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Endogenous Sources of Volatility in Housing Markets: The Joint Buyer-Seller Problem

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Abstract

This paper presents new empirical evidence that internal movement - selling one home and buying another - by existing homeowners within a metropolitan housing market is especially volatile and the main driver of fluctuations in transaction volume over the housing market cycle. We develop a dynamic search equilibrium model that shows that the strong pro-cyclicality of internal movement is driven by the cost of simultaneously holding two homes, which varies endogenously over the cycle. We estimate the model using data on prices, volume, time-on-market, and internal moves drawn from Los Angeles from 1988-2008 and use the fitted model to show that frictions related to the joint buyer-seller problem: (i) substantially amplify booms and busts in the housing market, (ii) create counter-cyclical build-ups of mismatch of existing owners with their homes, and (iii) generate externalities that induce significant welfare loss and excess price volatility.

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1 Introduction

The major boom and bust over the 2000s has drawn attention to the volatility of the US housing market and its implications for the broader economy. While the national scope of this most recent cycle was unusual, metropolitan and regional housing markets, as well those of smaller countries, exhibit cyclical behavior on a very regular basis.[1] Booms and busts generally occur over protracted periods of time and are characterized by large fluctuations in price, transaction volume, and time-to-sell.

While these facts about housing cycles are well-established, explanations for their size and duration are not as obvious. Several studies have shown that movements in fundamentals like income, wages, and rents are not large enough to explain the observed fluctuations in house prices (see Head et al. [2011] and Case and Shiller [1989]). Excess housing price volatility is perhaps even more puzzling when one considers that a large fraction of transactions consist of homeowners moving within a metro area. Even if aggregate volatility is driven by fluctuations in external demand – from new migrants or first-time home buyers – one might expect the supply and demand for housing by "internal movers" selling one house and buying another at about the same time to be less sensitive to the price level and, therefore, a stabilizing force on the local market. Yet, in this paper, we will argue that the timing of the buying and selling decisions of these internal movers has exactly the opposite effect, greatly amplifying price fluctuations over the cycle rather than smoothing them.

We begin the paper by using detailed records on the universe of transactions in the Los Angeles metropolitan area from 1992-2008 to establish a series of new empirical facts about the nature of housing transactions over the cycle. Following homeowners as they buy and sell houses, we first show that internal transaction volume is incredibly volatile and indeed much more pro-cyclical than external volume.[2] In particular, internal transaction volume at the peak of the boom in 2003-2005 is three times greater than in the preceding trough in 1993 and four times greater than in the subsequent trough in 2008, while external transaction volume varies in a much more narrow band. As a result, the fraction of homes sold by

[1] See Burnside et al. [2011] for empirical evidence.

[2] An internal transaction is defined as one in which the seller buys another property within the metro area. An external transaction is defined as one in which the seller does not.

internal movers is highly pro-cyclical, ranging from a low of 20 percent in the trough years to over 40 percent in the peak years. We demonstrate that similar patterns hold for internal transaction volume in various volatile housing markets across the country[3] and that the substantial volatility of internal movement over the cycle holds for households with both low and high loan-to-value ratios.[4]

To gauge the economic and welfare implications of the volatility of internal movement, we develop and estimate a dynamic equilibrium search model in which the complementarity of internal movers' buying and selling decisions has the potential to amplify fundamental cyclical forces. Our framework is a simple search model in the spirit of Mortensen and Pissarides [1994] and Pissarides [2000], in which the housing market is segmented into a market for "starter homes" and a market for "trade-up homes". The novel features of our model are (i) that the decision of internal movers to buy their trade-up home before selling their starter home, or vice versa, is *endogenous* and (ii) that the consumption value of holding two homes simultaneously is less than the sum of the values of residing in each property individually (e.g., a household gets little consumption value from holding a second house empty while awaiting a suitable buyer). In the model, an exogenous mismatch shock provides the impetus for homeowners to trade-up or exit the metropolitan area. The fundamental source of equilibrium volatility is the exogenous fluctuation in external demand to purchase a home in a metropolitan area housing market.

We estimate the model using data on prices, volume, time-on-market (TOM), and internal moves drawn from our Los Angeles sample. The estimated model fits the equilibrium co-movements of these variables as well as the level of price volatility and the new empirical facts that we document related to internal movement over the cycle very well.

In the estimated model, the attractiveness of buying-before-selling varies endogenously over the cycle in a way that amplifies boom-bust episodes and contributes to the pro-cyclicality of internal movement. To see how, consider a "buyer's market" in which prices

[3]We show internal movement patterns for MSAs outside Los Angeles using the FRBNY/Equifax Consumer Credit Panel data.

[4]As we discuss in more detail in Section 2, volatility in the internal movement of households with high LTVs may also be related to lock-in effects of equity constraints, while such considerations should not play a role for households with substantial equity remaining in their homes (low LTVs).

are declining and time-to-sell is high. In these market conditions, existing homeowners are especially unwilling to buy before selling. Such an action would put the household in a position of owning two assets declining in value – but only receiving the consumption benefits from one of them – in a market in which houses are generally taking a long time to sell. Collectively, as existing owners hold out to sell before purchasing, internal transaction volume slows considerably, further cooling the market. Over time, the pool of households mismatched with their homes builds and when the market begins to heat up again, these mismatched households are able to trade-up at a faster pace.

We conduct two counterfactual simulations to show how the presence of agents simultaneously active on both sides of a search market affects market volatility.[5] In the first simulation, we break the linkage between the starter and trade-up market so that sellers in the starter market make decisions without regard to market conditions in the trade-up market. This simulation distinguishes the role of basic search and matching frictions from the role of the joint buyer-seller problem in driving market volatility. Relative to a setting in which just search and matching frictions operate, the results imply that the joint buyer-seller problem increases the volatility of transaction volume by about 10 percent and *more than doubles* the price volatility.

The increase in price volatility associated with the joint buyer-seller problem is directly related to the effective cost of holding two homes simultaneously, which, not surprisingly, is estimated to be quite high. We show this with a second counterfactual simulation that re-introduces the joint buyer-seller problem, but allows homeowners to realize more of the consumption benefits from a second home, so that they are more willing to buy before selling in equilibrium. When the effective cost of holding two properties is small enough (as might be the case if a short-term tenant were available), we demonstrate that aggregate price and volume volatility can, in fact, be *lower* than in the first counterfactual simulation. In this case, internal demand helps to dampen fluctuations in external demand – e.g., when there is a negative shock to the pool of external buyers, demand from internal movers rises because buying conditions are favorable. When the cost of owning two homes is higher, however,

[5]Other classic search markets, such as labor or retail markets, are characterized by the presence of a distinct set of agents on each side of the market.

a drop in external demand leads to a decline in internal demand as internal movers are reluctant to trade-up until they have sold their starter home. At the parameters that best fit the data, this thin market effect dominates the smoothing effect, and the joint buyer-seller problem leads to a substantial increase in price volatility.

Like most search and matching models, our model delivers an inefficient equilibrium because buyers and sellers do not internalize the effect of their transaction decisions on market tightness. An additional externality arises in our context because there is feedback from one segment of the market to another: selling decisions in the starter market affect demand in the trade-up market. We quantify the inefficiency by numerically solving the social planner's problem. The social planner improves discounted lifetime utility per transaction by an equivalent variation of $7450 (or 1.5 percent of the average sales price) on average, and we show that a majority of the welfare loss is due to externalities that arise from the joint buyer-seller problem rather than basic search and matching frictions.

One notable feature of the centralized equilibrium is that there is half as much volatility over time in prices,[6] and we show that much of the price volatility in the decentralized equilibrium is due to inefficient timing of transactions when there is feedback from one segment of the market to another. This suggests that large booms and busts are not unavoidable consequences of search frictions; the right set of policy interventions could, in principal, attenuate fluctuations in price without changing the search technology. Indeed, we find that a revenue-neutral, time-invariant policy intervention that subsidizes home purchases by external buyers, taxes home purchases by internal buyers, and subsidizes the cost of remaining on the market for "motivated" sellers (i.e. those with high holding costs) shifts the economy to an equilibrium that closely coincides with the centralized equilibrium. The policies that we consider bear some resemblance to real-world first-time home buyer tax credits and housing transaction taxes. Our model offers some intuition for why these types of interventions may be welfare improving in the presence of search frictions and feedback from one segment of the market to another.

Our paper contributes to a growing literature starting with Wheaton [1990] that applies

[6] Note that this closely matches the price volatility in the counterfactual simulation in which we effectively break the jointness of the buying and selling problems for internal movers.

search theory to housing markets. From a methodological perspective, our paper extends the existing housing search literature by developing and estimating a dynamic equilibrium model with endogenous cycling. The vast majority of the existing literature selects parameter values to convey the broad intuition of the model's predictions (e.g. Krainer [2001],Novy-Marx [2009]) or calibrates the model based on steady state predictions. While some recent papers consider the non-steady state dynamics of their models, we are not aware of any other papers in the housing search literature that fits the model using the dynamics of the key market variables in the data, as we do. In this respect, our empirical approach is related to Shimer [2005] and Robin [2011] in the labor search literature, which estimate models using the dynamics of unemployment, wages, and vacancies. From an empirical perspective, we contribute to the growing literature on the causes and consequences of housing market cycles by highlighting a new mechanism – the joint buyer-seller problem – that is capable of matching the key stylized facts about equilibrium market dynamics, as well as the new facts that we document related to internal movement over the cycle.[7]

2 Motivating Empirical Facts

Before describing our model, we begin by establishing a series of new empirical facts that suggest that the dual buyer-seller roles of agents in the market may be an important source of market friction. We also summarize a few other key features of housing market dynamics that have been well-documented in the literature. These facts will both motivate the key elements of the model and serve as moments for the GMM estimator that we develop below.

[7]A number of recent papers emphasize alternative mechanisms that may be complementary to the joint buyer-seller problem. For example, Burnside et al. [2011] model heterogeneous expectations and social dynamics in a search environment; Head et al. [2011] focus on the interaction between an endogenous construction sector and search and matching frictions; Piazzesi and Schneider [2009] focus on the role of optimistic investors on prices in a simple search framework; and Ngai and Tenreyro [2010] focuses on increasing returns to scale in the search technology. Other related studies include Krainer [2001],Carrillo [2012],Albrecht et al. [2007],Diaz and Jerez [forthcoming],Genesove and Han [2012],Novy-Marx [2009],Caplin and Leahy [2011].

2.1 Data

The data for this section of the paper are drawn from detailed records on the universe of housing transactions in the Los Angeles metropolitan area from January 1988-June 2009. Dataquick is the provider of these data. The records include precise information on the property and structure, the transaction price, the date of the transaction, and, most importantly, the names of the buyer(s) and seller(s). When spouses purchase houses jointly, both names are observed on the property record.

By matching the names of individuals who are observed to sell and buy a house within a limited time frame, we are able to follow existing homeowners as they move within the metropolitan area. We classify a transaction as an internal move if 1) the seller appears as the buyer on a different transaction and 2) the transactions are within 12 months of each other. Because of abbreviations, marriages, name changes, etc., the name match is not straightforward and some arbitrariness is introduced when determining a match quality threshold. After familiarizing ourselves with the data, we decided that an appropriate *minimum* criteria for a match is that the last names of the buyer(s) and seller(s) match exactly and the first three letters of the first name(s) match exactly. However, we verified that the main empirical facts described below are robust to alternative choices for the match quality threshold. As described below, we also use the FRBNY/Equifax Consumer Credit Panel data as a robustness check and to provide external validity.

Before examining the data on transactions and movement, it is helpful to characterize the market cycles in the Los Angeles metropolitan area over this time period. To this end, Figure 1 presents a real housing price index for the LA metropolitan area from 1988-2008, calculated using a repeat sales analysis similar to Shiller [1991]. The underlying data for this and the other figures presented in this section are shown in Table 1. The Los Angeles market experienced booms in the late 1980s and in the early 2000s. In between these booms, the market experienced a substantial bust with real housing prices falling by 45 percent from 1990-1996. Much like the US housing market as a whole, the Los Angeles metropolitan area experienced a major bust following the early 2000s boom. Figure 1 also shows transaction volume and the median TOM over the cycle.[8] Like prices, transaction volume and TOM

[8]Dataquick does not report any information about the house listing such as TOM. The TOM data

are quite volatile over time, and they are positively and negatively correlated with prices, respectively.

2.2 Internal Movement

As shown in Table 1 and Figure 2, internal movement is highly pro-cyclical and volatile, much more so than external transaction volume.[9] The volume of internal transactions increased three-fold over the price run-up in the late 1990's and early 2000's, and fell by a comparable level during the most recent bust. External transaction volume was much steadier in comparison: it increased by less than 50 percent during the run-up and fell by less than 50 percent during the bust. Most of the pro-cyclicality of total transaction volume comes from the pro-cyclicality of internal volume. As a result, "the internal mover share" (i.e. the fraction of transactions where the seller is an internal mover) shown in Table 1 and Figure 4 is strongly pro-cyclical and volatile, ranging from a low of 20 percent in the trough years to over 40 percent in the peak years.

To ensure that our results on internal movement are not unique to Los Angeles or dependent on any assumptions in our name matching algorithm, we also examine internal movement using the FRBNY/Equifax Consumer Credit Panel data. Using these data, we can track when homeowners throughout the country move using a household id (i.e. we do not need to match names) and we can see whether they move within or outside their MSA. Owner occupancy is not observed directly but is inferred from the mortgage information of the individual. We find that the level of the internal mover share is comparable in the Equifax data during the years in which the two datasets overlap. In Equifax, the average internal mover share for MSAs in California between 2001-2008 is 38 percent, versus 35 percent for Los Angeles using the Dataquick data. We not only find that the internal mover share is positively correlated with the house price cycle for MSAs in California; we also find that across MSAs in the U.S., differences in the volatility of the internal mover

presented here comes from the California Association of Realtors (CAR) for LA county. Data provided to authors by Oscar Wei, Senior Research Analyst at CAR.

[9] We cannot break out total transaction volume into internal and external movement during the years before 1992 because the buyer and seller names are severely truncated in the Dataquick data for those years.

share over time are strongly related to across MSA differences in house price dynamics, as illustrated in Appendix Figure 1. The details of the Equifax data and the analyses are discussed in Appendix A. Appendix A also discusses a third robustness check we conduct using the American Housing Survey for Los Angeles. This dataset is more limited, but it confirms our finding that most housing transactions are indeed external.

