect the potential seller’s relative bargaining power and her incentive to delay. We show that the option effect on sale delay is smaller compared to the case where no new construction is allowed. Intuitively, as new supply is added, price growth rate is dampened and existing home owners also expect to extract less of the total trade gain due to a lower bargaining power, leading to a reduced incentive to wait.

In the model, the equilibrium transaction price and thus owners’ decisions whether to sell now or later are functions of the prevailing market rent. As a result, we are able to associate the agents’ trading behavior as well as the aggregate trading dynamics with the market fundamentals and directly test the model’s implications. The option exercise threshold (in terms of market rent) in our model defines the no-trade region. A higher threshold implies a larger no-trade region, so on average potential sellers delay their sale, which implies fewer transactions, and vice versa. The comparative statics of the trade threshold give us rich and testable implications. This paper focuses on the following three hypotheses. First, our model predicts that the exercise threshold (volume) is decreasing (increasing) in the rental growth rate and is increasing (decreasing) in the rental volatility. Second, transaction volume increases (decreases) in the rental growth rate (volatility) at a faster rate if supply is more inelastic. Third, the option effect on sale delay is stronger when the market rent and the house price are low and the no-trade threshold is more
Using state-level panel data in the US from 1989 to 2000, we find strong support for our model. Transaction volume is increasing (decreasing) in the expected growth rate (volatility) of the rental market, after we control for other possible determinants of volume, as well as year and state fixed effects. For example, a one percentage increase in the rental cap rate—a measure that is inversely related to the expected rental growth rate—predicts a statistically and economically significant decrease in transaction volume by approximately 4%. Since the the rental growth rate implied in the cap rate is a forward measure, our results are more consistent with the view that agents’ trading decisions are based on their forward looking rather than extrapolating behavior. Supply conditions affect the option value of waiting. Using population density as a proxy for supply elasticity, we find a 10% increase in population density would further reduce the sales volume by approximately 3% if either the cap rate or the volatility increases by one percentage point. Furthermore, the effects of rental growth rate and volatility are mostly driven by areas with low supply elasticity. This evidence thus highlights the importance of supply conditions in understanding the housing market dynamics, as previous research (Glaeser et al., 2008; Gyourko, 2009) suggests. Lastly, having a lower rental growth rate or a higher rental volatility is associated with a lower transaction volume especially in a sluggish housing market. This further corroborates the model’s prediction that agents’ reluctance to sell is driven by the optimal timing decision when the current market conditions are bad.

Broadly, this paper contributes to the literature on the housing market’s transaction dynamics by providing a rational explanation for depressed trading activity in down markets. The paper closest to ours is by Cauley and Pavlov (2002), which also considers an embedded resale option in explaining highly levered sellers’ rational decision to delay trade. The option value of waiting in their model is driven by home owners’ high leverage after a negative demand shock. Moreover, their focus is to estimate the option
premium associated with (levered) home ownership. In this paper, we assume no leverage and model the interaction between buyers and sellers. Combined with their result, our empirical evidence supports the view on an option-based explanation and suggests that the option effect on trading volume is likely to be amplified in the presence of leverage.

Another rational explanation that emphasizes optimal waiting studies time varying search costs in the market clearing process. The search literature in the housing context starts from the seminal paper by Wheaton (1990) and recent contributions take into account the irreversibility of trading decisions in the sense of a forgone opportunity to search for a better match (Williams, 1995; Krainer, 2001; Krainer and LeRoy, 2002; Novy Marx, 2009). Conditional on the trading decision, Krainer (2001) argues that the opportunity cost of further searching is low in the bad state so people tend to search longer for a better match, leading to a longer time-on-the-market and fewer trades at such times. Novy Marx (2009) builds a model to study time-on-the-market where the option value of waiting in the search process is driven by the relative bargaining power implied by a dynamic buyer-seller ratio.

Other explanations include constrained mobility due to leverage effects or sellers’ loss aversion. Stein (1995) and Ortalo-Magné and Rady (2006) argue that borrowing constraints as a result of credit market frictions restrict borrowers’ demand for housing in down markets. In support of the theory, Lamont and Stein (1999) find that house prices are more sensitive to macro shocks when investors are highly levered (and thus are more likely to be subject to borrowing constraints). Genesove and Mayer (1997) find, using data on the Boston condo transactions, that sellers with high leverage tend to experience longer time on the market. A recent paper by Ferreira et al. (2010) shows that negative equity substantially lowers mobility rates. Motivated by the prospect theory by Kahneman and Tversky (1979), Genesove and Mayer (2001) and Engelhardt (2003) test and find evidence consistent with the notion that sellers are unwilling to recognize reality and refuse to sell at low prices.
Our work is also related to the real options literature. In the context of the real estate market, research has extensively studied its implication on real estate development. In a seminal paper, Titman (1985) analyzes the value of land prices by incorporating the option to delay development. Later extensions incorporate the strategic exercise behavior (of real estate developers) and derive equilibrium implications for development and real estate cycles (Williams, 1993; Grenadier, 1996). Quigg (1993) empirically shows that the option of waiting is priced using land transaction data in Seattle. Capozza and Helsley (1990) model land conversion as an option and study its impact on urban growth. We model the option to delay trade in the investment decision faced by a household. While the previous literature focuses on the more sophisticated agents, our empirical findings suggest that individual households are also able to make optimal investment decisions taking into account of the option value of waiting.

The rest of the paper is organized as follows. Section 2 constructs the model and discusses its solution. First we study a model with fixed housing supply. Then we introduce a competitive developer industry which could add supply to maximize profits. We also study the model robustness by relaxing the assumptions of homogeneous buyer and seller group as well as exogenous market entry. Section 3 tests the model using the aggregate housing data. Section 4 concludes.

2 The Model

2.1 Benchmark Model

First we study a simple economy with exogenous market entry and fixed housing supply. In particular, there are $N$ units of owner-occupied houses and $N_r$ units of rental housing in the economy. Houses are identical, indivisible and we restrict one household to consume one unit of housing. Agents are risk neutral and long lived in our model. There is
an exogenous inflow and outflow of renters in the economy. This is to capture the life cycle feature that young people enter the economy on average as net renters (and are ready to move up the property ladder) and old people die and exit the economy also as net renters after selling their houses. Home buyers or owners do not enter or exit the economy directly. Buyers are current renters who wish to move to owner-occupied houses and current home owners will sell the house and move back to the rental market before they exit the economy. There are no repeat buyers who are at the same time sellers in the benchmark model. We further assume that in the steady state, the outflow from the rental market equals the inflow into the rental market, leading to a constant population in the economy. There are N owners and \( N_r \) renters in the economy, which implies the total population size to be \( N + N_r \). In addition, after a successful transaction, the seller becomes a renter while the buyer (renter) becomes an owner, leaving the size of the renter \( (N_r) \) and owner \( (N) \) pools constant.

We model agents’ housing preference types as driven by random shocks. With probability \( \eta (\eta_r) \), owners (renters) lose their match with their current dwellings and become potential sellers (buyers). We assume \( \eta < \eta_r \), which implies that renters’ incentive to become owners is stronger than current home owners’ incentive to move down. This (exogenous ordering of preference) can be interpreted by the notion that people prefer home ownership. For example, it maybe related to psychological preference towards home ownership compared with renting. Therefore, at a given point in time, the average number of potential buyers relative to potential sellers on the market is a constant \( \rho \), where,

\[
\rho = \frac{N_r \eta_r}{N \eta}
\]

The paper adopts a partial equilibrium approach by assuming an exogenously defined rent process\(^3\) and endogenously derive the equilibrium transaction price. The market

\(^3\)The partial equilibrium modeling approach has been used extensively in the literature (Krainer, 2001; Cauley and Pavlov, 2002). Although a general equilibrium model allows more realistic features such as endogenous rental market supply response, it significantly complicates the analysis without additional
rent per unit of housing \((Y_t)\) is characterized by a geometric Brownian motion\(^4\). Given the assumption of a constant renter population size, one can thus view the exogenously defined rent process as driven by macroeconomic conditions in the economy. There are no frictions in the rental market.

\[
dY = \mu Y dt + \sigma Y d\omega_t
\]  

\(\omega_t\) is the standard Brownian motion and \(\mu\) and \(\sigma\) are the respective drift and volatility parameters of the process and are assumed to be constant. In order to prevent infinite prices, we require \(\mu < r\) where \(r\) is the constant risk free interest rate.