Returning to the Los Angeles housing transaction data, Figure 3 plots the distribution of sell date minus purchase date for internal movers. It is much more common for internal movers to close on the sale of their existing home before closing on the purchase of their next home; over 70 percent of the mass lies to the left of zero, inclusive. We find evidence that selling-before-buying is more common using the Equifax data as well, as described in Appendix A. An explanation for this stylized fact is that buying-before-selling temporarily puts the homeowner in a position of owning two homes, but only receiving the consumption benefits from one of the homes. Recouping the consumption value of the vacant home by renting it out for a short period of time is usually not feasible given that renters prefer longer term leases due to large moving costs. Thus, the holding costs of owning two homes simultaneously are high, which discourages agents from taking this position, all else being equal.[10][11]

One prediction of a model in which the holding cost of a second home is high is that the sales price for homes sold by owners holding two positions should be lower, all else equal. The reason is that in an illiquid market, higher holding costs should translate into lower reservation prices for sellers and, therefore, lower transactions prices. Table 2 tests this prediction in the data. In particular, we estimate a regression in which the dependent variable is the difference between the log sales price and a log "predicted market" price and the regressors are dummy variables for each window of "sell date - purchase date" from Figure 3. The sample includes all internal movers, so that the comparison is between internal movers who buy and sell at various times. The log predicted market price is calculated in a

[10] Households may also face binding borrowing constraints that make it difficult to hold two mortgages simultaneously for a considerable length of time.

[11] Contingency clauses (i.e. agreeing to buy contingent on being able to sell) does not circumvent the cost of buying-before-selling. These contracts typically allot a finite period of time for the home to be sold, which effectively increases the holding costs of the second home.

first stage through a repeat sales analysis.[12] Homes sold by sellers who bought first sell for less than what a repeat sales analysis would predict. Depending on where around zero the cut-off for buying-before selling is made, the average discount is about 3-4 percent.[13] The second column shows that there is not much difference between internal movers who buy versus sell first in the price that they pay for the new home that they purchase. The theory in this case is more ambiguous. We discuss this within the context of our model in Section 5.

2.3 Alternative Explanations for Internal Transaction Volume Over the Cycle

The model that we develop below focuses on the high holding costs associated with two housing positions as an explanation for the pro-cyclicality of the internal mover share. A potential important alternative or complementary explanation is that internal moves slow *disproportionately* during busts because homeowners looking to buy another home within the metro area lack sufficient equity to make a downpayment on a new home.[14] If this explanation is the primary driver of the overall pro-cyclicality in the internal mover share, then we would expect the pro-cyclicality of internal movement to be weaker among sellers with high levels of implied equity in their initial property. However, Figure 4 shows that when we restrict our sample to transactions where the seller's LTV[15] is less than 80 percent,

[12]For each house, we apply the level of appreciation or depreciation estimated by the Case Shiller house price index for Los Angeles to the previous purchase price. Transactions that do not have a previous price during our sample window are excluded from the second stage regression.

[13]For transactions that close within a few days of each other, it is more likely that the order of the agreement dates for the buy and sell is not the same as the order of the closing dates because contingency clauses can be used to time moves within a couple days for each other.

[14]For a theoretical treatment of the effect of equity constraints on the housing market, see Ortalo-Magne and Rady [2006], Stein [1995]. Several empirical studies have tested whether low equity affects mobility and the results are mixed (see Chan [1997], Ferreira et al. [2010], Coulson and Grieco [2013], Schulhofer-Wohl [2011]). We are not aware of any studies that directly examine whether low equity affects the propensity of a mover to buy another home in the same MSA.

[15]We calculate LTV by amortizing the original loan amount (including first, second, and third mortgages) at the prevailing interest rate (assuming a 30 year fixed rate mortgage), and updating the original purchase

the pro-cyclicality of the internal mover share is just as strong, if not stronger, than the pro-cyclicality in the full sample. Since there is measurement error in LTV, we also restrict the sample at LTV less than 60 percent to be sure that we are indeed capturing homeowners with significant equity in their homes. As shown in Figure 4, the same results hold at LTV less than 60 percent, suggesting that equity constraints are not driving the pro-cyclicality of the internal mover share.[16][17]

3 Model

3.1 Overview

We now develop a dynamic equilibrium model of housing market search. Our primary goal is to develop the simplest model necessary to highlight how the complementarity of buying and selling decisions affects the housing market equilibrium. To this end, we build off of the classic Diamond-Mortensen-Pissarides random search framework. Buyers and sellers in a city are searching for one another, and each matching generates an idiosyncratic match quality that describes the buyer's taste for the particular home. Some sellers are also acting as buyers. We model this by segmenting the housing stock into two sectors, a starter market

price using the Los Angeles Case-Shiller house price index.

[16]Cutting the sample to LTV less than 80 percent drops 23 percent of the transactions in the full sample. Cutting the sample to LTV less than 60 percent drops 42 percent. Zillow also finds that a clear majority of homeowners have LTVs less than 80 percent, even at the trough of the market. Source: http://www.zillowblog.com/research/2013/02/20/nearly-2-million-american-homeowners-freed-from-negative-equity-in-2012/.

[17]We comment on two other explanations for a slowdown in internal movement and argue that they do not preclude a role for our mechanism either. One possibility is that the pro-cyclicality of internal movement is being driven by flippers (Bayer et al. [2011]). However, as discussed in Appendix A, when we use the Equifax data to document internal movement, we exclude movers who hold multiple mortgages at a time, which should minimize the role of flippers in explaining the dynamics of internal movement, and we still find that internal movement is highly pro-cyclical. Another possibility is nominal loss aversion (Genesove and Mayer [2001], Engelhardt [2003], Anenberg [2011]). However, loss aversion should slow *total* movement during busts. The theory does not predict that those moving internally are disproportionately susceptible to loss aversion.

and a trade-up market, and agents selling starter homes are simultaneously in the market to buy a trade-up home. Agents gradually flow up the housing ladder, although sometimes exogenous shocks will cause them to exit the city prematurely. Many features of our model are standard. Prices are determined through complete information Nash bargaining over the transaction surplus. The matching function is constant returns to scale as in most of the housing search literature. This ensures that any amplification of market shocks will come from the joint buyer-seller problem and not from an assumption on the search technology such as increasing returns to scale.

Two features of the model are unique. First, the decision to buy a trade-up home before selling a starter home, or vice versa, is endogenous, and, second, we allow the flow utility of being a seller to depend on whether the seller has already purchased a trade-up home. This extension to a basic search and matching model is not trivial because it means that buyer and seller value functions can no longer be written independently. Second, our model generates endogenous cycling through shocks to the size of the pool of active searchers. This is in contrast to much – but not all – of the existing housing search models, which investigate dynamics based on a comparison of steady states.[18]

3.2 Environment and Preferences

Time is discrete. Agents discount the future at rate β. As in the discussion in Section 2, the model focuses on activity in a single housing market, which we call a city, and takes activity outside this area as exogenous. There is a fixed stock of homes in the city normalized to have measure one. This assumption is motivated by the empirical evidence that large amounts of volatility occur in cities such as Los Angeles where increases in housing supply are limited by zoning laws, land scarcity, or infrastructure constraints.[19] We divide the housing stock into two types, which we call starter homes (abbreviated as S) and trade-up homes (abbreviated

[18]Krainer [2001] generates endogenous cycling, but only with significant fluctuations in prices when exogenous, aggregate shocks to the housing dividend are highly persistent. We generate cycling with time invariant housing dividends by allowing the search process to depend on the market tightness; market tightness plays no role in Krainer [2001] as each seller is automatically matched with one buyer each period.

[19]See e.g. Quigley and Raphael [2005] and Glaeser et al. [2005].

as R), with measure m_S and m_R. Agents in the economy have heterogenous preferences for these homes. In equilibrium, there will be three types of homeowners. Owners can be matched with one home, mismatched with one home, or mismatched with a single starter home and matched with a single trade-up home. Preferences are set such that no other combination of homes will be owned in equilibrium.

The mismatch process works as follows. New owners always begin in the matched state. Matched homeowners become mismatched at rate λ. Upon mismatch, trade-up owners become mismatched with the city and exit the city upon sale of their home.[20] A fraction $1-\pi$ of newly mismatched starter owners also become mismatched with the city. The remaining fraction, π, exogenously develop a taste for trade-up homes such that, upon purchase of a trade-up home, these mismatched starter owners will begin in the matched state. The notation for the mismatch process, and all of the other parameters that we introduce, are summarized in Table 4.[21]

There are also non-homeowners. Non-homeowners are either looking to buy a starter or trade-up home, but not both.[22] We assume that γ_t^τ non-homeowners with a preference for home type τ exogenously enter the economy each period, where (γ_t^S, γ_t^R) are random variables. In our empirical work, this inflow process will be iid over time.

We now specify the utilities associated with each of the possible states in equilibrium.

[20]The assumption that trade-up owners cannot get mismatched and then enter the starter market is made for simplicity and is not important for our results that follow.

[21]This discussion abstracts from a few technical points that formally deliver the preferences and equilibrium allocation of homes described above. We are assuming that a matched owner receives a large negative utility from being matched with another one of the homes in the economy and that the cost of owning three homes simultaneously is prohibitive. We also assume that the utility of owning a different home after having been matched with a trade-up home is sufficiently low that it never happens in equilibrium. Likewise, the utility of owning a different starter home after having been matched with a starter home is sufficiently low. Finally, we assume that agents who are mismatched with a single starter home and matched with a single trade-up home cannot get mismatched with the trade-up home while they are in this state. This assumption significantly simplifies computation and does not affect the main results because the mass of agents who would be mismatched with both homes is very small for the parameters we consider.

[22]Formally, we assume that agents can begin in the matched state upon purchase of either a starter home or a trade-up home, but not both.

Matched agents receive a flow utility, ϵ_i, that is heterogenous for each agent i. We assume that the distribution of ϵ depends neither on time nor house type. Mismatched owners receive the constant flow utility u_{mm} or u_{mmo} depending on whether they are mismatched with their house type or mismatched with the city, respectively. Agents who are mismatched with a single starter home and matched with a single trade-up home receive a flow utility $\epsilon_i + u_{mm} - u_d$. The penalty, u_d, reflects, in a reduced form way, that the frictions described in Section 2 constrain the ability of agents to fully realize the consumption benefits of two homes simultaneously. Non-homeowners receive the flow utility, u_b. Agents who exit the economy receive the flow utility u_O.

In order for an agent to buy or sell a house, the agent must be "on the market" as a buyer or seller. The markets for trading starter homes and trade-up homes are distinct. We assume that there are nominal fixed costs to being on the market such that in equilibrium, only mismatched owners are on the market as sellers and non-homeowners are on the market as buyers in the market of their preferred type. Mismatched starter owners with a taste for trade-up homes are on the market simultaneously as a potential buyer in the trade-up market and as a seller in the starter market. Note that under our assumptions, while a single agent can simultaneously be a buyer and a seller, a single agent is never simultaneously a buyer and seller in the same submarket. The latter situation would significantly complicate the equilibrium given the meeting technology described below. That internal movers buy and sell in distinct markets in our model is roughly consistent with the data, as changes in house type when households move are typically significant.

We summarize below the eight different pools of agents in the equilibrium of this economy, differentiated by their ownership status and whether they are on the market as a buyer or seller. We also summarize the flow utility associated with being in each pool.

- Starter Buyers (SB), u_b: Non-homeowners with a preference for starter homes.
- Starter Owners (S), ϵ_i: Agents that are matched with a starter home.
- Starter Sellers with Preference for Trade-up homes (SS), u_{mm}: Agents that are mismatched with a starter home and have a taste for trade-up homes.

- Trade-up Buyers (RB), u_b: Non-homeowners with a preference for trade-up home.
- Trade-up Owners (R), ϵ_i: Agents that are matched with a trade-up home.
- Trade-up Sellers (RS), u_{mm}: Agents that are mismatched with a trade-up home.
- Dual Position Sellers (D), $\epsilon_i + u_{mm} - u_d$: Agents that own a starter home and a trade-up home.
- Starter Sellers with Preference to exit (SSO), u_{mmo}: Agents that are mismatched with a starter home and have a taste to exit the city.

Note that the higher is u_d, the higher is the match quality, ϵ_i, that is necessary to induce internal movers to buy before selling.

3.3 Meetings

A necessary condition for a house sale is a meeting between a buyer and seller. Following Pissarides (2000), the number of meetings in market $\tau = S, R$, is determined through a matching function $M_\tau(\cdot, \cdot)$ which takes as inputs the mass of buyers and sellers for house type τ. The matching function is increasing in both its arguments, concave, and homogeneous of degree one. Buyers and sellers experience at most one match with the opposite type each period. The probability that any buyer (seller) finds a match is simply M divided by the mass of active buyers (sellers).

Each meeting produces the idiosyncratic match quality, ϵ_i, that is revealed to both the buyer and the seller. This shock can be interpreted as the buyer's idiosyncratic taste for the particular house. We impose our parametric assumption on ϵ now to ease presentation of the value functions that follow:

$$\epsilon \sim N(u_m, \sigma^2) \tag{1}$$

and is *iid* across time, matches, and markets.

3.4 Trade

Trade occurs whenever the total gains from trade exceed the total gains from continued search by both parties. Below, we make these transaction thresholds explicit. If a transaction occurs, the total surplus is split among the buyer and selling according to the weights $1-\theta$ and θ, respectively. Formally, this is the solution to the complete information Nash bargaining game when the bargaining power of the buyer and seller is $1-\theta$ and θ. In order to achieve this allocation of the surplus, a transfer, p^*, is made from one party to the other if necessary. This transfer can be interpreted as a price. The five types of housing transactions that can occur in this economy are given by: 1) SB buys from SS; 2) SB buys from SSO; 3) SB buys from D; 4) RB buys from RS; 5) SS buys from RS.

To summarize, agents transition between pools as follows:

$$
\begin{array}{lllllllllllll}
\gamma^S & & & & & & \gamma^R & & & & & & \\
\downarrow & & & & & & \downarrow & & & & & & \\
SB & \Rightarrow & S & \rightarrow & SS & \Rightarrow & RB \text{ or } D & \Rightarrow & R & \rightarrow & RS & \Rightarrow & \text{Exit} \\
 & & \downarrow & & & & & & & & & & \\
 & & SSO & \Rightarrow & \text{Exit} & & & & & & & &
\end{array}
$$

Transitions that occur endogenously through trade are highlighted with thick arrows. The remaining transitions are the result of exogenous mismatch shocks or inflow into the market. We define a sale of a starter home by a member of SS or D as an internal transaction.