**Lemma 1.** Agents are risk neutral and infinitely-lived, with a constant rate of time preference \(\delta\) for consumption of a numeraire good and house. Suppose house sale requires a fixed transaction cost \(K\)^5 and with probability \(\eta\) the match is broken between the existing owner and the house, we have the following reservation prices for a potential buyer/seller:

\[
P_{\text{seller}}(y) = K + h(y)
\]

\[
P_{\text{buyer}}(y) = (1 - \eta)f(y) + \eta(K + h(y))
\]

where \(f(y)\) equals \(\frac{y}{r-\mu}\), which is the perpetuity of rental costs. \(h(y)\) is the value of the resale option associated with home ownership (i.e., the option to wait to sell). Consequently, fundamental insight to the option effect emphasized in this paper. For example, if there is rental supply optimally added when the price-to-rent ratio is low, rents will drop and renting is more attractive to potential buyers, reducing the number of potential buyers. As a result, potential sellers face a tradeoff between an increased bargaining power (higher immediate trade gain) and increased opportunity cost of selling (due to the lower rent). The magnitude of the option effect may differ, but the fundamental insight remains in that potential sellers make the sale timing decision by weighing the benefits with the costs of an immediate sale. However, in such a model, an endogenous market rent in general will not be a well-defined stochastic process, posing a significant barrier to solving the real options problem.

\(^4\)The modeling approach is similar to Canley and Pavlov (2002), in which the housing price follows a geometric Brownian motion. As we explicitly derive transaction prices endogenously as the result of a bargaining game between buyers and sellers, the transaction price will not exactly equal the present value of rents, as suggested by the traditional valuation model.

\(^5\)Kan (1999) finds an empirical result that is more in support of a fixed monetary transaction cost rather than a proportional cost.
the trade gains from a buyer seller pair is thus,

\[ G(y) = (1 - \eta)(f(y) - h(y) - K) \]  

(2.5)

**Proof.** See Appendix A.

Having described agents in the economy, we will discuss the micro mechanism of the trade process. According to the housing preference shock probabilities, there will be certain agents in the economy motivated to look for a new home at any given point in time. If existing home owners decide to exercise their resale option, they will meet buyers according to a matching technology that is linear in the population size of the buyer and seller group. At each encounter between any buyer and seller pair, in order to determine the terms of trade, they will engage in the alternating bilateral bargaining game as in Rubinstein and Wolinsky (1985).\(^6\)

The bargaining game is described and solved in detail in Appendix B. Under some assumptions, the endogenous (seller’s) bargaining power \( q \) is a function of the relative population size of buyers and sellers as in (2.6). Intuitively, if there are more active buyers than sellers, then sellers will be at an advantageous position in the bargaining game and extract a bigger share of the trade gains.

\[ q = \frac{N_r \eta_r}{N_r \eta_r + N \eta} = \frac{\rho}{\rho + 1} \]  

(2.6)

Given those, it immediately follows that,\(^6\)

---

\(^6\)Similar bargaining concepts are introduced in modeling market clearing in bilateral trades as in (Duffie et al., 2008; Novy Marx, 2009).
Lemma 2. The equilibrium transaction price between a buyer and seller is given by,

\[ P(y) = P_{\text{seller}}(y)(1 - q) + P_{\text{buyer}}(y)q \]
\[ = (h(y) + K)(1 - q) + ((1 - \eta)f(y) + \eta(h(y) + K))q \]
\[ = (K + h(y))(1 - (1 - \eta)\frac{\rho}{\rho + 1}) + (1 - \eta)f(y)\frac{\rho}{\rho + 1} \] (2.7)

According to the bargaining equilibrium, once matched, a buyer and seller pair completes the transaction *instantaneously* according to the above sharing rule. The equilibrium transaction price is essentially a weighted average of the buyer’s and seller’s reservation price, with the weight equal to the relative bargaining power of each party. In the special case where \( \eta = 0 \) and buyer’s bargaining power is one \( (q = 0) \), the transaction price is then \( y/(r - \mu) \), the usual present value formula.

Given the pricing rule, a potential seller will decide whether it is the optimal time to sell by comparing the benefits of continued waiting with the gain from an immediate sale. As expected, the benefits associated with continued holding (i.e., the option value of waiting) arise from the opportunity to have a larger trade gain in the future.

Proposition 1. The resale option value \( h(y) \) satisfies the following ordinary differential equation,

\[ rh(y) = \mu y h'(y) + \frac{1}{2} \sigma^2 y^2 h''(y) \] (2.8)

which is subject to the boundary conditions as follows:

\[ h(y^*) = P(y^*) - P_{\text{seller}}(y^*) \]
\[ = \frac{\rho}{\rho + 1} G(y^*) \quad \text{value matching condition} \] (2.9)

\[ h'(y)|_{y=y^*} = \frac{\rho}{\rho + 1} G'(y)|_{y=y^*} \quad \text{smooth pasting condition} \] (2.10)
Solving it gives,

\[
\begin{align*}
    h(y) &= C_1 y^{\theta_1} \\
    C_1 &= \frac{(y^*)^{1-\theta_1}}{\theta_1} \frac{1}{(r-\mu)(1+\rho+\rho(1-\eta))} \\
    y^* &= \frac{K \theta_1}{\theta_1 - 1} (r-\mu) \\
    \theta_1 &= \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right) + \sqrt{\frac{2r}{\sigma^2} + \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right)^2}
\end{align*}
\]  

(2.11) (2.12) (2.13) (2.14)

Proof. See Appendix C.

The two boundary conditions as in (2.9) and (2.10) are essentially optimality conditions for the exercise threshold. A potential seller could wait and keep the resale option alive, or she could sell the house for the current market price and realize gains from the immediate sale. At the optimum, the potential seller should be indifferent between the two choices.\footnote{We assume that the buyer seller ratio \( \rho > 1 \) so each seller is surely able to find a buyer and complete the transaction. This is without much loss of generality since here the buyer seller ratio is a constant. And explicit treatment of expected sale proceeds in the event of more sellers than buyers would change the result only quantitatively but not qualitatively.} Furthermore, optimality requires that this indifference condition should hold given infinitesimal changes in the underlying rent process \( y \). As a result, the resale option value at the exercise threshold equals the potential seller’s share of the trade gain \( \left( \frac{\rho}{\rho+1} G(y) \text{ in (2.9)} \right) \) out of an immediate sale. In other words, the potential seller waits until her share of the trade gain is large enough. Recall from (2.5) that the total gain from trade, \( G(y) \), is a function of the resale option \( h(y) \) as it is reflected in both the potential seller’s and the potential buyer’s reservation price. This gives us a fixed point problem in which \( h(y) \) needs to satisfy.

Equation (2.11) fully characterizes the evolution of the value function of the potential seller’s resale option. For small values of \( y \), the option value \( h(y) \) dominates the trade gains from immediate sale, which implies potential sellers are better off holding on to the house and keeping the resale option alive. \( y^* \) is the critical threshold value of \( y \) such that
trade gain from an immediate sale is big enough to offset the value associated with further waiting. In addition, increasing (decreasing) $y$ by a small amount leaves the potential seller indifferent. Consequently, a potential seller will exercise the resale option and sell the house as soon as the underlying rent process $y$ reaches $y^*$ the first time from below.

This lends a natural explanation for the observed seller behavior in the down market. The market rent, as well as price (which is a monotonic function of rent), is relatively low compared to the associated optimal exercise threshold, which renders an immediate sale unattractive to potential sellers. Instead of selling the house immediately, owners are better off holding on to the house since the expected gain from a future sale is larger. Alternatively, owners are willing to let go the houses at such times only if the gain from an immediate sale is sufficiently high to cover the value of the right to exercise their resale options later at a better time. Therefore, in addition to seller’s irrational “fishing” behavior, this model provides another rationale for the empirical regularity that sellers seem to set a high asking price and refuse to lower it, although they are fully aware that this asking price may be beyond buyer’s reservation price.

The closed form solution of the exercise threshold $y^*$ in (2.13) makes it easy to infer the impact of economic fundamentals on the optimal sale timing for potential sellers. To guide our empirical analysis, we focus on the key implication of the rental growth rate $\mu$ and volatility $\sigma$.

**Corollary.** Denote $\frac{\sigma}{\sqrt{1-\Gamma}}$ as $\Theta$. It is easy to show that $\frac{\partial \Theta}{\partial \sigma} > 0$, $\frac{\partial \Theta}{\partial \mu} > 0$. Then,

$$\frac{\partial y^*}{\partial \mu} = K \frac{\partial \Theta}{\partial \mu} (r - \mu) + K \Theta(-1) < 0$$

$$\frac{\partial y^*}{\partial \sigma} = K \frac{\partial \Theta}{\partial \sigma} (r - \mu) > 0$$

(2.15)

**Proof.** By straightforward algebra. □

It is clear that for larger uncertainty ($\sigma$) of the underlying process $y$, we obtain
comparative statistics consistent with the usual option effect. That is, the higher the volatility, the greater the option value and the longer potential sellers delay. Intuitively, that is because the more volatile the rent process, the more likely it will hit a high value in the future which means the opportunity cost of trading now (or the option value of waiting) is larger.