3.5 Timing

In each period, the following sequence of events occurs:

1. Buyers in the starter market meet sellers in the starter market according to the matching technology.

2. Trade occurs.

3. Buyers in the trade-up market meet sellers in the trade-up market according to according to the matching technology.

4. Trade occurs.

5. Agents consume their flow utility.

6. Mismatch shocks are realized.

7. Inflow into the city shocks are realized.

3.6 Value Functions

We now characterize the dynamic problem of each type of agent given the vector of state variables (Ω, I) where $\Omega = (SB_t, RB_t, SS_t, RS_t, D_t, SSO_t)$ denotes the mass of agents in each pool, $I = 1$ indicates that the starter market is moving, and $I = 2$ indicates that the trade-up market is moving. In some cases, it will not be necessary to define the value function, V, for both $I = 1$ and $I = 2$. For example, agents can only make decisions that result in entry or exit from the starter buyer pool when $I = 1$, and thus we omit the characterization of $V^{SB}(\Omega, 2)$. Note that with a fixed housing stock, $R = m_R - D - RS$ and $S = m_S - D - SS - SSO$ so it is redundant to include R and S in the state space.

3.7 Owners

The expected lifetime utility of being a starter owner given match quality ϵ_i is

$$V^S(\Omega, 1, \epsilon_i) = \epsilon_i + \beta \int_{\gamma^S, \gamma^R} \Big(\lambda(\pi V^{SS}(\Omega', 1) + (1-\pi) V^{SSO}(\Omega', 1)) + (1-\lambda) V^S(\Omega', 1, \epsilon_i) \Big). \quad (2)$$

In words, with probability λ, the starter owner becomes mismatched and either becomes a member of SS or SSO with probability π and 1-π, respectively; with probability (1-λ), the owner remains a starter owner, which produces the flow benefit ϵ_i. Uncertainty is over the number of new entrants into the buyer pools. The state space also changes from Ω to Ω' due to the buying and selling activity in the starter and trade-up market, but this is perfectly forecastable using the laws of motion outlined in Appendix B.

Iterating on the above expression, we can rewrite (2) as a component that depends on the match quality, ϵ_i, and an additively separable component that does not:

$$\begin{aligned}
V^S(\Omega, 1, \epsilon_i) = \frac{\epsilon_i}{1-\beta(1-\lambda)} + \beta \int_{\gamma^S, \gamma^R} \Big(& \lambda(\pi V^{SS}(\Omega', 1) + (1-\pi) V^{SSO}(\Omega', 1)) + \\
& \beta(1-\lambda) \int_{\gamma^{S'}, \gamma^{R'}} (\lambda(\pi V^{SS}(\Omega'', 1) + (1-\pi)V^{SSO}(\Omega'', 1)) + ...) \Big) \\
& = \tilde{\epsilon}_i + U^S(\Omega', 1)
\end{aligned} \tag{3}$$

where $\tilde{\epsilon}_i \sim N(\tilde{u}_m, \tilde{\sigma}^2)$ and

$$\tilde{u}_m = \frac{u_m}{1-\beta(1-\lambda)} \tag{4}$$

and

$$\tilde{\sigma}^2 = \frac{\sigma^2}{(1-\beta(1-\lambda))^2}. \tag{5}$$

Similarly, we write the expected lifetime utility of being a trade-up owner as:

$$\begin{aligned}
V^R(\Omega, 1, \epsilon_i) &= \epsilon_i + \beta \int_{\gamma^S, \gamma^R} (\lambda V^{RS}(\Omega', 1) + (1-\lambda)V^R(\Omega', 1, \epsilon_i)) \\
&= \tilde{\epsilon}_i + U^R(\Omega', 1)
\end{aligned} \tag{6}$$

3.8 Starter Buyers

Before writing down the remaining value functions, we first introduce some notation that defines the total surplus of the five types of potential transactions in the economy:

Total Surplus when a SB and SS meet: $U^S + \tilde{\epsilon}_i - V^{SB} + V^{RB} - V^{SS} = TS_{SB,SS} + \tilde{\epsilon}_i$

Total Surplus when a SB and SSO meet: $U^S + \tilde{\epsilon}_i - V^{SB} + V^O - V^{SSO} = TS_{SB,SSO} + \tilde{\epsilon}_i$

Total Surplus when a SB and D meet: $U^S + \tilde{\epsilon}_i - V^{SB} + V^R - V^D = TS_{SB,D} + \tilde{\epsilon}_i$

Total Surplus when a RB and RS meet: $U^R + \tilde{\epsilon}_i - V^{RB} + V^0 - V^{RS} = TS_{RB,RS} + \tilde{\epsilon}_i$

Total Surplus when a SS and RS meet: $U^D + \tilde{\epsilon}_i - V^{SS} + V^0 - V^{RS} = TS_{SS,RS} + \tilde{\epsilon}_i$

where $V^O = \frac{u_O}{(1-\beta)}$ is the lifetime utility of an agent that exits the economy. Once we present the equations for the remaining value functions, it will be clear that for a given transaction type and within a given time period, the only idiosyncratic component to the total surplus is $\tilde{\epsilon_i}$.[23]

Using this notation and plugging in the solution to the nash bargaining problem when a match occurs, we can write the expected lifetime utility of being in the SB pool when the starter market is moving as:

$$\begin{aligned} V^{SB}(\Omega,1) =& u_b + \beta \int_{\gamma^S,\gamma^R} \Bigg(V^{SB}(\Omega',1) + \frac{M(SB', SS'+D'+SSO')}{SB'} \sum_{j=SS',D',SSO'} (\frac{j}{SS'+D'+SSO'})* \\ & (1-\theta)(\Phi(\frac{TS_{SB',j}+\tilde{u}_m}{\tilde{\sigma}})(TS_{SB',j}+\tilde{u}_m) + \phi(\frac{TS_{SB',j}+\tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma})\Bigg) \end{aligned} \tag{7}$$

where Φ is the standard normal cdf and ϕ is the standard normal pdf. We interpret the term within the integral as follows. If there is a match, which occurs with probability $\frac{M(SB',SS'+D'+SSO')}{SB'}$, the buyer receives a share $(1-\theta)$ of the expected total surplus of the transaction (if the total surplus is positive) in addition to his outside option, $V^{SB}(\Omega',1)$ (enter the next period as a starter buyer). Given properties of the normal distribution, the expected total surplus has a closed form. The total surplus depends on the type of seller j that the buyer meets. With random search, the probability of matching with seller type j is just the relative frequency of type j sellers among the population of all starter sellers.

3.8.1 Trade-up Buyer

Since agents can choose to be trade-up buyers when the starter market moves (by selling a starter house) and when the trade-up market moves (by remaining a trade-up buyer), we will need to define both $V^{RB}(\Omega,1)$ and $V^{RB}(\Omega,2)$:

$$\begin{aligned} V^{RB}(\Omega,1) = V^{RB}(\Omega',2) + \frac{M(RB'+SS', RS')}{RB'+SS'} * \\ (1-\theta)(\Phi(\frac{TS_{RB',RS'}+\tilde{u}_m}{\tilde{\sigma}})(TS_{RB',RS'}+\tilde{u}_m) + \phi(\frac{TS_{RB',RS'}+\tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma}) \end{aligned} \tag{8}$$

[23] The idiosyncratic component in V^R and V^D, which is the match quality draw with the trade-up home, is differenced out of the total surplus formula. In other words, we can write $TS_{SB,D}+\tilde{\epsilon_i}$ as $U^S+\tilde{\epsilon_i}-V^{SB}+U^R-U^D$.

$$V^{RB}(\Omega,2) = u_b + \beta \int_{\gamma^S,\gamma^R} V^{RB}(\Omega',1) \tag{9}$$

$V^{RB}(\Omega,1)$ is similar in form to $V^{SB}(\Omega,1)$, except that there is only one type of seller (RS) that the buyer can transact with.

In a slight abuse of notation, note that the transition of Ω to Ω' in equation (8) is due to movements when the starter market is moving (and thus there is no intergral). In (7), it is due to movements when the starter market moves, the trade-up market moves and the realization of the inflow shocks. We continue to abuse notation in this way below to ease presentation.

3.8.2 Starter Seller

First consider the problem of a starter seller that is not mismatched with the city. Each period, this seller has two decision points: when $I = 1$, they make decisions as sellers in the starter market, and when $I = 2$, they make decisions as buyers in the trade-up market. The value functions associated with each case are:

$$V^{SS}(\Omega,1) = V^{SS}(\Omega',2) + \frac{M(RB'+SS',RS')}{RB'+SS'} * \\ (1-\theta)(\Phi(\frac{TS_{SS',RS'}+\tilde{u}_m}{\tilde{\sigma}})(TS_{SS',RS'}+\tilde{u}_m) + \phi(\frac{TS_{SS',RS'}+\tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma}) \tag{10}$$

$$V^{SS}(\Omega,2) = u_{mm} + \beta \int_{\gamma^S,\gamma^R} (V^{SS}(\Omega',1) + \frac{M(SB',SS'+D'+SSO')}{SS'+D'+SSO'} * \\ \theta(\Phi(\frac{TS_{SB',SS'}+\tilde{u}_m}{\tilde{\sigma}})(TS_{SB',SS'}+\tilde{u}_m) + \phi(\frac{TS_{SB',SS'}+\tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma})) \tag{11}$$

For mismatched starter owners that want to exit the city, the value function is

$$V^{SSO}(\Omega,1) = u_{mmo} + \beta \int_{\gamma^S,\gamma^R} (V^{SSO}(\Omega',1) + \frac{M(SB',SS'+D'+SSO')}{SS'+D'+SSO'} \\ \theta(\Phi(\frac{TS_{SB',SSO'}+\tilde{u}_m}{\tilde{\sigma}})(TS_{SB',SSO'}+\tilde{u}_m) + \phi(\frac{TS_{SB',SSO'}+\tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma})) \tag{12}$$

3.8.3 Trade-up Sellers

Trade-up sellers only make decisions when $I = 2$. If a matching occurs, it is either with a member of RB or SS. The value function is

$$V^{RS}(\Omega, 2) = u_{mm} + \beta \int_{\gamma^S,\gamma^R} (V^{RS}(\Omega', 2) + \frac{M(RB' + SS', RS')}{RS'} \sum_{j=RB',SS'} (\frac{j}{RB' + SS'})*$$

$$\theta(\Phi(\frac{TS_{j,RS'} + \tilde{u}_m}{\tilde{\sigma}})(TS_{j,RS'} + \tilde{u}_m) + \phi(\frac{TS_{j,RS'} + \tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma})) \quad (13)$$

3.8.4 Dual Position Sellers

Dual position sellers only make decisions when $I = 1$. If they get matched with a buyer, they can choose to sell their starter home and become a trade-up owner. The value function is

$$\begin{aligned} V^D(\Omega, 1, \epsilon_i) = \epsilon_i + u_{mm} - u_d + \beta \int_{\gamma^S,\gamma^R} (V^D(\Omega', 1, \epsilon_i) + (\frac{M(SB', SS' + D' + SSO')}{SS' + D' + SSO'}*\\ \theta(\Phi(\frac{TS_{SB',D'} + \tilde{u}_m}{\tilde{\sigma}})(TS_{SB',D'} + \tilde{u}_m) + \phi(\frac{TS_{SB',D'} + \tilde{u}_m}{\tilde{\sigma}})\tilde{\sigma})))\\ = \tilde{\epsilon_i} + U^D(\Omega, 1). \quad (14) \end{aligned}$$

3.9 Market Equilibrium

A policy rule is a function

$$\delta_i(\Omega, \epsilon_i) \to A \quad (15)$$

which maps the state variables and the outcome of the matching process, ϵ_i, into an action A for player type $i = SB, SS, RS, RB, D, SSO$. Note that ϵ can be the empty set if a match does not occur. In a slight abuse of notation, we refer to the complete state space (Ω, I) as simply Ω. If a match occurs, the action space is either to transact or not transact. Else, the only action is to not transact.

A belief is a function

$$\sigma_{ij}(\Omega) \to \Pr(\delta_i = j|\Omega, i). \quad (16)$$

which maps each state into a probability distribution over the potential actions j for a type i player. A player's beliefs do not depend on ϵ_i because each player is of inconsequential size relative to the entire economy.

Definition 1 *A Markov perfect equilibrium is a collection of policy rules, δ_i $\forall i$, and a set of beliefs, $\sigma_{ij}(\Omega)$ $\forall i, j, \Omega$, such that*

1. *The policy rules are optimal.*

2. *Agents have the correct beliefs about other players' policy rules.*

We focus on a symmetric equilibrium in which all agents have identical beliefs.[24]

3.10 Equilibrium Price

The solution to the complete information Nash bargaining problem for each of the five transaction types gives the following prices:

1. SB buys from SS

   - $p^*(SB, SS) = \theta(U^S - V^{SB} + \tilde{\epsilon}^*_{SB,SS}) - (1-\theta)(V^{RB} - V^{SS})$

2. SB buys from D

   - $p^*(SB, D) = \theta(U^S - V^{SB} + \tilde{\epsilon}^*_{SB,D}) - (1-\theta)(V^R - V^D)$

3. SB buys from SSO

   - $p^*(SB, SSO) = \theta(U^S - V^{SB} + \tilde{\epsilon}^*_{SB,SSO}) - (1-\theta)(V^O - V^{SSO})$

4. RB buys from RS

   - $p^*(RB, RS) = \theta(U^R - V^{RB} + \tilde{\epsilon}^*_{RB,RS}) - (1-\theta)(V^O - V^{RS})$

[24]In the classic dynamic search models, increasing returns to scale for the matching technology is a necessary condition for multiple equilibria (Pissarides [2000]). While we do not have a formal proof of uniqueness for our particular model, we note that 1) our matching function is CRS and 2) for the parameter vector that best fits the data, we searched numerically for other equilibria, but always converged to a unique equilibrium regardless of the initial conditions.

5. SS buys from RS

   - $p^*(SS,RS) = \theta(V^D - V^{SS} + \tilde{\epsilon}^*_{SS,RS}) - (1-\theta)(V^O - V^{RS})$

where $\tilde{\epsilon}^*_{i,j}$ is a truncated normal random variable, with a minimum value of $-TS_{i,j}$. For each transaction type, the price is equal to the buyer's surplus, weighted by the seller's bargaining power, minus the seller's surplus, weighted by the buyer's bargaining power. Conditional on house type and the state of the economy, there is price dispersion due to idiosyncratic match quality and the motivation of the seller (in the starter market) or buyer (in the trade-up market). For example, the second type of transaction listed above should result in a low starter home price, on average, because the seller's surplus from unloading a costly second position is high.

Appendix B outlines the equations for the equilibrium transaction volumes and laws of motion.

4 Estimation

In taking the model to the data, we make functional form assumptions on the matching technology and the inflow process. Following Pissarides (2000), we assume the Cobb-Douglass form for the matching technology:

$$M_\tau(B_\tau, S_\tau) = \min(B_\tau, \min(S_\tau, (B_\tau)^\eta (S_\tau)^{1-\eta}))\text{for } \tau\text{=S,R.} \tag{17}$$

The *min* functions guarantee that the probability of a match always lies in the unit interval. This is a common assumption in search and matching models (e.g. Shimer [2005], Menzio and Shi [2011]). With this form for the matching technology, it is straightforward to show that the probability of a match will generally depend on the *market tightness*, or the ratio of buyers to sellers. We assume that the functional form and parameter values of the matching function are symmetric for the starter and trade-up market.

We assume that the inflow process is jointly normal

$$(\gamma_t^S, \gamma_t^R) \sim N(\mu_\gamma, \Omega_\gamma) \tag{18}$$

where μ_γ is a 2x1 vector of means and Ω_γ is the variance-covariance matrix. If the variances of the inflow process were set to zero, the equilibrium would be characterized by a steady state with zero equilibrium volatility in prices and volume.

The parameter values of the model are determined in two steps. In a first step, we make several exogenous assumptions and calibrate any parameters for which there is a one-to-one mapping between the parameter value and some feature of the data. Then, the remaining parameter values are estimated through simulated method of moments. Table 4 summarizes the parameters of the model.

4.0.1 Parameters Calibrated a Priori

We assume that each period in the model is equal to one month. We set the monthly discount factor, β, so that the annual discount rate is 0.95. We assume that the stock of starter homes and the stock of trade-up homes are equal (i.e. $m^S = m^R$). We assume symmetric bargaining power ($\theta = 0.5$). We set the mismatch rate, λ, so that mismatch occurs about once every 12 years, which is roughly consistent with the average housing tenure in the American Housing Survey. We assume that the flow utility associated with exiting the housing market, u_O, equals u_m. We calibrate the share of newly mismatched starter owners that also become mismatched with the city to be $(1 - \pi) = .4$ to match the average internal move share (i.e. the share of transactions where the seller is buying another home within the city) of 0.3 calculated from the data in Table 1. We set $\gamma_t^R = (1 - \pi)\gamma_t^S$ so that the average number of entrants into the starter market equals the average number of entrants into the trade-up market. We calibrate the mean of the inflow process, μ_γ, so that average inflows and outflows of agents in the economy are balanced. At our choice of λ and μ_γ, the annual average transaction volume as a share of the total housing stock predicted by the model is equal to .08, the average value in the data for the U.S.[25] We set the exponent of the matching function, η, equal to 0.16 to match the contact elasticity for sellers with respect to the buyer-to-seller ratio estimated in Genesove and Han [2012] based on the National Association of Realtors survey.

[25] Source: a HUD report titled "U.S. Housing Market Conditions." We use a national figure because the figure for Los Angeles is unavailable.

4.0.2 Parameters Estimated by Simulated Method of Moments

The remaining unknown parameters are the flow utility parameters u_m, σ^2, u_{mm}, u_{mmo}, u_d, u_b; and the variance of the inflow process, σ_γ^2. After normalizing the level and scale of utility by fixing u_b and u_{mm}, we estimate the unknown parameters by simulating a very long time series[26] so as to match the following moments:

- The mean and coefficient of variation of median time on market, and the correlation of median time on market with real price changes.
- The coefficient of variation of sales volume, and the correlation of sales volume with real price changes.
- The coefficient of variation of real price.
- The mean within-period coefficient of variation of price (i.e. equilibrium price dispersion).[27]
- The mean of the fraction of internal movers who buy first, and the correlation of this fraction with real price changes.
- The correlation of the internal move share with real price changes.

All of these means, variances, and correlations are taken over the time series. To be consistent with the data, each variable is aggregated to its annual level first. All changes are 1 year changes.

Simulating the model involves solving for each of the value functions defined above. We do this through value function iteration combined with linear (in parameters) interpolation. Interpolation is necessary because the state space is continuous. Since the integrals are one-dimensional given our assumption on the inflow process, we use quadrature to approximate them.

[26]We start from arbitrary initial conditions and "throw out" the first 300 simulated months.

[27]To calculate within-period price dispersion in the data, we measure the standard deviation of the price residual after partialing out time-invariant housing quality and year-by-zip code fixed effects using a repeat sales specification.

5 Model Fit and Discussion

The parameter estimates and the simulated moments we target are reported in Tables 3 and 4.[28] The parameter values are sensible: (i) a matched homeowner with a match quality one standard deviation above the mean receives a flow utility that is 4 percent higher than a homeowner with the mean match quality, (ii) mismatched homeowners receive about 15 percent lower flow utility than well matched ones and (iii) the mean flow utility of holding two positions, $u_m + u_{mm} - u_d$, is significantly lower than that of being either matched well or mismatched with a single home.

Qualitatively the model fit is also very good. The estimated model generates a significant amount of volatility while fitting the sign of the correlations between price, volume, time on market, the internal move share, and buy-before-sells observed in the data. The fit on the moments using time-on-market are the poorest; however, a few studies have noted that TOM data as reported by realtors is noisy.[29] Although the estimated model generates the level of price volatility observed in the data, it under-predicts volume volatility over the cycle. This is perhaps not too surprising given that the only channel for volume to fluctuate in the model is through shifts in the timing of when mismatched sellers choose to sell. In reality, more agents may list their homes for sale when the market is strong, which should lead to further amplification of transaction volume relative to what we capture here.

The model performs well on a number of other moments that we do not specifically target in estimation. The estimated model predicts a correlation between end of year unsold inventory (i.e. mismatch) and real price of -0.71. In the data, the correlation is -0.87.[30]

[28] The weighting matrix is calculated using the 2-step procedure described in Lee and Wolpin [2010]. The weighting matrix adjusts for differences in the scale of each moment and gives more weight to moments that are estimated more precisely in a first stage. The variance-covariance matrix of the parameter estimates is given by $(G'W^{-1}G)^{-1}$, where G is the matrix of derivatives of the moments with respect to the parameters and W is the weighting matrix.

[29] See, for example, the discussion in Levitt and Syverson [2008]. This has led to a wide range of calibrations in the literature. For example, Caplin and Leahy [2011] use an average TOM of 3 months; Burnside et al. [2011] use 7.5 months.

[30] This correlation is for the aggregate U.S. housing market. The data source is the American Housing Survey and the National Association of Realtors. Inventory is normalized by the owner occupied housing

Figure 5 illustrates how mismatch endogenously builds, and then is released, leading to the negative correlation between inventory and price. We plot a snapshot of mismatch and prices for an arbitrary, but representative 25 year window of our simulations. During busts, mismatch (SS+RS) builds as new entrants are relatively scarce and mismatched owners wait for a stronger market to sell. When inflow into the starter market strengthens, mismatched agents in that market sell, which releases demand into the trade-up market, allowing mismatched agents in the trade-up market to sell as well. The build-up of mismatch in busts and its release in booms is completely endogenous since the rate of mismatch is exogenous and time-invariant in our model. As we will show below, the high effective holding cost of holding two positions is key for these mismatch dynamics. Although total mismatch is highly counter-cyclical, the subset of mismatched owners who become pre-maturely mismatched with the metro area (the SSO pool) is mostly flat over the cycle. Holding costs for these sellers are estimated to be high; as a result, they do not have the luxury of waiting for a stronger market to sell. The steady outflow of external movers combined with the endogenous build-up and release of internal movements results in pro-cyclicality of the internal move share.

Our model also generates the qualitative patterns in Table 2 on the effect of holding two positions on sales prices (not targeted). In particular, our model predicts that buying-before-selling has a larger impact on the selling price accepted by internal movers (for the starter home) compared to the price paid (for the trade-up home). This is possible because when a seller is holding two positions, the seller's surplus from selling is high and the match quality accepted tends to be low due to high holding costs, both of which lower the price according to the price equations in Section 3.10. When buying-before-selling, the buyer's surplus from buying is low due to the high holding costs of owning two homes, which tends to lower the price, but buying-before-selling only occurs when the match quality is sufficiently high, which works to raise the price. Quantitatively, we overpredict the discount on the selling price of internal movers who buy before sell by several percentage points, and as in the data, we generate almost no difference between internal movers in the price that they pay for their trade-up home.

stock.

6 Sources of Volatility and the Pro-Cyclicality of Internal Movement

In this section, we quantify the contribution of the two key sources of friction in the model – 1) basic search/matching frictions, 2) frictions due to the joint buying and selling decisions of internal movers – to market volatility and seek to understand how the effect of the joint buyer-seller frictions vary with the key parameters of the model. We do so through a series of counterfactual simulations.[31]

6.1 Joint Buyer-Seller Versus Search Frictions

To isolate the role of joint buyer-seller frictions, we compare the baseline model to a simulation in which there is no internal movement. In particular, we break the linkage between the starter and trade-up market so that sellers in the starter market make decisions without regard to market conditions in the trade-up market. Mechanically, we do this by assuming that upon selling, sellers in the starter market receive the time-invariant and market conditions-invariant lifetime utility $V^O = \frac{u_O}{(1-\beta)}$, and the flow into the trade-up market is replaced by $\gamma^R + \kappa$, where κ is a constant that sets the mean inflow in the baseline model equal to the mean inflow in this counterfactual model.

Table 5 shows volatility (defined as the coefficient of variation) in prices and transaction volume for this counterfactual model relative to the baseline model. The counterfactual model without joint buyer-seller frictions generates only 45 percent of the price volatility and 90 percent of the volume volatility as in the baseline model. This implies that, at the parameter values that best fit the data, the joint buyer-seller problem increases the volatility of transaction volumes by about 10 percent and, more importantly, more than doubles the price volatility. As we discuss in greater detail below, such an increase in price volatility is likely to have a number of important welfare consequences for home owners and the economy more generally.

[31] In each simulation, the seed for the inflow process is set to be the same so that differences in the simulated dynamics are not the result of simulation noise.

6.2 The Cost of Holding Two Homes and Joint Buyer-Seller Frictions

To better understand how the effective costs of holding two homes gives rise to these important frictions associated with the joint buyer-seller problem, we conduct another counterfactual simulation that increases the flow utility of holding two positions. Mechanically, this involves lowering u_d in the model. In practice, the owner of two houses might be able to capture more of the consumption flow of a vacant home if short term rental frictions were not as severe. We make these changes relative to the baseline model, so that the comparison of the results to the baseline model characterizes how the cost of holding two positions affects equilibrium dynamics in the model.

Table 5 shows volatility for values of u_d such that 55 percent, 70 percent, and 80 percent of internal movers buy before sell on average over the cycle in equilibrium. Market volatility declines monotonically with the effective cost of holding two positions simultaneously and, interestingly, when the cost of holding two positions is sufficiently low (e.g., for the simulation that results in 80 percent of movers buying-before-selling) both volume and price volatility fall below the levels associated with the first counterfactual simulation, which eliminated the joint buyer-seller frictions altogether. In this case, the presence of internal movers within the metropolitan area actually works to smooth the fluctuations that come from external demand! For example, when there is a negative shock to the pool of external buyers, demand from internal movers compensates because buying conditions are favorable; they buy the trade-up home now and worry about selling the starter home later. These results make it clear that the effect of having agents operating simultaneously on both sides of a market is ambiguous and depends directly on whether the costs of holding two properties are such that increases in external demand lead to (i) increases in internal demand due to a thick market effect or (ii) decreases in internal demand due to a competitive or smoothing effect.

6.3 Endogenous Variation in Attractiveness of Holding Two Positions

The results presented in Table 5 show that a time invariant cost of holding two positions significantly amplifies fundamental volatility. The reason is that in the presence of search frictions, the total attractiveness of taking on two positions depends not only on the per-period cost of holding two positions but also on the expected length of time that one expects to incur the cost. This length of time is shorter during booms and longer during busts, and so the attractiveness of holding two positions is pro-cyclical. Through this mechanism, internal demand becomes positively correlated with external demand, causing prices to rise more during booms and fall more during busts than they otherwise would in a market where agents' buying and selling decisions are not complementary.

Figure 6 compares the price dynamics for a 100-year period (one in which the inflow realizations are such that there is a long boom and bust in the baseline model) in the baseline model, the model without internal movement, and the model in which holding costs are low enough that 80 percent of internal movers buy before selling. The amplification of house price cycles due to the joint buyer-seller problem when the costs of holding two positions are high is immediately obvious in the figure. By comparing prices to the inflow process, Figure 6 also shows how search frictions prolong the effect of inflow shocks, generating persistence in prices even though the fundamentals are completely mean-reverting.

As discussed above, the pro-cyclicality of internal movements comes from the endogenous build up and release of internal movement over the cycle, combined with the steady outflow of sellers who are mismatched with the city. Since a cost of holding two position exacerbates the build up and release of internal movement, the pro-cyclicality of internal movement is strongest in the baseline model. Figure 7 illustrates this point. We plot mismatch in the baseline model and mismatch in the model where 80 percent of internal movers buy before sell for the same 100 year period shown in Figure 6. The cost of holding two positions drives the build-up and release of mismatch over the cycle, which is much more prevalent in the high holding costs baseline model. The build-up and release of mismatch generates the pro-cyclicality of internal movement and, as a result, the correlation between price and both internal and total transaction volume is strongest in the baseline model.

7 Welfare

The decentralized equilibrium in a model with the type of search frictions considered here is generally inefficient because buyers and sellers do not internalize the effect of their transaction decision on the market tightness in following periods (see Hosios [1990]). In addition, when matchings produce a stochastic match quality, as is the case here, the decentralized reservation match quality value is generally too low. The private benefit of searching for a higher match quality draw is smaller than the social benefit because under decentralization, each agent only receives a share of the gains from a higher match quality according to his bargaining weight.[32]

An additional potential source of welfare loss arises when there is feedback from one segment of the market to another, which is not the case in the canonical labor search models. In our model, buyers and sellers in the starter market do not fully internalize their effect on the tightness in the trade-up market. Our goal is to understand the quantitative importance of the various externalities present in the decentralized equilibrium of our model economy. We begin with a definition of social welfare and the social planner's optimization problem.