Our model delivers a unique prediction on the effect of $\mu$. A typical option result implies that the value of waiting is increasing in the asset growth rate. In our context, there is an additional growth rate effect because the benefit of an immediate sale also depends on $\mu$: buyer’s reservation price is increasing in the rental growth rate. A higher expected growth rate raises buyer’s willingness to pay and seller’s gain from an immediate sale, thus requiring less waiting on the potential seller’s part. In net, the second effect dominates and potential sellers wait less in a market when rent is expected to grow faster.

2.2 Endogenous Supply

The benchmark model in the previous section studies an economy where supply is held fixed. The only potential sellers on the market are existing home owners who lose match with their current dwellings. This is more likely to be the case in areas where there are stringent supply regulations or in regions with natural constraints. However, in areas with abundant land, supply respond to prices and it is plausible that supply conditions affect existing owners’ resale option exercise behavior. In this section, we discuss an example of endogenous supply as an extension to the benchmark model.

Same as in the benchmark model, existing home owners and renters are driven by exogenous housing preference shocks upon which they become potential sellers and buyers. In addition, there is a competitive industry for developers (or investors) who are risk neutral profit maximizers. In response to economic fundamentals and current market prices, they will optimally convert the empty land into owner-occupied housing. For the
purpose of our paper, we assume no construction lag and newly constructed houses are immediately available for sale after developers make the optimal decision. However, they need to go through the same selling process as existing owners. In particular, the new house(s) will be sold by a broker on behalf of the developers and the transaction price will be determined as the result of a bilateral bargaining game with the same equilibrium concept as described in Appendix B.\(^8\) While determining the optimal units of housing to be added, developers realize that adding new supply would change the number of buyers relative to the number of available units, and this in turn would change each seller’s share of the trade gains and thus the equilibrium price.

To illustrate, we consider a simple and stylized production technology. Each new unit of housing added requires a constant variable cost \(L\) and there is no fixed cost. An extra one unit of housing added with a total of \(Q\) new supply installed yields additional revenue of,

\[
\min\left[1, \frac{N_r \eta_r}{N \eta + Q}\right] P_{se}(y, Q) = \min\left[1, \frac{N_r \eta_r}{N \eta + Q}\right] (h(y) + K + \frac{N_r \eta_r}{N \eta + Q} G(y)) \tag{2.16}
\]

The first term above reflects the possibility of “over-building” so that the developer may not be able to sell it at the current price and \(\frac{N_r \eta_r}{N \eta + Q}\) reflects in expectation how likely the additional unit can be sold to one buyer. Now the equilibrium price depends on the endogenously added supply since new supply changes how buyers and sellers share the trade gains. In a competitive market, equilibrium requires the no profit condition,

\[
\min\left[1, \frac{N_r \eta_r}{N \eta + Q}\right] P_{se}(y, Q) = L \tag{2.17}
\]

From (2.17), we see the equilibrium quantity of new housing will depend on the prevalent market conditions. In particular, \(Q\) will be a function of the option value which in turn

\(^8\)For simplicity, we assume that developers will have the same reservation price so the trade gains will be the same for all available units. In particular, we assume developers cannot rent out the unit before the sale and the rental housing supply remains the same as the benchmark model.
depends on the current level of \( y \). This in turn affects the existing owners’ exercise behavior since they will optimally take into account the impact of the new supply on their bargaining power and transaction prices.

**Proposition 2.** If supply can be competitively added, the resale option \( h(y) \) satisfies the same ordinary differential equation as in (2.8), subject to the following modified boundary conditions.

\[
\begin{align*}
h(y^*) &= \min[1, \frac{N_r \eta r}{N \eta + Q(y^*)}]\left(\frac{N_r \eta r}{N_r \eta r + N \eta + Q(y^*)} G(y^*)\right) \quad (2.18) \\
h'(y) \bigg|_{y = y^*} &= \frac{d \min[1, \frac{N_r \eta r}{N \eta + Q(y)}] (\frac{N_r \eta r}{N_r \eta r + N \eta + Q(y)} G(y))}{dy} \bigg|_{y = y^*} \quad (2.19)
\end{align*}
\]

**Proof.** The existing owner’s resale option value follows the same functional form as in (2.8) since its evolution is determined by the same absence of arbitrage rule. The boundary conditions need to be adjusted in order to reflect the fact that existing owners will optimally take into account the impact of new supply on prices. The second term in (2.18) is the owner’s share of the trade gain, should she choose to sell, in the presence of new supply. The first term in (2.18) means that if the new total supply exceeds demand, any existing owner gets to sell with probability equal to the proportion of buyers relative to all available units of housing.

Since \( Q(y) \) depends on \( y \) in a complicated non-linear way, there is no closed form solution in this case. Nevertheless, given the functional form of the value function of the resale option (2.11), we can easily obtain the remaining two unknowns (\( C_1 \) and \( y^* \)) by numerically solving a system of two nonlinear equations.

The comparative statics are presented in Fig 1.\(^9\) The exercise threshold is strictly below that in the case with a fixed supply for a wide range of rental volatilities and expected rental growth rates. The underlying intuition can be better understood from

\(^9\)We do not attempt to match the model parameters to their real world counterparts, as this is intended to be a comparative statics to guide empirical hypothesis development instead of a calibration exercise. We have used other parameter numbers and the qualitative result remain unchanged.
Fig 2. Since the option value takes the functional form $C_1 y^{\theta_1}$ and $\theta_1$ does not vary with supply conditions, difference in the constant $C_1$ determines the level and sensitivity of the resale option values. It is clear that the fixed supply case strictly dominates the endogenous supply case in the magnitude of the constant $C_1$. That means, the value of the resale option is less sensitive to change in rental growth rate and volatility in areas that allow new supply. As a result, a free entry of new supply makes the marginal value of waiting less valuable. Intuitively, existing owners will be less patient and accelerate their resale option exercise. The benefit of waiting is dampened due to a decreased bargaining power and a lower gain from trade for potential sellers, as more supply is introduced.

Empirically this suggests that the options effect in areas with high supply elasticity will be smaller than regions with supply inelasticity. More specifically, in places where supply cannot be easily adjusted, owners’ resale option value increases at a faster rate as the level of the rental growth rate (volatility) decreases (increases). This gives us an extra cross-sectional prediction to be tested in the data.

2.3 Further Discussion

In this section, we further discuss the robustness of our key predictions in the benchmark model by relaxing various assumptions.

2.3.1 Heterogeneous Agents

Many market participants in the housing market are repeat buyers who are current home owners but want to own a different house instead of downgrading to the rental market (Ortalo-Magné and Rady, 2006). We incorporate repeat buyers in a “property-ladder” set up and study its implications for the optimal exercise problem in Appendix D.

Although we have one more layer of buyers and sellers, the fundamental result is the
same as in the benchmark model. Potential sellers will optimally wait until their share of the trade gain rises to a sufficiently high level. If the market rent \( y \) is below the optimal threshold, they are better off holding on to their houses and keep the resale option alive. In addition, the comparative statics of the exercise threshold, either for the starter home seller or for the trade-up home seller, remains the same as in the benchmark model. This insight leaves us assured when we later use the implications from the benchmark model for our empirical test.

### 2.3.2 Endogenous Entry of Buyers and Sellers

It is also assumed in the benchmark model that agents’ mobility needs are exogenously determined. While there is empirical evidence in support of the demographics-driven household expected mobility (Kan, 1999), it is plausible that households’ preference for home ownership might change according to the prevailing market conditions. For example, household formation (e.g., marriage and childbearing) as well as retirement decision is likely to be influenced by the current market conditions. In addition, investors and speculators will make the market entry decision mostly based on the market price level. In these circumstances, market entry is endogenous and potential buyer and seller ratio is a function of the current market price (relative to the rent level). We consider a case in which there is an additional market factor influencing agents’ mobility needs and (dis)investment decisions. We leave the detailed analysis to Appendix E. Under the assumption that there are more (fewer) potential buyers (sellers) entering the market when the market price is low relative to the rent level, the option value of waiting is smaller in equilibrium compared to the case in which market entry is exogenously determined. This is because a rise in potential buyers, given a low market price, effectively increases the potential sellers’ bargaining power at such times. In addition, an expected increase in seller entry in response to high market price implies less trade surplus to be extracted by each potential seller, which reduces the expected gain in waiting to sell the house at a
favorable time in the future. Taken together, waiting is less attractive for potential sellers with endogenous market entry. However, the option effect remains and all the qualitative results derived in the benchmark model are robust to the relaxation of exogenous market entry assumption.