7.1 Definition

Social welfare is defined as follows:

[32] Additional details are provided in Pissarides [2000]. One difference between our search model and the canonical labor search models is that in our model, entry of agents into the pool of active buyers and sellers is exogenous. Thus, we do not get any inefficiency from an entry margin. In the Diamond-Mortenson-Pissarides framework, welfare is affected by inefficient entry (i.e. too much or too little job creation) depending on the Hosios condition.

$$W = \sum_{t=0}^{\infty} \beta^t E\Bigg((SS_t + RS_t)u_{mm} + D_t(u_{mm} - u_d) + (SSO_t)u_{mmo} + (SB_t + RB_t)u_b$$
$$+ M(SB_t, SS_t + D_t + SSO_t) * \sum_{j=SS,D,SSO} (\frac{j}{SS_t + D_t + SSO_t})\Phi(\frac{\tilde{\epsilon}^*_{SB,j}(\Omega_t) - \tilde{u}_m}{\tilde{\sigma}})E[\tilde{\epsilon}|\tilde{\epsilon} > \tilde{\epsilon}^*_{SB,j}(\Omega_t)])$$
$$+ M(RB_t + SS_t, RS_t) * \sum_{k=RB,SS} (\frac{k}{RB_t + SS_t})\Phi(\frac{\tilde{\epsilon}^*_{k,RS}(\Omega_t) - \tilde{u}_m}{\tilde{\sigma}})(V^O + E[\tilde{\epsilon}|\tilde{\epsilon} > \tilde{\epsilon}^*_{k,RS}(\Omega_t)])\Bigg). \quad (19)$$

$\tilde{\epsilon}^*_{k,j}(\Omega_t)$ is the match quality threshold for a transaction to occur between a type k buyer and a type j seller. The threshold can vary depending on the state of the economy, (Ω_t). We choose to define total welfare in terms of match quality thresholds because it facilitates numerically solving the planner's problem. Note that the total discounted present value of the entire steam of ϵ shocks is accounted for at the time of the transaction. We can express welfare in these terms because the expected duration of a match is constant and exogenous in the model. The outer expectation in (19) is with respect to realizations of the inflow process, γ^S_t and γ^R_t. The V^O term reflects the fact that when there is a transaction in the trade-up market, a lifetime utility of V^O is also generated for an agent that exits the city. Prices do not enter (19) because they are simply transfers from one agent to another. We ignore the contribution of the initial conditions to welfare because they do not affect the solution to the social planner's problem, which is the focus of our welfare exercises.

7.2 Social Planner's Problem

The social planner solves

$$\underset{\epsilon^*_{SB,SS}(\Omega_t),\epsilon^*_{SB,D}(\Omega_t),\epsilon^*_{SB,SSO}(\Omega_t),\epsilon^*_{RB,RS}(\Omega_t),\epsilon^*_{SS,RS}(\Omega_t)}{\text{maximize}} \quad (19)$$
$$\text{subject to:} \quad (17), (24),$$
$$\text{given:} \quad \Omega_0.$$

In words, the planner chooses transaction thresholds, which can vary depending on the state of the economy, to maximize welfare subject to the exogenous inflow process, the matching technology, the mismatch process, and some initial conditions Ω_0. Note that we are only allowing the planner to affect agents' decision rules, but not search frictions themselves.

7.3 Quantifying Inefficiency in the Decentralized Economy

To quantify the total inefficiency, we compare welfare when transaction thresholds are determined by the value functions in the decentralized equilibrium to welfare when transaction thresholds are chosen by the social planner. We solve for the planner's problem numerically. To do so, we flexibly parameterize the planner's policy rules as a function of the state variables, and choose the parameters of the policy functions so as to maximize W.[33]

Table 6 shows that the social planner increases welfare per transaction by an equivalent variation of $7,450 dollars, which is about 1.5 percent of the average sales price. Table 7 highlights some predictions of the model under decentralization relative to centralization. A comparison of the average match quality thresholds under centralization and decentralization shows that in general, agents are too quick to accept matches in the decentralized equilibrium, which, as described above, is also the case in the canonical labor search models with stochastic model quality. The exception is starter sellers (SS), who are actually too slow to accept matches from the planner's perspective. For these agents, a social benefit of quicker transactions is a thicker buyer pool in the trade-up market. On net, the inefficiencies cause the planner to lower the match quality threshold for this transaction type. The share of internal moves in the decentralized equilibrium that involve buy before sells is roughly equal to the level that the planner desires. A key difference, however, is that the planner would like dual position agents to be more patient when selling their starter home.

Another notable difference between the centralized and decentralized equilibrium highlighted in Tables 6 and 7 is that price volatility is 50 percent lower in the planner's equilibrium.[34] In fact, the price volatility in the centralized equilibrium is almost identical to that

[33] For each trial parameter vector, we simulate W 500 times. Each simulation involves a different random sequence of inflow realizations and a random set of initial conditions, Ω_0. Ω_0 is a draw of a row vector from a Tx6 matrix of Ω_t realizations in the decentralized equilibrium, where T is very large.

[34] To calculate price in the social planner equilibrium, we calculate the value functions associated with each pool assuming that matches are accepted/rejected according to the planner's transaction thresholds. Price is then calculated according to the price equations in the Section 3.10.

reported for first simulation described in Section 6, which eliminates the joint-buyer seller frictions, due to the fact that the social planner eliminates the externalities associated with the segmented market and joint buyer-seller problem.

It is worth emphasizing that our model likely substantially understates the welfare benefits of the reduced price volatility in the economy for at least three broad reasons. Most directly, the agents in our economy are assumed to be risk neutral and, therefore, experience no consequences of fluctuations in their wealth per se. Instead all of the welfare costs associated with the joint buyer-seller problem in our model come from the inefficient matches of households to homes over the cycle. Second, in the presence of traditional mortgages, house price volatility generates a host of potential costs during busts. Homeowners who are underwater on their mortgages may be less mobile[35] and are certainly more likely to default, which may have sizable social costs.[36] Finally, as the recent boom and bust cycle has clearly demonstrated, large fluctuations in the housing market generate substantial fluctuations in effective household wealth, leading to corresponding fluctuations in aggregate consumption that have important consequences for the broader economy.[37] Taken together, these considerations suggest that the welfare consequences of the increased price volatility generated by the joint buyer-seller problem may be much larger than the already sizable \$7,450 figure that we estimate within the model.

Finally, a potential concern with our conclusion about the magnitude of inefficiency in the decentralized economy is that it is sensitive to our assumption that bargaining power is symmetric. This is a possibility because the bargaining parameter, θ, does not appear in the planner's objective function (19), but it appears in each of the value functions outlined in Section 3. In Figure 8, we report welfare under the social planner to welfare under decentralization for various choices of θ. All other parameters are fixed at their estimated values. The decentralized equilibrium is inefficient for any choice of θ, and symmetric bargaining power results in inefficiency that is at the lower end of what might in fact arise.

[35]The empirical evidence is mixed. Chan [1997], Ferreira et al. [2010] argue that there is an effect, while Coulson and Grieco [2013], Schulhofer-Wohl [2011] argue that there is no lock in effect from negative equity.

[36]See, for example Campbell et al. [2011], Anenberg and Kung [2012].

[37]See Case et al. [2005], Mian and Sufi [2011].

7.4 Decomposing the Sources of Inefficiency

To determine the relative importance of frictions related to search versus those related to the joint buyer-seller problem in driving inefficiency in the baseline economy, we solve the social planner's problem for the counterfactual economy described above where we shut down feedback between the starter and trade-up markets. Table 6 shows that the planner in this economy improves welfare by 0.4 percent of the average sales price, which amounts to about $2,000 or about one-quarter of the welfare gains that the planner realizes in the baseline model. Interestingly, in the absence of the frictions associated with the joint buyer-seller problem, price volatility in the centralized and decentralized equilibria is almost identical.

These findings suggest that the primary sources of inefficiency in the baseline economy are externalities generated by the joint-buyer seller problem and that essentially all of the increase in price volatility is due to the frictions associated with the joint buyer-seller problem. This suggests that large fluctuations in price are not unavoidable consequences of search frictions but instead that the right set of policy interventions could potentially reduce volatility without changing the underlying search technology. We investigate this further in the next subsection.

7.5 Policy

We can interpret the planner's solution as an upper bound on what policy can achieve subject to the existing matching technology in the economy. Here we consider the welfare effects of a policy intervention that is motivated by the results in Tables 6 and 7. In particular, we consider time-invariant taxes on: each transaction in the starter market (τ^S), each transaction in the trade-up market (τ^R), the per-period utility of holding two positions (τ^D), and the per period utility of a starter seller who is mismatched with the metro area (τ^{SSO}). These taxes can be either positive or negative but we impose revenue neutrality: i.e. $\sum_{t=0}^{T}(trans_t^S * \tau^S + trans_t^R * \tau^R + D_t * \tau^D + SSO_t * \tau^{SSO}) > 0$.

We find that the optimal scheme involves a tax on trade-up transactions, a subsidy for starter transactions, and subsidies for "motivated" sellers to stay on the market (i.e. those holding two positions and starter owners who are mismatched with the city). As shown in

Table 6, the optimal policy almost approaches the welfare gains under the social planner. Thus, this simple, time-invariant policy does much to correct the inefficiencies that arise in the decentralized equilibrium. That optimal policy involves slowing down the transaction rate in the trade-up market through taxes and speeding it up in the starter market through subsidies is attractive in the sense that we can improve the efficiency of the market without running a deficit – we can simply transfer utility among the agents in our economy.

Subsidies for starter transactions and taxes on other transactions bear resemblance to the types of first-time home buyer tax credits and real estate transfer taxes, respectively, that the federal and many local governments have implemented. Although our model is too stylized to capture the full general equilibrium effects of these types of interventions, it highlights a role for these types of interventions in the presence of search frictions and feedback between different segments of the housing market.

The fourth row of Table 6, however, shows that the transaction taxes and subsidies need to be implemented along with subsidies for high holding cost sellers to have a significant effect on welfare. This column reports the welfare gains that are possible using a policy that only involves transactions taxes and, importantly, cannot subsidize holding times. These results indicate that a lack of liquidity for high holding costs sellers is the most important source of social welfare loss. While real world analogues that replicate the kinds of holding subsidies we consider here are not obvious, these results suggest that substantial welfare gains and decreases in housing price volatility could be achieved through mechanisms that increase liquidity in the market. The activity of market middlemen (i.e., flippers) who effectively help a seller to more patiently wait to connect with the right buyer, for example, help to increase the liquidity of the market. As such, policies that make it easier rather than more difficult for market intermediaries to transact in the housing market may have significant welfare consequences.

8 Conclusion

Our paper is motivated by new empirical evidence that we document on internal movement over the metropolitan-area housing-market cycle. We find that a significant share of overall transaction volume consists of households buying and selling homes at about the same time. Such internal movement is highly volatile and drives the pro-cyclicality of overall transaction volume. We show that these and other well-established stylized facts about housing market cycles can be matched very well with only a modest extension to classical search theory. In particular, we extend the Diamond-Mortensen-Pissarides search model only to (i) endogenize the decisions of internal movers to buy or sell first and (ii) account for the fact that it is costly for households to own two homes simultaneously, even for a short amount of time. With this framework, we show that the joint buyer-seller problem in particular amplifies fundamental volatility and gives rise to externalities that generate significant welfare loss and inefficient price fluctuations. We argue that we likely understate the welfare consequences of the additional volatility because we abstract from mortgage markets and foreclosures, and the effects that fluctuations in housing wealth have on aggregate consumption and thus the broader economy.

Perhaps an optimistic message from our paper is that a significant portion of housing market volatility is not an unavoidable consequence of the existing technology for buying and selling homes. Our results show that a natural role for homeowners moving with a metropolitan area is to *smooth* shocks to external demand and dampen aggregate volatility, if only they could more easily buy and sell homes in a thin market. Indirect policies or technologies that could alleviate this constraint for internal movers and thus decrease equilibrium volatility could include 1) making tax and legal policies more accommodative for flippers who act to provide liquidity to high holding cost sellers, 2) using the internet to facilitate a market for short term rental[38], and 3) easing financing constraints that may serve to effectively increase the costs of holding two homes (e.g. make bridge loans more accessible).

References

James Albrecht, Axel Anderson, Eric Smith, and Susan Vroman. Opportunistic matching in the housing market. *International Economic Review*, 48(2):641–664, 2007.

[38] Examples of such platforms include www.airbnb.com and www.craigslist.org.

Elliot Anenberg. Loss aversion, equity constraints and seller behavior in the real estate market. *Regional Science and Urban Economics*, 41(1):67 – 76, 2011.

Elliot Anenberg and Ed Kung. Estimates of the size and source of price declines due to nearby foreclosures. Working Paper 84, Federal Reserve Board, December 2012.

Patrick Bayer, Christopher Geissler, and James W. Roberts. Speculators and middlemen: The role of flippers in the housing market. Working Paper 16784, National Bureau of Economic Research, February 2011.

Craig Burnside, Martin Eichenbaum, and Sergio Rebelo. Understanding booms and busts in housing markets. Working Paper 16734, National Bureau of Economic Research, January 2011.

John Campbell, Stefano Giglio, and Parag Pathak. Forced sales and house prices. *American Economic Review*, 2011.

Andrew Caplin and John Leahy. Trading frictions and house price dynamics. *Journal of Money, Credit and Banking*, 43:283–303, 2011.

Paul E. Carrillo. An empirical stationary equilibrium search model of the housing market*. *International Economic Review*, 53(1):203–234, 2012.

Karl E. Case and Robert J. Shiller. The efficiency of the market for single-family homes. *The American Economic Review*, 79(1):125–137, 1989.

Karl E Case, John M Quigley, and Robert J Shiller. Comparing wealth effects: the stock market versus the housing market. *Advances in macroeconomics*, 5(1), 2005.

Sewin Chan. Spatial lock-in: Do falling house prices constrain residential mobility? *Journal of Urban Economics*, 49(3):567–568, 1997.

N. Edward Coulson and Paul L.E. Grieco. Mobility and mortgages: Evidence from the psid. *Regional Science and Urban Economics*, 43(1):1 – 7, 2013.

Antonia Diaz and Belen Jerez. House prices, sales, and time on the market : a search-theoretic framework. *International Economic Review*, forthcoming.

Gary Engelhardt. Nominal loss aversion, housing equity constraints, and household mobility: evidence from the united states. *Journal of Urban Economics*, 53(1):171–195, 2003.

Fernando Ferreira, Joseph Gyourko, and Joseph Tracy. Housing busts and household mobility. *Journal of Urban Economics*, 68(1):34 – 45, 2010.

David Genesove and Lu Han. Search and matching in the housing market. *Journal of Urban Economics*, 2012.

David Genesove and Christopher Mayer. Loss aversion and seller behavior: Evidence from the housing market. *The Quarterly Journal of Economics*, 116(4):1233–1260, 2001.