3 Empirical Implications and Results

3.1 Testable Implications

Our model generates testable predictions on sales volume in the residential housing markets. The optimal exercise threshold defines the no-trade region, as owners will rationally choose not to exercise their resale options if the market rent (or price) level is below the critical threshold value. Therefore, a lower threshold implies more transactions on average, and the aggregate transaction volume should be closely linked to determinants of the optimal exercise threshold predicted in the theoretical model. In the remainder of the paper, we will carry out empirical tests of the following three hypotheses, which are derived from our model’s predictions.

Hypothesis 1: The average transaction volume is positively related to the expected rental growth rate, and negatively related to the rental volatility.

We start our empirical tests based on the basic implication on the relationship between the optimal transaction threshold and rental market fundamentals in Equation (2.15). First of all, our model derives unique prediction on the role of rental market fundamentals. As mentioned earlier, the effect of the rental growth rate on the optimal threshold (and thereby transaction volume) is in contrast to the traditional option pricing model’s prediction, since the benefit of immediate sale is also increasing in the growth rate, making the potential seller less patient. Secondly, the rest of the hypotheses are extensions of the key model prediction by incorporating the role of supply and time-varying
market conditions.

**Hypothesis 2**: The effect of the expected rental growth rate or volatility on the transaction volume is stronger in areas where supply is inelastic.

Hypothesis 2 focuses on the interaction between supply conditions and the expected rental growth rate and volatility to identify potential sellers’ exercise behavior in response to different supply conditions. For example, high rental volatility and high supply inelasticity areas should experience particularly weak trading activities on average.

**Hypothesis 3**: The positive (negative) effect of the expected rental growth rate or volatility on the transaction volume is stronger if market prices are low.

The model derives a constant optimal exercise threshold which defines a no-trade region. Probabilistically, it is more likely for potential sellers to be in the no-trade region and delay their trade if the current market conditions are bad (i.e., the current price level is low). Potential sellers “hold-out” more often in the down markets as the resale option is more likely to be in the money at such times.

### 3.2 Data and Empirical Specification

#### 3.2.1 Data

In order to test the hypotheses, we merge data on housing transaction volume, price, rent along with other economic and demographic data from multiple sources. We obtain the state-level quarterly sales volume of existing homes from National Association of Realtors (NAR). For housing price, we use the state level HPI index from the Federal Housing Finance Agency (formerly Office of Federal Housing Enterprise Oversight(OFHEO)).

Rental market data are obtained from National Real Estate Index (NREI), which is a data provider of information on both commercial and residential markets covering
50 metropolitan areas. Data are based on actual sales rather than appraisals. For our purposes, we collect the time series of apartment rents and the associated cap rates at the MSA level. Cap rates, which are derived from the pro forma net operating income, are forward-looking measures and thus correspond to $r - \mu$ in our model. We use the cap rates as a proxy for $\mu$. All else equal, a higher cap rate implies a lower expected growth rate. We also compute the realized growth rate based on the quarterly apartment average rent, in order to differentiate from explanations based on agents’ backward-looking behavior. Rental volatility is computed on a rolling basis. At time $t$, volatility is defined as the standard deviation of the realized growth rate of real rent using all data as of that time.

We use two approaches to aggregate the MSA level data. The first one is to construct a simple average within each state. We also calculate a weighted average of within state’s cap rates and volatility, using population of each component MSA as weights.

Other economic and demographic data are from the Current Population Survey (CPS) at the state level. We use CPI from the Bureau of Labor Statistics to calculate values in real terms. Although all housing and financial data are available at the quarterly frequency, other economic and demographics data through CPS are on the annual basis. As a result, in the main regressions, the control variables (e.g., population density) are at a lower frequency than the transaction as well as rental market data. The detailed data description and summary statistics are presented in Table 1.

Rental volatility in the pooled sample is on average 1.98%, with a standard deviation of 0.66%. The cap rate, which is inversely correlated with the expected growth rate, is on average 9.23% with a standard deviation of 0.68%. The summary statistics of the rental market measures based on different weighting schemes are very close, so we will focus on the simple measure in our main regressions.
3.2.2 Construction of Supply Inelasticity and Down Market Proxies

We need to construct a measure of supply inelasticity. Green et al. (2005) find that population density is an important (negative) predictor of supply elasticity, based on which we create three different measures of supply inelasticity. The primary measure is the continuous variable of population density (in log term). However, the geography of supply inelasticity is quite concentrated in a few areas that are subject to land constraints (Saiz, 2010). Thus we also create a dummy variable for supply inelasticity that takes one for the states in the top 10% distribution of the population density in the cross section of all states in sample and zero otherwise. As another robustness control, we classify a state to be supply inelastic if it is within the top 20% of the population density distribution. Since the population density data is highly persistent over time, the states which persistently belong to the first classification are DC, MA and NJ, while the states that persistently fall into the second classifications are DC, MA, NJ, CT, MD and NY.

We define a state quarter to be in the “down market” if that particular quarter’s HPI index is in the bottom tercile of the time series distribution of HPI for that state. If the state’s HPI is relatively low in its empirical time series distribution, it is very likely that the state is experiencing a low price period with a more binding no-trade threshold. As a robustness control, we create another dummy variable that equals one if the state’s HPI in one quarter is below the median of its HPI times series distribution.\(^\text{10}\)

\(^{10}\text{Strictly speaking, the model predicts that the trade option exercise is affected by the current rent level. Nevertheless, the equilibrium transaction price is monotonic in rent in our model. We choose to define our “down market” proxy based on the price data in our sample mainly out of the empirical concern that the rent level data is available from limited metropolitan areas and is like to have a larger measurement error.}\)
3.2.3 Empirical Specification

The major empirical specification is as follows,

\[ Volume_{i,t} = \alpha_{volume} + \beta_{volume}X_{i,t} + \delta_{volume}Q_{i,t} + Dummy_i + Dummy_t + \epsilon_{volume} \quad (3.1) \]

where \( i \) and \( t \) denote state and time. \( X_{i,t} \) are major variables of interest including apartment rental cap rate, volatility, rent level, and measures of supply inelasticity. In the test, we are looking mainly at the coefficient set \( \beta_{volume} \) and test if they are consistent with theoretical predictions.

In all empirical specifications, we also include as controls other economic and demographic variables which are possible determinants of transaction volume \( (Q_{i,t}) \), such as unemployment rate, job turnover rate and home ownership rates. Specifically, we include the price index level in the regressions in order to control for any unobservable factors that determine both prices and volume. State and time fixed effects are included throughout the test.

For our sample, the quarterly trading volume within a state is highly persistent over time, as the average auto correlation coefficient of the state-level trading volume is 0.80. This probably explains why the \( R^2 \) is very high when we include the state fixed effect in the analysis. In all tests, we cluster our standard errors at the state level, since quarterly volume variables within a state are not independent observations given the high persistence.

Before we carry out the formal econometric tests, we first examine the correlation among the major variables (Table. 2). Cap rates are not highly correlated with rental volatility rates, nor with the realized apartment rental growth rates. This first check suggests that the cap rate is a forward-looking measure of the expected growth rate, as it is not affected by the realized performance. This will help us differentiate our story.
from one based on agents’ extrapolative behavior based on past growth. Cap rates are significantly negatively correlated with measures of wealth (e.g., HPI, unemployment, income and education levels), so we need to control for the wealth effect in our analysis.

Rental volatility, on the other hand, tends to be big when the realized rental growth rates are high. This may raise the concern on the measurement error of the volatility measure, which is computed based on past growth rates. We include the realized rental growth rate in our analysis as a control. In addition, we will use finer tests (e.g., interacting with supply conditions and market conditions) to better identify the volatility effect.

3.3 Results

3.3.1 The Effect of the Expected Rental Growth Rate

We start by testing the effect of the expected rental growth rate on the average transaction volume at the state level. Table 3 presents the results, which are consistent with our model predictions. In general, cap rates are negatively correlated with transaction volume, implying a positive relationship between the rental growth rate and transaction volume. To interpret the result, a 1% increase in rent cap rate reduces the sales volume index by approximately 4% (column 4 of Table 3). This result is statistically significant at the 5% level.

In an extrapolation-based story, given a positive historical trend, sellers are over-optimistic about the near term market prospect and therefore delay their trades. This argument would imply that the transaction volume in aggregate will be greatly affected by the realized growth rates in the past. We have shown in Table 2 that our measure of the rental growth rate is rather uncorrelated with the past rental market performance and is therefore unlikely a proxy for the past market trend. Furthermore, we include
in the regressions the realized apartment growth rate as a control and find our results unaffected. As a further robustness check, we also experiment with the alternative cap rate measure, computed by taking the population weighted average of the MSA-level cap rates for each state. Results are essentially unaffected and are not reported in the table for brevity.

3.3.2 The Effect of the Rental Volatility

Table 4 shows the results of the effect of rental volatility on the average transaction volume. In columns (1)-(3) of Table 4, the coefficients on the rental volatility are positive. It becomes negative after we include the state fixed effects (column (4)), which suggests that our measure of rental volatility may be correlated with some state-specific unobservables. However, the negative coefficient on rental volatility in column (4) is not statistically significant. In an unreported test, we also use the alternative population weighted volatility, but the effect of rental volatility remains insignificant.

3.3.3 Is the Option Effect Stronger in Areas with Inelastic Supply?

Next, we study whether more stringent supply conditions, interacted with rental market characteristics, have a marginal impact on transaction volume as our model predicts. Results are presented in Table 5. We first discuss the results using the supply inelasticity metric based on the continuous variable of (logged) population density (column (1)). As expected, given the same rental market characteristics, being in the state with a higher population density would strengthen the option effect on the average transaction volume. For example, a 10% increase in population density would further reduce the sales volume by 3% approximately if the cap rate increases by one percentage point. A positive coefficient associated with cap rate in column (1) suggests that the negative relationship between cap rate and transaction volume is driven by states with more inelastic supply.
Although the effect of volatility on transaction volume is insignificant (Table 4), a 1% increase in rental volatility in a state with 10% higher population density is associated with a further significant decrease in transaction volume by approximately 3%. Again, rental volatility is strongly associated with transaction volume primarily in areas where supply is more constrained.

Results related to both cap rate and volatility are consistent (albeit somewhat weaker) by alternative proxies for supply inelasticity. Column (2) reports results using the top 10% states in terms of population density as the classification, and column (3)'s results are based on a dummy variable that equals one for the top 20% states in the distribution of population density. Taken together, we show support to our model’s prediction that the option value of delaying trade is stronger and concentrated in areas with supply constraints.

### 3.3.4 Are Down Markets Affected More?

Table. 6 presents test results related to our Hypothesis 3. The first two columns use the down market classification based on the 30% cutoff. Consistent with the model prediction, a higher cap rate (or equivalently lower expected growth rate) will have a disproportionately larger negative impact on the average transaction volume if the current market is experiencing a bad time (an extra 0.4% decrease in volume in the down market for one percentage increase in cap rate). Similarly, one percentage increase in volatility reduces transaction volume by 2% only when the market price is low.

As a robustness control, the last two columns’ results are based on the definition with the 50% threshold in the HPI distribution for each state. Results are qualitatively the same, but the effect is much weaker based on this down market definition. Specifically, the effect of rental volatility is statistically indistinguishable from zero. This is consistent with the model prediction, as the no-trade region is more binding in the more extreme
down markets.

4 Concluding Remarks

In this paper, we build a parsimonious real options model that explains home owners’ selling decisions in the housing markets. Potential sellers compare the gain with the opportunity cost of an immediate trade. In holding on to their homes and delaying sale, home owners expect to benefit from a higher trade gain in the future. This option (to delay) is precisely valuable when the current price is low, making home owners reluctant to sell. Moreover, supply inelasticity amplifies the option effect, providing a stronger incentive for potential sellers to delay. The empirical findings using state-level housing market data provide strong support to our model. Overall, this paper offers one explanation for why owners, in the absence of financial constraints or search frictions, rationally hold on to their homes when the current prices are low. Liquidity shortage is to be expected when owners’ option to delay sale is valuable, resulting in a mismatch between potential buyer’s and seller’s valuation.
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References


Figure 1: Comparative Statics on the Exercise Threshold

The following are the figures of the exercise threshold ($y^*$) with and without endogenous supply. In each of the following figures, we use the benchmark parameters: $r = 0.1; \mu = 0.08; \sigma = 0.15; \eta = 0.1; K = 100; L = 125; \rho = 1$.

Figure 2: Comparative Statics on the Option Constant $C_1$

The following are the figures of the constant in the value function of the resale option ($C_1$) with and without endogenous supply. In each of the following figures, we use the benchmark parameters: $r = 0.1; \mu = 0.08; \sigma = 0.15; \eta = 0.1; K = 100; L = 125; \rho = 1$. 

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Table 1: Summary Statistics of State-Level Housing and Demographic Data

The apartment rental volatility data are computed from the growth rates of the real rent levels. For each year, we calculate the standard deviation of the quarterly real apartment rental growth rates using data up to that year as the volatility measure. The states in our sample are: AL, AZ, CA, CO, CT, DC, FL, GA, IL, IN, KS, LA, MA, MD, MI, MN, MO, NC, NJ, NM, NV, NY, OH, OK, OR, PA, SC, TN, TX, UT, VA, WA, WI. HPI index, rent index as well as average income levels are all in real terms using CPI from BLS. Quarterly MSA level data are aggregated to the state level data (using either simple averages or population-weighted averages) for the rent data from NREI using either simples averages. Rent and HPI data are also at the quarterly basis, while other demographic data are on the annual basis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Mean</th>
<th>Std Ev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>Quarterly Housing Transaction Volume Index</td>
<td>131.63</td>
<td>116.17</td>
</tr>
<tr>
<td>Real HPI</td>
<td>HPI Index (real terms)</td>
<td>153.18</td>
<td>33.13</td>
</tr>
<tr>
<td>Cap Rate</td>
<td>Capitalization Rate for Apartments (%)</td>
<td>9.23</td>
<td>0.68</td>
</tr>
<tr>
<td>weighted cap rate</td>
<td>Population Weighted Cap Rate</td>
<td>9.21</td>
<td>0.69</td>
</tr>
<tr>
<td>Rental Volatility</td>
<td>Quarterly Volatility of Apartment Rental Growth (%)</td>
<td>1.98</td>
<td>0.66</td>
</tr>
<tr>
<td>weighted apt vol</td>
<td>Pop. Weighted Quarterly Apt Volatility</td>
<td>1.96</td>
<td>0.68</td>
</tr>
<tr>
<td>Realized Rental Growth Rate</td>
<td>Quarterly Realized Apartment Rental Growth (%)</td>
<td>0.06</td>
<td>1.81</td>
</tr>
<tr>
<td>Real Rent</td>
<td>Apartment Rent Index (real terms)</td>
<td>7.87</td>
<td>1.98</td>
</tr>
<tr>
<td>Pop Density</td>
<td>Population per Square Miles</td>
<td>199.32</td>
<td>689.37</td>
</tr>
<tr>
<td>Real Income</td>
<td>Average annual income (in thousands, real terms)</td>
<td>34.57</td>
<td>4.61</td>
</tr>
<tr>
<td>Job Turnover</td>
<td>% of Population with Job Change in the last year</td>
<td>13.71</td>
<td>2.15</td>
</tr>
<tr>
<td>Unemployment</td>
<td>Fraction of Population Unemployed</td>
<td>5.68</td>
<td>1.61</td>
</tr>
<tr>
<td>homeownership</td>
<td>Fraction of Home Owners</td>
<td>65.78</td>
<td>7.15</td>
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<td>Middle-aged</td>
<td>Population Aged between 40 and 65</td>
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</tr>
<tr>
<td>Old</td>
<td>Population Aged above 65</td>
<td>23.10</td>
<td>2.82</td>
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</tbody>
</table>

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Table 2: Correlation Statistics

This table presents pairwise correlation statistics among major variables. All variables except those in percentage terms are taken logs first. The sample is quarterly data at the state level and covers from 1989 to 2000. From NREI, we get the quarterly capitalization rate for apartments and compute the rental volatility by MSA. Then we compute a simple average of the cap rate and rental volatility by state and quarter. For the other macro data, we obtain annual demographic data (e.g., unemployment rate) from CPS at the state level (see Table 1 for variable definitions).