Edward L. Glaeser, Joseph Gyourko, and Raven Saks. Why have housing prices gone up? *The American Economic Review*, 95(2):pp. 323–328, 2005.

Allen Head, Huw Lloyd-Ellis, and Hongfei Sun. Search, liquidity and the dynamics of house prices and construction. *mimeo Queens University*, 2011.

Arthur J. Hosios. On the efficiency of matching and related models of search and unemployment. *The Review of Economic Studies*, 57(2):279–298, 1990.

John Krainer. A theory of liquidity in residential real estate markets. *Journal of Urban Economics*, 49(1):32 – 53, 2001.

Donghoon Lee and Wilbert Van der Klaauw. An introduction to the frbny consumer credit panel. Working Paper 479, FRB of New York Staff, November 2010.

Donghoon Lee and Kenneth I. Wolpin. Accounting for wage and employment changes in the us from 1968-2000: A dynamic model of labor market equilibrium. *Journal of Econometrics*, 156(1):68 – 85, 2010.

Steven D. Levitt and Chad Syverson. Market distortions when agents are better informed: The value of information in real estate transactions. *Review of Economics and Statistics*, 90(4):599–611, 2008.

Guido Menzio and Shouyong Shi. Efficient search on the job and the business cycle. *Journal of Political Economy*, 119:468–510, 2011.

Atif Mian and Amir Sufi. House prices, home equity-based borrowing, and the us household leverage crisis. *American Economic Review*, 101(5):2132–56, 2011.

Raven Molloy and Hui Shan. The postforeclosure experience of us households. *Real Estate Economics*, 2012.

Dale T. Mortensen and Christopher A. Pissarides. Job creation and job destruction in the theory of unemployment. *The Review of Economic Studies*, 61(3):397–415, 1994.

Rachel Ngai and Silvana Tenreyro. Hot and cold seasons in the housing market. *mimeo London School of Economics*, 2010.

Robert Novy-Marx. Hot and cold markets. *Real Estate Economics*, 37(1):1–22, 2009.

Francois Ortalo-Magne and Sven Rady. Housing market dynamics: On the contribution of income shocks and credit constraints. *Review of Economic Studies*, 73(2):459–485, 2006.

Monika Piazzesi and Martin Schneider. Momentum traders in the housing market: Survey evidence and a search model. *American Economic Review Papers and Proceedings*, 99(2): 406–411, 2009.

Christopher Pissarides. Equilibrium unemployment theory. *MIT Press*, 2000.

John M. Quigley and Steven Raphael. Regulation and the high cost of housing in california. *The American Economic Review*, 95(2):pp. 323–328, 2005.

Jean-Marc Robin. On the dynamics of unemployment and wage distributions. *Econometrica*, 79(5):1327–1355, 2011.

Sam Schulhofer-Wohl. Negative equity does not reduce homeowners' mobility. Technical report, National Bureau of Economic Research, 2011.

Robert J. Shiller. Arithmetic repeat sales price estimators. *Journal of Housing Economics*, 1(1):110–126, 1991.

Robert Shimer. The cyclical behavior of equilibrium unemployment and vacancies. *The American Economic Review*, 95(1):pp. 25–49, 2005.

Jeremy C. Stein. Prices and trading volume in the housing market: A model with down-payment effects. *The Quarterly Journal of Economics*, 110(2):379–406, 1995.

William C. Wheaton. Vacancy, search, and prices in a housing market matching model. *Journal of Political Economy*, 98(6):pp. 1270–1292, 1990.

A Robustness of Stylized Facts on Internal Movement

A.1 Equifax Data

This section describes how we use the FRBNY/Equifax Consumer Credit Panel to document internal movement. The panel comprises a nationally representative 5 percent random sample of US individuals with credit files. A detailed overview of the data can be found in Lee and Van der Klaauw [2010]. We observe credit information for each individual at a quarterly frequency. We classify an individual as having purchased a home in quarter t (i.e. the denominator of the internal mover share) if the following conditions are satisfied: the mailing address reported to Equifax for quarter t is different from the one reported in quarter $t-1$, a new first mortgage was opened in quarter t, the individual has at most one first mortgage open in quarters t and $t-1$.[39] Since some individuals temporarily have two first mortgages open (perhaps because they bought before selling), we also classify an individually as having purchased a new house if the conditions specified hold for quarters $t-2$, $t-3$, or $t-4$. Internal movers (i.e. the numerator of the internal mover share) are the subset of these movers where 1) a first mortgage existed in quarter $t-1$ that is not the same as the first mortgage in quarter t and 2) the MSA in quarter t is the same as the MSA in quarter $t-1$.[40] For studying internal movement, an advantage of Equifax relative to Dataquick is that we have household identifiers so we do not need to match names. A disadvantage is that we rely on mortgage information to identify home purchases, so, for example, purchases where the buyer pays in cash are dropped from our analysis.

Appendix Figure 1 plots the internal mover share by year for MSAs in California, averaged across MSAs. We smooth through the year 2003 because there is an uptick in internal movement (not just in California but in all states) due to a change in Equifax's methodology of determining someone's address. The level of the internal mover share is similar to the level of the internal mover share calculated from the Dataquick data specifically for Los

[39] In period $t-1$, we allow the individual to have two first mortgages if the smaller is less than half the size of the larger mortgage to accommodate junior liens. This restriction is borrowed from Molloy and Shan [2012].

[40] The mailing address in Equifax is a unique identifier, but is scrambled to preserve the anonymity of individuals. We do observe the unscrambled county and state, which we use to determine the MSA.

Angeles. The internal mover share is also pro-cyclical for MSAs in California. Interestingly, the internal mover share peaks just before the house price index, which we also find to be the case in Dataquick (see Figure 1). Since the Equifax data is nationally representative, we can also investigate across MSA differences in the dynamics of the internal mover share. The states in the left panel of Appendix Figure 1 had large price run-ups in the early 2000's, followed by large house price declines starting in the middle of the decade. The states in the right panel had more subdued house price dynamics according to CoreLogic. The evidence strongly suggests that the dynamics of internal movement are correlated with the house price cycle.

We also examine whether our finding in Dataquick that internal movers tend to sell before buying holds up in the Equifax data. In the Equifax data, we classify an internal mover as buying-before-selling if the mover temporarily has two first mortgages open. For MSAs in California, 30 percent of internal movers buy before sell on average, which is identical to the number we arrive at with Dataquick. For the country as a whole, the share is 25 percent.

A.2 American Housing Survey

We use the American Housing Survey data for Los Angeles to calculate the share of owner-occupied housing units with recent movers where the previous unit of the recent mover was also owner-occupied (Source: Table 3-10). This should overstate the internal mover share as we define it because a move between two owner occupied units from one MSA to another would be included in the numerator. The survey is only conducted every 5 years or so, but the average share in the six most recent surveys is 40 percent, consistent with our finding that most housing transactions are external. The share is the highest in 1989 (during a house price boom) and the lowest in 1995 (during a house price bust).

B Additional Details on the Equilibrium

B.1 Equilibrium Transaction Volume

The equilibrium transaction volume in each period is

$$\text{Starter Market: } \frac{M(SB, SS + D + SSO)}{SS + D + SSO} * (\Phi(\frac{TS_{SB,SS} + \tilde{u}_m}{\tilde{\sigma}})SS + \Phi(\frac{TS_{SB,D} + \tilde{u}_m}{\tilde{\sigma}})D + \Phi(\frac{TS_{SB,SSO} + \tilde{u}_m}{\tilde{\sigma}})SSO) \quad (20)$$

$$\text{Trade-up Market: } \frac{M(RB + SS, RS)}{RB + RS} * (\Phi(\frac{TS_{RB,RS} + \tilde{u}_m}{\tilde{\sigma}})RB + \Phi(\frac{TS_{SS,RS} + \tilde{u}_m}{\tilde{\sigma}})SS) \quad (21)$$

B.2 Laws of Motion

In equilibrium, the state variables transition according to the following equations:

- After Starter Market Moves

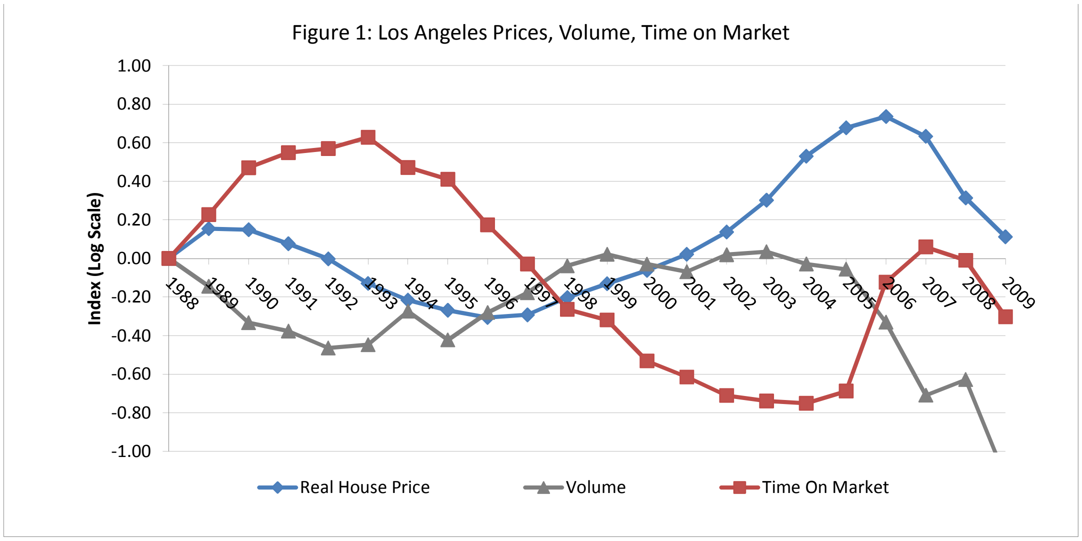
$$\begin{aligned}
SB' &= SB - \frac{M(SB, SS + D + SSO)}{SS + D + SSO} * \\
&(\Phi(\frac{TS_{SB,SS} + \tilde{u}_m}{\tilde{\sigma}})SS + \Phi(\frac{TS_{SB,D} + \tilde{u}_m}{\tilde{\sigma}})D + \Phi(\frac{TS_{SB,SSO} + \tilde{u}_m}{\tilde{\sigma}})SSO) \\
SS' &= SS - M(SB, SS + D + SSO)\frac{SS}{SS + D + SSO}\Phi(\frac{TS_{SB,SS} + \tilde{u}_m}{\tilde{\sigma}}) \\
RB' &= RB + M(SB, SS + D + SSO)\frac{SS}{SS + D + SSO}\Phi(\frac{TS_{SB,SS} + \tilde{u}_m}{\tilde{\sigma}}) \\
D' &= D - M(SB, SS + D + SSO)\frac{D}{SS + D + SSO}\Phi(\frac{TS_{SB,D} + \tilde{u}_m}{\tilde{\sigma}}) \\
SSO' &= SSO - M(SB, SS + D + SSO)\frac{SSO}{SS + D + SSO}\Phi(\frac{TS_{SB,SSO} + \tilde{u}_m}{\tilde{\sigma}})
\end{aligned} \quad (22)$$

- After trade-up Market Moves

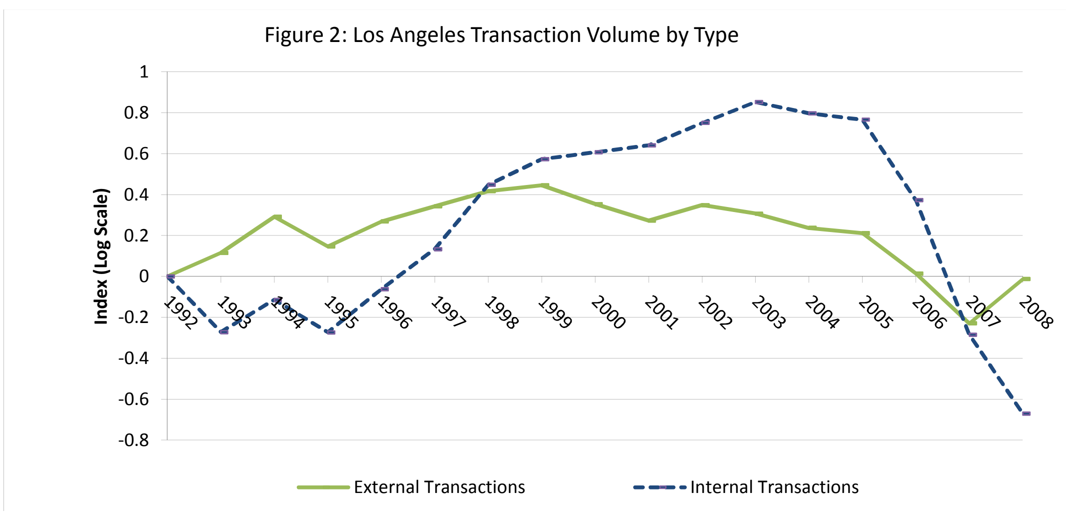
$$\begin{aligned}
SS' &= SS - M(RB + SS, RS)\frac{SS}{RB + SS}\Phi(\frac{TS_{SS,RS} + \tilde{u}_m}{\tilde{\sigma}}) \\
RB' &= RB - M(RB + SS, RS)\frac{RB}{RB + SS}\Phi(\frac{TS_{RB,RS} + \tilde{u}_m}{\tilde{\sigma}}) \\
RS' &= RS - M(RB + SS, RS)(\frac{RB}{RB + SS}\Phi(\frac{TS_{RB,RS} + \tilde{u}_m}{\tilde{\sigma}}) + \frac{SS}{RB + SS}\Phi(\frac{TS_{SS,RS} + \tilde{u}_m}{\tilde{\sigma}}))
\end{aligned} \quad (23)$$