<table>
<thead>
<tr>
<th>Cap Rate</th>
<th>Rental Volatility</th>
<th>Realized Growth Rate</th>
<th>Real Rent</th>
<th>Real HPI</th>
<th>Real Income</th>
<th>Unemployment</th>
<th>Job Turnover</th>
<th>Middle-aged</th>
<th>Old</th>
<th>Ownership</th>
<th>College</th>
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<td>Cap Rate</td>
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<td></td>
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<td></td>
<td></td>
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<td>1.00</td>
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<tr>
<td>Growth Rate</td>
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<td></td>
<td></td>
<td></td>
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<td>-0.01</td>
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<td>0.00</td>
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<tr>
<td>Real Income</td>
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<td>-0.05</td>
<td>0.11</td>
<td>0.64</td>
<td>0.63</td>
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<tr>
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<td>-0.06</td>
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<td>-0.40</td>
<td>0.18</td>
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<td>1.00</td>
</tr>
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Table 3: OLS Transaction Volume Regression: The Effect of Cap Rate

All variables except those in percentage terms are taken logs first. Then regressions are done on the log basis. The sample is quarterly data at the state level and covers from 1989 to 2000. We obtain the transaction volume data from NAR. From NREI, we get the quarterly capitalization rate for apartments and compute the rental volatility by MSA. For the other macro data, we obtain annual demographic data (e.g. unemployment rate) from CPS at the state level. Please see Table 1 for a detailed discussion of variable definitions. Standard errors are clustered at the state level. T-stats are reported in parentheses and **, * indicate statistical significance at the 1% and 5% level respectively.

<table>
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<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
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<td>-0.11</td>
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<td></td>
<td>(-1.8)</td>
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<td>0.05**</td>
<td>0.03</td>
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</tr>
<tr>
<td></td>
<td>(2.1)</td>
<td>(3.8)</td>
<td>(2.0)</td>
<td>(1.6)</td>
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<tr>
<td>Real Rent</td>
<td>0.68</td>
<td>2.31**</td>
<td>2.48**</td>
<td>0.47**</td>
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<td>(0.6)</td>
<td>(3.0)</td>
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<td>(-0.5)</td>
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<td>(0.9)</td>
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<td>(-0.5)</td>
<td>(-0.6)</td>
<td></td>
</tr>
<tr>
<td>Job Turnover (%)</td>
<td>0.03</td>
<td>0.04</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.2)</td>
<td>(1.2)</td>
<td>(0.2)</td>
<td></td>
</tr>
<tr>
<td>Middel-aged (%)</td>
<td>0.01</td>
<td>-0.00</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.4)</td>
<td>(-0.1)</td>
<td>(-1.1)</td>
<td></td>
</tr>
<tr>
<td>Old (%)</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.01*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0.1)</td>
<td>(-2.1)</td>
<td></td>
</tr>
<tr>
<td>Ownership (%)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.1)</td>
<td>(1.0)</td>
<td>(0.3)</td>
<td></td>
</tr>
<tr>
<td>College (%)</td>
<td>-0.08*</td>
<td>-0.08*</td>
<td>-0.01**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.2)</td>
<td>(-2.3)</td>
<td>(-2.8)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>7.65</td>
<td>-9.96</td>
<td>-9.76</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>(1.8)</td>
<td>(-0.7)</td>
<td>(-0.6)</td>
<td>(0.5)</td>
</tr>
<tr>
<td>Fixed Effects</td>
<td>N/A</td>
<td>N/A</td>
<td>Time</td>
<td>State,Time</td>
</tr>
<tr>
<td>Observations</td>
<td>1051</td>
<td>1051</td>
<td>1051</td>
<td>1051</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.04</td>
<td>0.34</td>
<td>0.36</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Table 4: OLS Transaction Volume Regression: The Effect of Rental Volatility

All variables except those in percentage terms are taken logs first. Then regressions are done on the log basis. The sample is quarterly data at the state level and covers from 1989 to 2000. We obtain the transaction volume data from NAR. From NREI, we get the quarterly capitalization rate for apartments and compute the rental volatility by MSA. For the other macro data, we obtain annual demographic data (e.g. unemployment rate) from CPS at the state level. Please see Table 1 for a detailed discussion of variable definitions. Standard errors are clustered at the state level. T-stats are reported in parentheses and **, * indicate statistical significance at the 1% and 5% level respectively.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) log volume</th>
<th>(2) log volume</th>
<th>(3) log volume</th>
<th>(4) log volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rental Volatility</td>
<td>0.09</td>
<td>0.16*</td>
<td>0.10</td>
<td>-0.00</td>
</tr>
<tr>
<td></td>
<td>(1.3)</td>
<td>(2.2)</td>
<td>(1.2)</td>
<td>(-0.1)</td>
</tr>
<tr>
<td>Real Rent</td>
<td>0.61</td>
<td>2.18**</td>
<td>2.35**</td>
<td>0.48**</td>
</tr>
<tr>
<td></td>
<td>(0.5)</td>
<td>(2.9)</td>
<td>(3.0)</td>
<td>(3.4)</td>
</tr>
<tr>
<td>Real HPI</td>
<td>-0.32</td>
<td>-1.04</td>
<td>-1.04</td>
<td>-0.23</td>
</tr>
<tr>
<td></td>
<td>(-0.3)</td>
<td>(-1.3)</td>
<td>(-1.2)</td>
<td>(-1.9)</td>
</tr>
<tr>
<td>Real Income</td>
<td>1.78</td>
<td>1.76</td>
<td>0.42*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.1)</td>
<td>(0.9)</td>
<td>(2.3)</td>
<td></td>
</tr>
<tr>
<td>Unemployment (%)</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.7)</td>
<td>(-0.7)</td>
<td>(-1.4)</td>
<td></td>
</tr>
<tr>
<td>Job Turnover (%)</td>
<td>0.04</td>
<td>0.04</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.3)</td>
<td>(1.4)</td>
<td>(0.5)</td>
<td></td>
</tr>
<tr>
<td>Middle-aged (%)</td>
<td>0.02</td>
<td>-0.01</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(-0.2)</td>
<td>(-1.2)</td>
<td></td>
</tr>
<tr>
<td>Old (%)</td>
<td>0.02</td>
<td>0.01</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.3)</td>
<td>(0.1)</td>
<td>(-1.9)</td>
<td></td>
</tr>
<tr>
<td>Ownership (%)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.0)</td>
<td>(0.9)</td>
<td>(0.1)</td>
<td></td>
</tr>
<tr>
<td>College (%)</td>
<td>-0.08*</td>
<td>-0.08*</td>
<td>-0.01**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.3)</td>
<td>(-2.4)</td>
<td>(-3.1)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>4.78</td>
<td>-14.55</td>
<td>-13.36</td>
<td>-0.79</td>
</tr>
<tr>
<td></td>
<td>(1.5)</td>
<td>(-1.1)</td>
<td>(-0.8)</td>
<td>(-0.4)</td>
</tr>
<tr>
<td>Fixed Effects</td>
<td>N/A</td>
<td>N/A</td>
<td>Time</td>
<td>State, Time</td>
</tr>
<tr>
<td>Observations</td>
<td>1084</td>
<td>1084</td>
<td>1084</td>
<td>1084</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.02</td>
<td>0.32</td>
<td>0.34</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Table 5: OLS Transaction Volume Regression: Effect of Supply Inelasticity

All variables except those in percentage terms are taken logs first. Then regressions are done on the log basis. The sample is quarterly data at the state level and covers from 1989 to 2000. We obtain the transaction volume data from NAR. From NREI, we get the quarterly capitalization rate for apartments and compute the rental volatility by MSA. For the other macro data, we obtain annual demographic data (e.g. unemployment rate) from CPS at the state level. Please see Table 1 for a detailed discussion of variable definitions. We construct a measure of supply inelasticity by creating a dummy (or continuous) variable and interact this with Cap Rate and Rental Volatility to study the effect of supply inelasticity. Column (1) shows the result using the continuous variable Pop Density directly as a proxy for supply inelasticity. Column (2) shows the result using the definition that states in the top 10% of the population density distribution are subject to supply inelasticity. As robustness checks, we experiment with two alternative measures. Column (3) uses the definition of inelasticity based on the top 20% states in the population density distribution. In all specifications, both time and state fixed effects are included. We also include the same set of control variables as in Table 3, but we do not report their regression coefficients in this table to save space. Standard errors are clustered at the state level. T-stats are reported in parentheses and **, * indicate statistical significance at the 1% and 5% level respectively.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap Rate</td>
<td>0.06*</td>
<td>-0.03**</td>
<td>-0.03**</td>
</tr>
<tr>
<td></td>
<td>(2.1)</td>
<td>(-3.2)</td>
<td>(-2.9)</td>
</tr>
<tr>
<td>Rental Volatility</td>
<td>0.09**</td>
<td>-0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(3.1)</td>
<td>(-0.6)</td>
<td>(0.2)</td>
</tr>
<tr>
<td>Popdensity × Cap Rate</td>
<td>-0.03**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-3.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Popdensity × Rental Volatility</td>
<td>-0.03**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-4.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inelastic Dummy × Cap Rate</td>
<td></td>
<td>-0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.9)</td>
<td></td>
</tr>
<tr>
<td>Inelastic Dummy × Rental Volatility</td>
<td>-0.10*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.1)</td>
<td></td>
</tr>
<tr>
<td>Inelastic Dummy 2 × Cap Rate</td>
<td></td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.9)</td>
<td></td>
</tr>
<tr>
<td>Inelastic Dummy 2 × Rental Volatility</td>
<td>-0.13**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-4.2)</td>
<td></td>
</tr>
<tr>
<td>Realized Rental Growth Rate</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(1.4)</td>
<td>(1.7)</td>
<td>(1.4)</td>
</tr>
<tr>
<td>Real Rent</td>
<td>0.54**</td>
<td>0.53**</td>
<td>0.56**</td>
</tr>
<tr>
<td></td>
<td>(4.3)</td>
<td>(4.1)</td>
<td>(4.4)</td>
</tr>
<tr>
<td>Real HPI</td>
<td>-0.25*</td>
<td>-0.37***</td>
<td>-0.38**</td>
</tr>
<tr>
<td></td>
<td>(-2.2)</td>
<td>(-3.4)</td>
<td>(-3.6)</td>
</tr>
<tr>
<td>Constant</td>
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<td>0.65</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0.4)</td>
<td>(0.7)</td>
</tr>
<tr>
<td>Fixed Effects</td>
<td>state,time</td>
<td>state,time</td>
<td>state,time</td>
</tr>
<tr>
<td>Observations</td>
<td>1051</td>
<td>1051</td>
<td>1051</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.99</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Table 6: The Effect of the Down Market

All variables except those in percentage terms are taken logs first. Then regressions are done on the log basis. The sample is quarterly data at the state level and covers from 1989 to 2000. We obtain the transaction volume data from NAR. From NREI, we get the quarterly capitalization rate for apartments and compute the rental volatility by MSA. For the other macro data, we obtain annual demographic data (e.g. unemployment rate) from CPS at the state level. Please see Table 1 for a detailed discussion of variable definitions. We define a Down Market dummy to be equal to one if the quarterly price (HPI) index of the state is relatively low in the time series distribution within that state. In the first two columns, Down Market Dummy is defined if a state’s HPI in a given quarter is in the bottom tercile in the time series distribution of that particular state. In the last two columns, Down Market Dummy is taken to be one if for any given quarter, a state’s HPI is below the time series median for that state. In all specifications, both time and state fixed effects are included. We also include the same set of control variables as in Table 3, but we do not report their regression coefficients in this table to save space. Standard errors are clustered at the state level. T-stats are reported in parentheses and **, * indicate statistical significance at the 1% and 5% level respectively.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap Rate</td>
<td>-0.04*</td>
<td>-0.04*</td>
<td>-0.04*</td>
<td>-0.04*</td>
</tr>
<tr>
<td>Down Market Dummy × Cap Rate</td>
<td>-0.004**</td>
<td>-0.00*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rental Volatility</td>
<td>-0.01</td>
<td>-0.00</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Down Market Dummy × Rental Volatility</td>
<td>-0.02*</td>
<td>-0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realized Rental Growth Rate</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Real Rent</td>
<td>0.50**</td>
<td>0.49**</td>
<td>0.50**</td>
<td>0.49**</td>
</tr>
<tr>
<td>Real HPI</td>
<td>-0.49**</td>
<td>-0.45**</td>
<td>-0.46**</td>
<td>-0.41**</td>
</tr>
<tr>
<td>Constant</td>
<td>1.30</td>
<td>1.20</td>
<td>1.71</td>
<td>1.44</td>
</tr>
</tbody>
</table>

Fixed Effects: state,time state,time state,time state,time

Observations: 1051 1051 1051 1051
R-squared: 0.99 0.99 0.99 0.99
Appendix

A Proof of Lemma 1

House sale requires a fixed transaction cost $K$ so potential sellers will not accept any price lower than that. Furthermore, there will be an opportunity cost of immediate sale which is the option value of keeping the house. Therefore, a potential seller’s reservation price will be the sum of transaction cost $K$ and the option value of waiting $h(y)$. For potential home buyers, the maximum amount they are willing to pay has two components. Buyers are willing to pay at least the present value of their rental cost for the expected duration. In addition, compared to rental housing, home ownership is endowed with the right to gain from future resale. As a result, in the event of broken match which occurs with probability $\eta$, owners become potential sellers and thus value the house as the sum of the resale option value and the transaction cost (i.e., $\eta(h(y) + K)$). Otherwise, their valuation equals the expected rental costs during tenure (i.e., $(1 - \eta)f(y)$).

B The Bargaining Game

We model the explicit bargaining game between buyers and sellers as an alternating-offers bargaining following Rubinstein and Wolinsky (1985)’s set up with simplifications and modifications needed by the specifics of our set up. We start with a discrete time game where agents can interact only at discrete periods in time, $t$ apart. Later, we get the continuous time result, which we use in our model, by letting $t$ go to zero.

At the beginning of each time period there is a matching stage in which each buyer (seller) may meet at most one new partner. We adopt a linear matching technology so that the overall rate of encounters is $M = L_{\text{buyer}}N_{\text{buyer}} + L_{\text{seller}}N_{\text{seller}}$ where $L_i$ can be
interpreted as the search intensity of each type of agents. Thus $L_{\text{buyer}}N_{\text{buyer}}$ for example is the total number of meetings initiated by buyers. Assume that all buyers (sellers) are equally likely to take part in one of the period’s meetings. Then it follows that at each matching stage the probability for each seller to meet a new partner is $\alpha = \frac{M}{N_{\text{seller}}t}$. Similarly, the match probability for each buyer is then $\beta = \frac{M}{N_{\text{buyer}}t}$. At the bargaining stage after a buyer seller pair is matched, each one of them is chosen randomly with probability $\frac{1}{2}$ to make an offer on how to split the trade gains. The other either rejects or accepts the offer immediately. If the offer gets accepted, trade is completed immediately and both agents leave the market. If, however, the offer is rejected, seller keep staying in the house during the current period. At the next period, one of the two agents is chosen at random independently with the same probability to make a new offer. However, the bargaining with the existing partner could break down before the new offer is made. The breakdown could happen if one of the two agents meet another partner (in the new matching stage at the beginning of the following period) and leaves his current partner.

Following Rubinstein and Wolinsky (1985), we consider symmetric semi-stationary strategies and look for a subgame-perfect equilibrium in steady state. The key insight is that at each period the offerer suggests an offer to leave the other agent indifferent between accepting and rejecting it and the value from rejecting is associated with the equilibrium strategies being played from then onwards. In the unique subgame perfect equilibrium, the offer is accepted immediately (Rubinstein, 1982; Rubinstein and Wolinsky, 1985). Let $q_s$ be the seller suggested seller’s share of trade gains and let $q_b$ be the buyer suggested seller’s share of trade gains. In addition, let $V_s(V_b)$ be seller’s (buyer’s) value function when the agent does not have a partner and let $W_s(W_b)$ be seller’s (buyer’s) value function when the agent has a partner. Then given linear utility, the equilibrium requires the
following conditions,

\[
q_s = e^{-\delta t} (\alpha W_s + \beta (1 - \alpha)V_s) + e^{-\delta t} (1 - \alpha)(1 - \beta)\left(\frac{1}{2}(q_s + q_b)\right) + O(t^2)
\]

\[
1 - q_b = e^{-\delta t} (\beta W_b + (1 - \beta)V_b) + e^{-\delta t} (1 - \alpha)(1 - \beta)\left(\frac{1}{2}(1 - q_s) + \frac{1}{2}(1 - q_b)\right) + O(t^2)
\]

\[
W_s = \frac{q_s + q_b}{2} + O(t^2)
\]

\[
W_b = \frac{1 - q_s}{2} + \frac{1 - q_b}{2} + O(t^2)
\]

\[
V_s = e^{-\delta t} (\alpha W_s + (1 - \alpha)V_s) + O(t^2)
\]

\[
V_b = e^{-\delta t} (\beta W_b + (1 - \beta)V_b) + O(t^2)
\]

(B.1)

This is a system of six equations in the six unknowns \(\{q_s, q_b, W_s, W_b, V_s, V_b\}\). Solving for \(q_s\) and \(q_b\), we plug in \(\alpha = \frac{M}{N_{\text{seller}}} t\) and \(\beta = \frac{M}{N_{\text{buyer}}} t\), let \(t\) go to zero and get,

\[
q \equiv q^* = q^*_b = \frac{N_{\text{buyer}} (M + N_{\text{seller}} \delta)}{M (N_{\text{seller}} + N_{\text{buyer}}) + 2N_{\text{buyer}} N_{\text{seller}} \delta}
\]

(B.2)

For our purpose, we assume \(\delta = 0\) and thus obtain the result in (2.6), where \(N_{\text{buyer}} = N_r \eta_r\) and \(N_{\text{seller}} = N \eta\).