- Exogenous movements

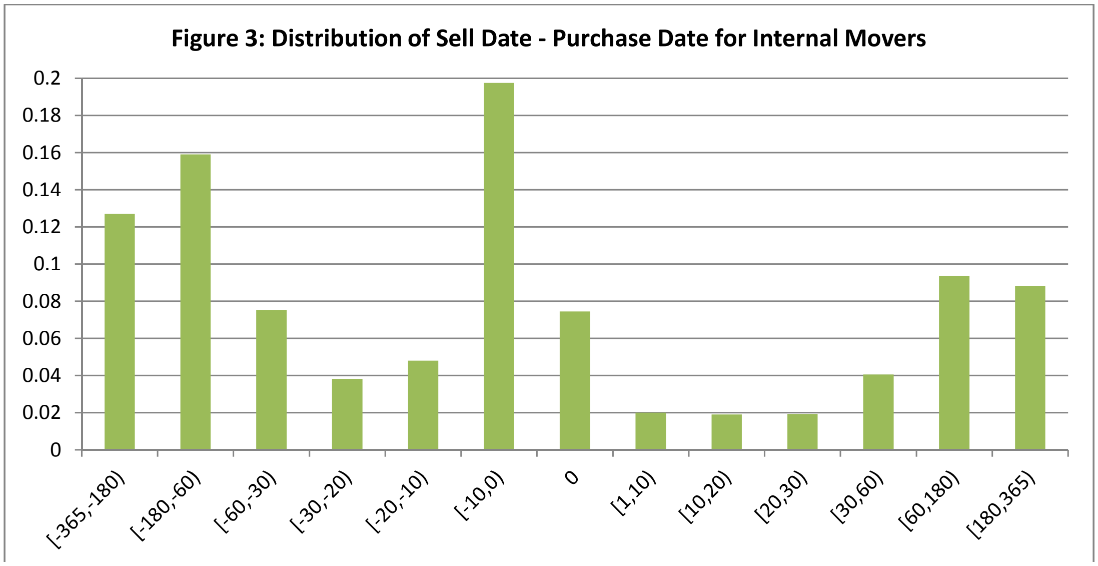
$$
\begin{aligned}
SS' &= SS + \lambda * \pi * (m^S - SS - D - SSO) \\
SSO' &= SSO + \lambda * (1 - \pi) * (m^S - SS - D - SSO) \\
RS' &= RS + \lambda(m^R - RS - D) \\
SB' &= SB + \gamma^S \\
RB' &= RB + \gamma^R
\end{aligned} \tag{24}
$$



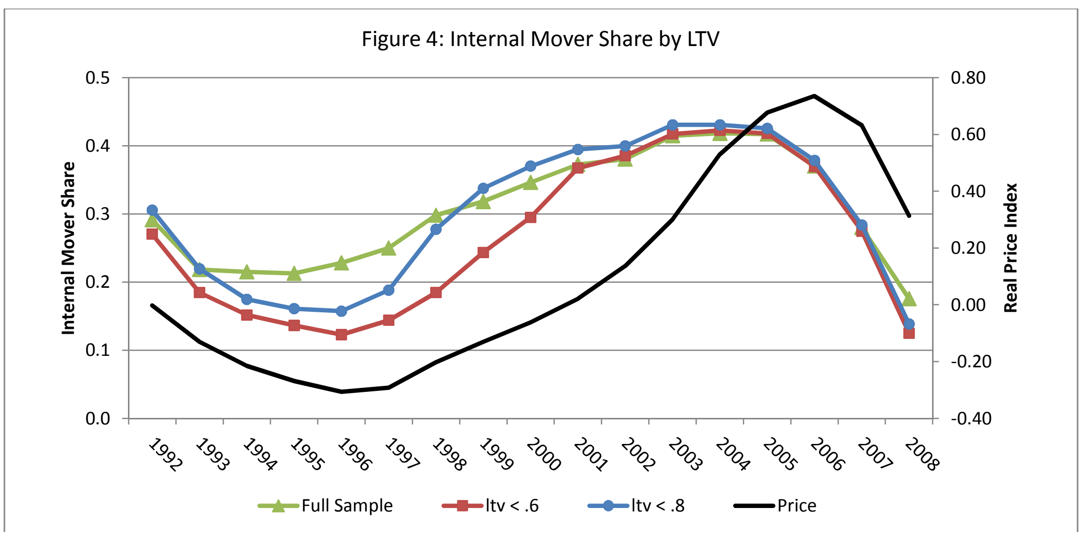
Notes: Real house price and total transaction volume index based on Dataquick data. Median time on market from California Association of Realtors. The underlying data are presented in Table 1.



Notes: The underlying data (from Dataquick) are presented in Table 1. A transaction is internal if the seller bought a house in the Los Angeles MSA within twelve months of the selling date. Otherwise, it is external.

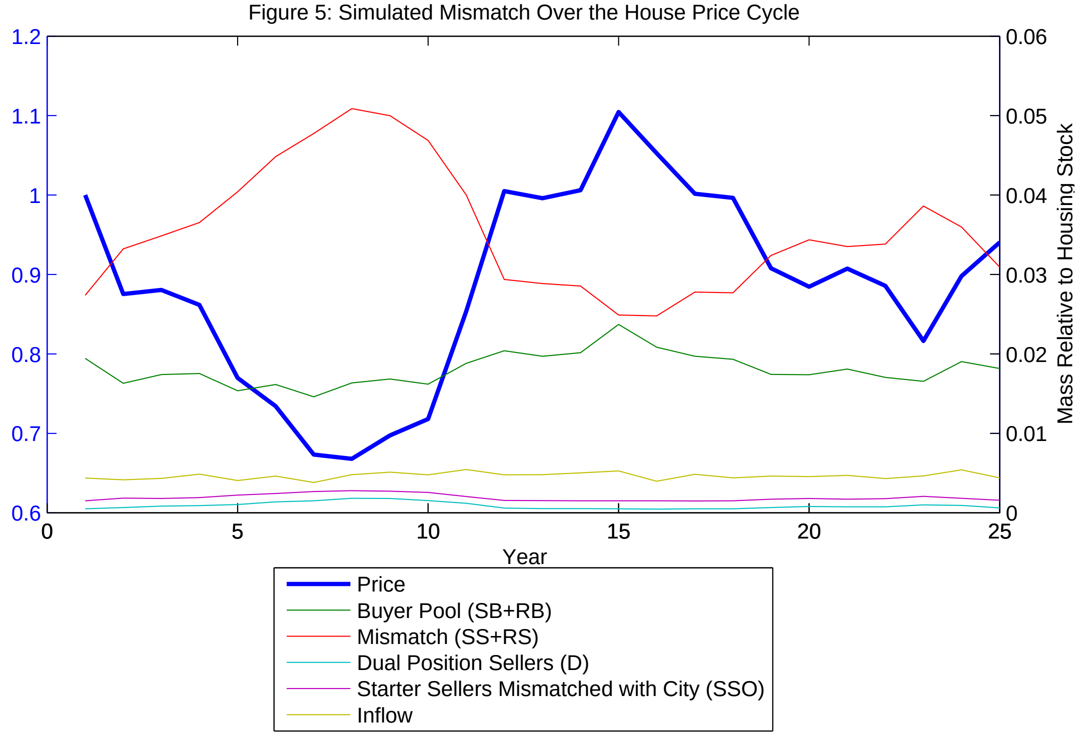


Notes: Histogram of days between sale and purchase for internal movers in Los Angeles for years 1992-2008 calculated using Dataquick. A mover is internal if he sells one house and buys another within the Los Angeles MSA within twelve months of each other. Date of buy and sell are defined using closing dates.



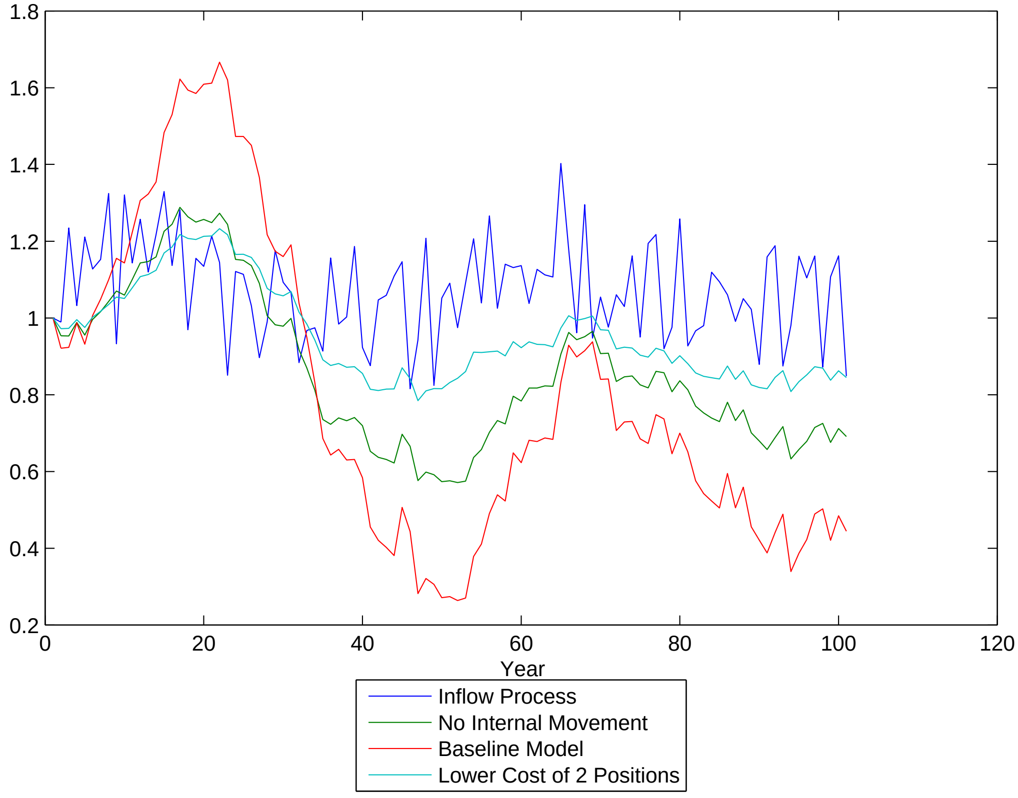
Notes: This graph shows the share of transactions by internal movers when we restrict the sample by the loan-to-value (LTV) ratio of the seller at the time of the sale (calculated using Dataquick data). LTV is imputed, as described in the main text, using data on the original loan amount (including all mortgages) and the original purchase price. A transaction is internal if the seller bought a house in the Los Angeles MSA within twelve months of the selling date.

Figure 5: Simulated Mismatch Over the House Price Cycle



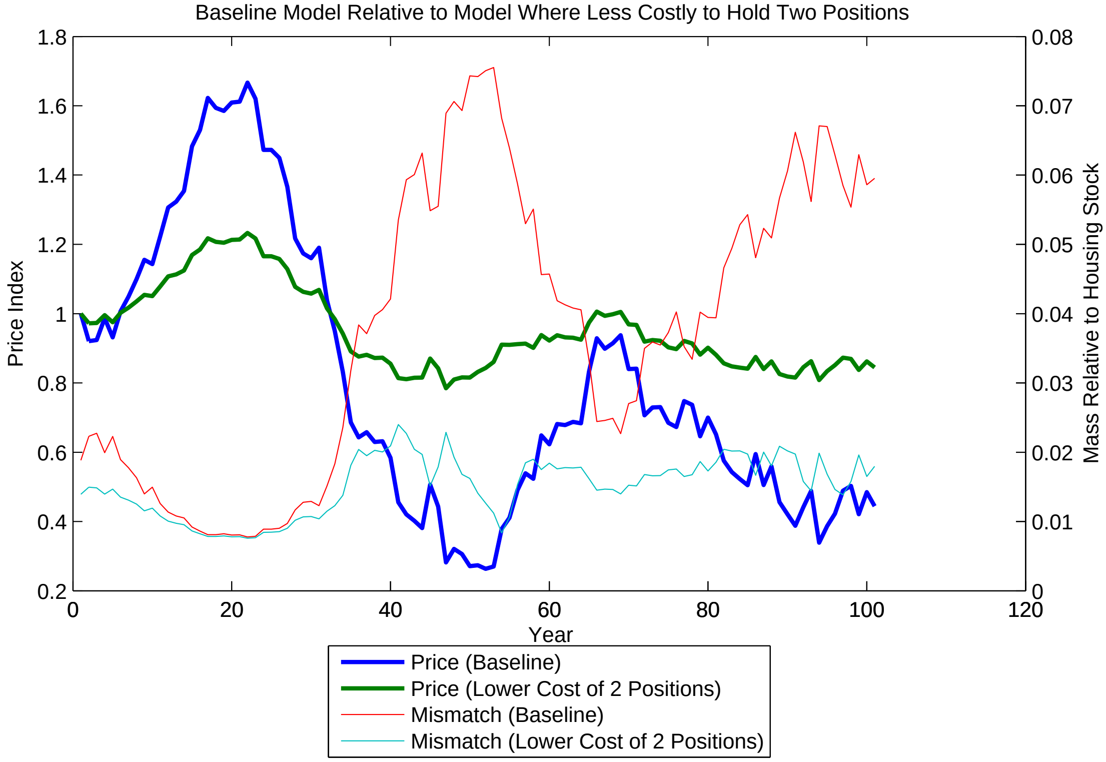
Notes: This figure illustrates how the estimated model generates endogenous build-ups and release of mismatched homeowners over time. The different pools of agents in the model are plotted for an arbitrary, but representative 25 year simulation on the right y-axis. The average house price is plotted on the left y-axis, where the house price in period one is indexed to one. The buyer pool consists of starter buyers (SB) and trade-up buyers (RB). The pool labeled mismatch consists of starter sellers who want to trade-up (SS) and trade-up sellers who want to exit the city (RS). Dual position sellers own both a starter home and a trade-up home (D). Starter sellers who are mismatched with the city will exit the city upon selling (SSO). Inflow plots the mass of agents who exogenously flow into the city each period.