C Proof of Proposition 1

Standard options pricing theory suggests that in a risk-neutral setup, absence of arbitrage requires that the value function of the resale option should evolve in such a way that the instantaneous return of the option value equals the risk-free interest rate. This leads to the ordinary differential equation as in (2.8).

We guess the functional form of \(h(y)\) to be \(Cy^\theta\) and plug it back in (2.8), which yields the quadratic function in \(\theta\),

\[
\frac{1}{2} \sigma^2 \theta (\theta - 1) + \mu \theta - r = 0
\]

(C.1)
There are two roots to the quadratic equation and the resale option is thus \( h(y) = C_1y_1 + C_2y_2 \), where
\[
\theta_1 = \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right) + \sqrt{\frac{2r}{\sigma^2} + \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right)^2} > 1
\]
\[
\theta_2 = \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right) - \sqrt{\frac{2r}{\sigma^2} + \left( \frac{1}{2} - \frac{\mu}{\sigma^2} \right)^2} < 0 \tag{C.2}
\]
Observe that zero is an absorbing boundary for the fundamental process \( y \). By continuity, this implies that as \( y \) approaches zero, the option value of further waiting should also go to zero, which helps us to eliminate the negative root of the above quadratic equation. The final form of \( h(y) \) is \( C_1y^{\theta_1} \) with \( C_1 \) and the exercise threshold \( y^* \) to be determined by invoking the boundary conditions. And we have,
\[
C_1 = \frac{(y^*)^{1-\theta_1}}{\theta_1} \frac{1}{(r-\mu)} \frac{\rho(1-\eta)}{1+\rho+\rho(1-\eta)} \tag{C.3}
\]

\section{D Repeat Buyers}

This section explicitly models repeat buyers who are at the same time sellers. For analytical tractability, we continue to adopt the fixed supply setting. There are two types of owner-occupied houses. Following the notation in Ortalo-Magne and Rady (2006), we call them “starter” homes and “trade-up” homes. For simplicity, they are identical in quality, so the implied rent processes are the same for the two types of houses. Potential buyers have different demands for the specific type of house to move in due to their idiosyncratic preferences. In particular, the three types of agents in this model are assumed to follow an order to climb their “property ladder”. Renters will move up to the starter homes. Starter home owners are potential buyers for the trade-up homes while the trade-up home owners will move back to the rental market if necessary. Again, mobility is driven by some exogenous random processes, upon which agents lose match with their current dwellings.
and need to move up (or down). We denote the exogenous probabilities of mobility as \( \eta_{\text{renter}} \), \( \eta_{\text{repeat}} \), and \( \eta \) for renters, repeat buyers and trade-up owners respectively. Then, with the population size for each group of agents being \( N_{\text{renter}} \), \( N_{\text{repeat}} \) and \( N \), we have the relative buyer seller ratio for each type of house as below,

\[
\rho_{\text{starter}} = \frac{N_{\text{renter}}\eta_{\text{renter}}}{N_{\text{repeat}}\eta_{\text{repeat}}}
\]

\[
\rho_{\text{tradeup}} = \frac{N_{\text{repeat}}\eta_{\text{repeat}}}{N\eta}
\]  \( \quad \text{(D.1)} \)

The trade gains for both types of houses are given by similar formulae as in (2.5),

\[
G_{\text{starter}}(y) = (1 - \eta_{\text{repeat}})(f(y) - h_{\text{repeat}}(y) - K)
\]

\[
G_{\text{tradeup}}(y) = (1 - \eta)(f(y) - h_{\text{tradeup}}(y) - K) \]  \( \quad \text{(D.2)} \)

Similarly the equilibrium bargaining powers for the seller of each type of house, using the explicit bargaining game as in B, are as follows,

\[
q_{\text{starter}} = \frac{\rho_{\text{starter}}}{\rho_{\text{starter}} + 1}
\]

\[
q_{\text{tradeup}} = \frac{\rho_{\text{tradeup}}}{\rho_{\text{tradeup}} + 1}
\]  \( \quad \text{(D.3)} \)

In determining the optimal sale timing, both starter seller (i.e. repeat buyer)’s resale option \( h_{\text{repeat}}(y) \) and trade-up seller’s resale option \( h_{\text{tradeup}}(y) \) follow the same evolution as in (2.8). It turns out that both types of agents’ optimal transaction thresholds are only functions of rental market fundamentals, as in the benchmark solution (2.13). Therefore, both starter home owners and trade-up owners face the same optimal transaction threshold, regardless of their mobility probabilities.

\[
y^*_\text{repeat} = y^*_{\text{tradeup}} = \frac{K\theta_1}{\theta_1 - 1}(r - \mu)
\]  \( \quad \text{(D.4)} \)
This confirms our benchmark model’s prediction that the optimal transaction thresholds and thus the decision to sell (or wait) only depend on key market fundamentals and they are identical across agents with different housing and mobility needs.

### E Endogenous Market Entry

We consider a case in which, in addition to the demographics-driven housing needs, agents choose to enter the market as a function of the price-rent ratio. When the current market price is high relative to the rent, there will be fewer (more) potential buyers (sellers) entering the market. This applies to both genuine home buyers and speculators who are trying to arbitrage on the price rent difference. Specifically, the additional market timing motives are captured by a scaling factor, i.e., $e^{A_b \frac{P(y)}{y} + B_b}$ for potential buyers and $e^{A_s \frac{P(y)}{y} + B_s}$ for potential sellers, where $A_b < 0$, $A_s > 0$, and $B_b$ and $B_s$ are constant numbers. One can also formalize and derive agent’s optimal response to the current price-to-rent ratio in a more structured model. For our purpose, we choose this reduced-form specification to capture the key intuition while ensuring a well-defined buyer (seller) entry and allow tractability as well as comparison with the benchmark model, which is a special case (by having $A_b,A_s,B_b,B_s$ equal zero).

\[
\text{# of potential buyers} = e^{A_b \frac{P(y)}{y} + B_b} N_r \eta_r \\
\text{# of potential sellers} = e^{A_s \frac{P(y)}{y} + B_s} N \eta
\]
and,

\[
\tilde{\rho}(y) = \frac{\# \text{ of potential buyers}}{\# \text{ of potential sellers}} = \frac{e^{A_b y + B_b N_r \eta r}}{e^{A_s y + B_s N_r \eta}} = e^{A_s y + B_s \rho} 
\]

where \( A = A_b - A_s < 0, B = B_b - B_s \), and \( \rho \) is the constant buyer seller ratio in the benchmark model.

In this case, there is no change in each individual buyer’s or seller’s reservation price \((P_{buyer}(y), P_{seller}(y))\) and total trade gain \((G(y))\). However, the equilibrium price takes the following form and will be affected by the endogenous market entry decisions of potential buyers and sellers (through a time-varying bargaining position of potential buyers and sellers).

\[
\tilde{P}(y) = (K + h(y))(1 - (1 - \eta)\frac{\tilde{\rho}(y)}{\tilde{\rho}(y) + 1}) + (1 - \eta) f(y) \frac{\tilde{\rho}(y)}{\tilde{\rho}(y) + 1}
\]

The resale option value follows the same ODE as in (2.8). The modified boundary conditions become,

\[
h(y^*) = \frac{\tilde{\rho}(y^*)}{\tilde{\rho}(y^*) + 1} G(y^*)
\]

\[
h'(y)|_{y=y^*} = \frac{d(\frac{\tilde{\rho}(y)}{\tilde{\rho}(y) + 1} G(y))}{dy}|_{y=y^*}
\]

There is no closed form solution to this system, since the buyer-seller ratio \((\tilde{\rho}(y))\) and thus the equilibrium price \(\tilde{P}(y)\) is highly nonlinear in \(y\). Numerical solution is derived and compared with the benchmark case. Similar as before, the optimal exercise threshold \((y^*)\) is decreasing in the rental growth rate and increasing in the volatility. On the other hand, under the assumption that more (fewer) buyers (sellers) enter the market when the
price is relatively low, allowing endogenous market entry on average decreases the resale option value. This is because a rise in in potential buyers, given a low market price, effectively increases the potential sellers’ bargaining power at such times. In addition, an expected increase in seller entry in response to high market price implies less trade surplus to be extracted by potential sellers, which reduces the expected gain in waiting to sell the house at a favorable time in the future. Taken together, waiting is less attractive for potential sellers with endogenous market entry. For brevity, we do not present the numerical solution or the comparative statics of the extended model with endogenous entry. The results are available upon request.