Figure 6: Simulated Price Index
Under Counterfactual Models Relative to Baseline Model



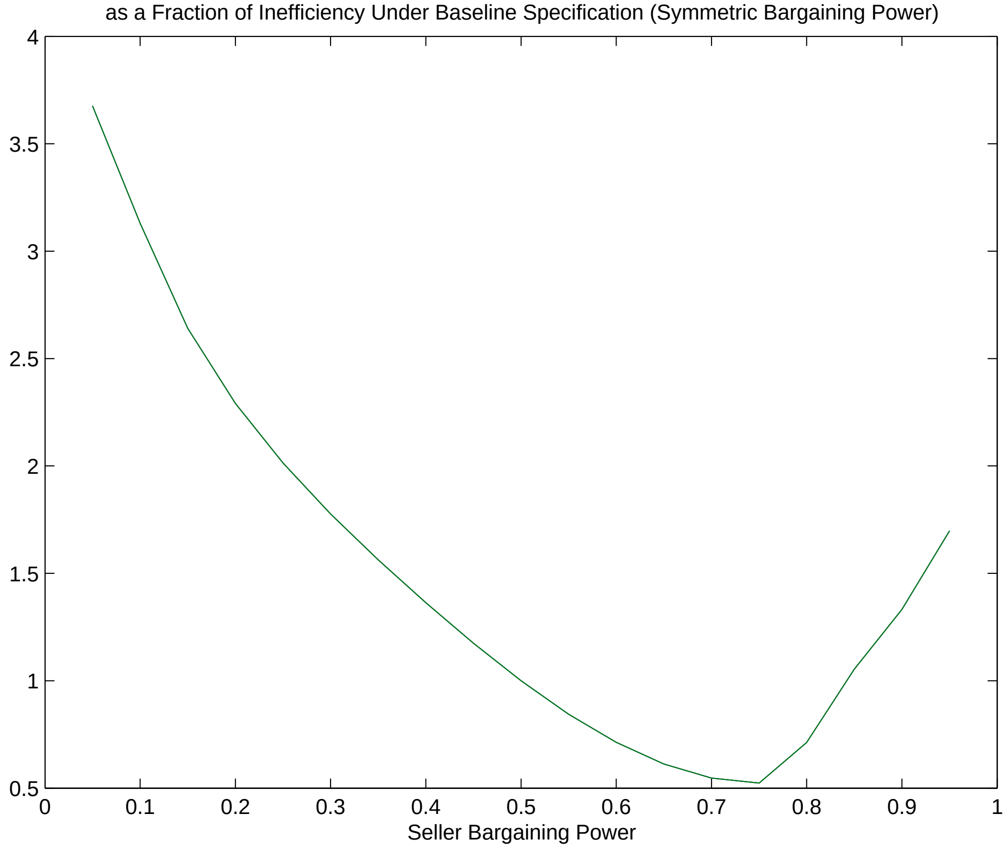
Notes: This figure compares the price dynamics for a 100-year period (one in which the inflow realizations are such that there is a long boom and bust in the baseline model) in the baseline model, the model without internal movement, and the model in which holding costs are low enough that 80 percent of internal movers buy before selling. Prices are indexed to one in period one. Prices are shown relative to an index measuring the mass of agents who exogenously flow into the city each period ("inflow process"). In the model without internal movement, we break the linkage between the starter and trade-up market so that sellers in the starter market make decisions without regard to market conditions in the trade-up market. We increase the share of internal movers who buy before selling in equilibrium by adjusting the parameter values to allow homeowners to realize more of the consumption benefits from two homes.

Figure 7: Simulated Mismatch Over the House Price Cycle
Baseline Model Relative to Model Where Less Costly to Hold Two Positions



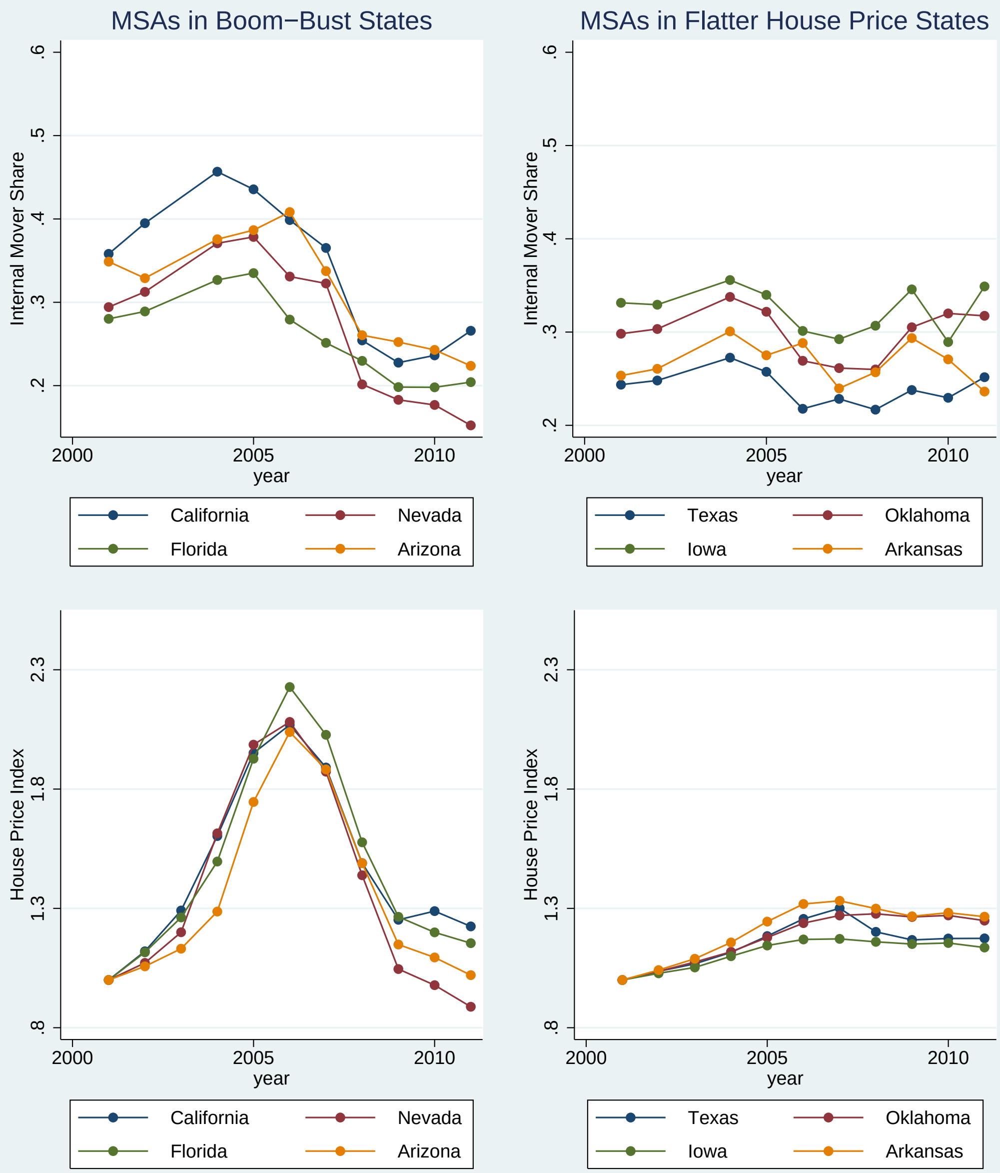
Notes: This figure compares the mismatch dynamics in the baseline model relative to the counterfactual model where holding costs are low enough that 80 percent of internal movers buy before selling for a 100-year period (one in which the inflow realizations are such that there is a long boom and bust in the baseline model). Indexes summarizing price dynamics in each of the two models are plotted on the left y-axis. The pool labeled mismatch consists of starter sellers who want to trade-up (SS) and trade-up sellers who want to exit the city (RS).

Figure 8: Inefficiency for Different Choices of Nash Bargaining Parameter
as a Fraction of Inefficiency Under Baseline Specification (Symmetric Bargaining Power)



Notes: This figure compares welfare under the social planner to welfare under decentralization for various choices of the seller's bargaining power. The difference between welfare under decentralization and welfare under the social planner in the baseline model (i.e. seller's bargaining power is equal to 0.5) is normalized to one. In all simulations, all parameter values other than the bargaining power are fixed at their estimated values reported in Table 4.

Appendix Figure 1: Internal Mover Share from Equifax Data (Top Panel) and House Prices (Bottom Panel)



Notes: Internal mover share is the share of moves into owner occupancy where the previous home for the owner occupant was in the same MSA and also owner occupied. See Appendix for additional details. The source for internal mover share is Equifax and the source for house price index is CoreLogic.

Notes: Internal mover share is the share of moves into owner occupancy where the previous home for the owner occupant was in the same MSA and also owner occupied. Owner occupancy is inferred from the mortgage information of the individual. See Appendix for additional details. The source for internal mover share is Equifax and the source for house price index is CoreLogic.

Table 1: Summary Of Transactions and Prices, Los Angeles Metropolitan Area 1988-2009

Year	Real House Price Index	Total Transactions	Median Days on Market	External Transactions	Internal Transactions	Internal Mover Share
1988	0.00	152,363	50	--	--	--
1989	0.15	131,890	62	--	--	--
1990	0.15	109,238	80	--	--	--
1991	0.08	104,532	86	--	--	--
1992	0.00	95,813	88	67,903	27,910	29.1
1993	-0.13	97,441	93	76,170	21,271	21.8
1994	-0.22	115,865	80	90,966	24,899	21.5
1995	-0.27	99,876	75	78,632	21,244	21.3
1996	-0.31	115,053	59	88,821	26,232	22.8
1997	-0.29	127,579	48	95,671	31,908	25.0
1998	-0.20	146,705	38	102,987	43,718	29.8
1999	-0.13	155,617	36	106,084	49,533	31.8
2000	-0.06	147,946	29	96,727	51,219	34.6
2001	0.02	142,185	27	89,207	52,978	37.3
2002	0.14	155,375	24	96,270	59,105	38.0
2003	0.30	157,820	24	92,356	65,464	41.5
2004	0.53	148,012	23	86,084	61,928	41.8
2005	0.68	144,048	25	83,966	60,082	41.7
2006	0.73	109,414	44	68,887	40,527	37.0
2007	0.63	74,984	53	53,981	21,003	28.0
2008	0.31	81,295	49	67,020	14,275	17.6
2009	0.11	49,037	37	--	--	--

Notes: Year 2009 includes sales through June only. A transaction is internal if the seller also bought a house in the Los Angeles MSA within 12 months of the selling date. A transaction is external if the seller does not buy a house in the Los Angeles MSA within 12 months of the selling date. All data except for Days on Market comes from Dataquick. Days on Market data comes from California Association of Realtors. We cannot break out total transaction volume into internal and external movement during the years before 1992 because the buyer and seller names are severely truncated in the Dataquick data for those years.

Table 2: Influence of Holding Two Positions on Sales Prices

	Log Sales Price - Log Predicted Price of Sell	Log Sales Price - Log Predicted Price of Buy
I[60 < (Sell Date - Purchase Date) < 180]	-0.0115***	-0.0088*
	(0.0041)	(0.0053)
I[30 < (Sell Date - Purchase Date) < 60]	-0.0253***	-0.0008
	(0.0052)	(0.0068)
I[20 < (Sell Date - Purchase Date) < 30]	-0.0391***	-0.0039
	(0.0068)	(0.0090)
I[10 < (Sell Date - Purchase Date) < 20]	-0.0352***	0.0032
	(0.0067)	(0.0089)
I[0 < (Sell Date - Purchase Date) < 10]	-0.0437***	-0.0042
	(0.0064)	(0.0086)
I[(Sell Date - Purchase Date) == 0]	-0.0168***	0.0129**
	(0.0043)	(0.0056)
I[0 < (Sell Date - Purchase Date) < -10]	-0.0123***	-0.0015
	(0.0035)	(0.0046)
I[-20 < (Sell Date - Purchase Date) < -10]	0.0129***	-0.0015
	(0.0048)	(0.0064)
I[-30 < (Sell Date - Purchase Date) < -20]	0.0166***	-0.0049
	(0.0052)	(0.0069)
I[-30 < (Sell Date - Purchase Date) < -60]	0.0312***	-0.0129**
	(0.0043)	(0.0057)
I[-60 < (Sell Date - Purchase Date) < -180]	0.0205***	-0.0152***
	(0.0036)	(0.0048)
I[-180 < (Sell Date - Purchase Date) < -365]	0.0013	-0.0009
	(0.0038)	(0.0050)
Observations	423322	338062

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: These regressions investigate how sales prices of homes bought and sold by internal movers depend on the number of days between the sale date and the purchase date. The source is the Los Angeles Dataquick data. Log sales price are normalized by a log predicted market price, which is calculated in a first stage through a repeat sales analysis. Transactions that do not have a previous price during our sample window are thus excluded from the second stage regression. The sample is restricted to internal movers, so that the price comparisons are between internal movers who buy and sell at various times. A mover is internal if they bought a house in the Los Angeles MSA within 12 months of the selling date. The first column investigates the price of the home sold by internal movers. The second column investigates the price of the home purchased by internal movers. The independent variables are different categories for the length of time between the sale date and purchase date. The excluded group is internal movers who bought between six and twelve months before selling.

Table 3: Moments Targeted in Estimation

Moment	Data	Simulated Value
Median Months on market for sellers (μ)	2.000	3.882
Median Months on market for sellers (σ/μ)	0.436	0.498
Correl(Median Months on market, Δ Real Price)	-0.390	-0.165
Sales volume (σ/μ)	0.210	0.075
Correl(sales volume, Δ Real Price)	0.850	0.779
Real price (σ/μ)	0.316	0.312
Within-period price dispersion as a share of average price (μ)	0.130	0.111
Share of internal movers who buy first (μ)	0.286	0.287
Correl(Share of internal movers who buy first,Δ Real Price)	-0.100	-0.079
Correl(Share of transactions by internal movers,Δ Real Price)	0.880	0.894

Notes: The means (μ) and standard deviations (σ), as well as the correlation coefficients (Correl), are taken over the time series. All changes are annual.

Table 4

Parameters Calibrated A Priori/Normalizations

Parameter	Description	Value
μ_b	Monthly Flow utility of being a buyer	0.0000
μ_{mm}	Monthly Flow utility of being mismatched	0.0240
β	Monthly Discount factor	0.9950
μ_{infl}	Monthly Average inflow into economy	0.0033
λ	Monthly Probability of transition to mismatch	0.0069
η	Exponent of matching function	0.1600
θ	Bargaining power of seller	0.5000
m_S	Mass of Starter Homes	0.5000
m_R	Mass of Trade-up Homes	0.5000
$(1-\pi)$	Share of Mismatched Starter Owners Get Mismatched with City	0.4000

Parameters Estimated by Simulated MOM

Parameter	Description	Estimate	Standard Error
μ_m	Monthly Flow utility of being matched	0.0273	0.0007
μ_{mmo}	Monthly Flow utility of being mismatched with metro area	0.0014	0.0114
μ_d	Monthly Flow utility penalty of having 2 positions	0.0483	0.0050
\tilde{σ}	Stdev. Of match quality shocks	0.0937	0.0333
σ_{infl}	Monthly Stdev of inflow into economy	0.0012	0.0002

Table 5: Model Generated Volatility in Transaction Volume and Price

	Baseline Model	Counterfactual Models: No Internal Movement	Adjust Flow Utility of Holding two Positions Such that: 55% buy-before-sell	70% buy-before-sell	80% buy-before-sell
Prices	0.312	0.137	0.266	0.184	0.077
Volume	0.074	0.067	0.067	0.062	0.060

Notes: Volatility is defined as the coefficient of variation over time. The unit of observation is a year. Volume is total annual sales volume and price is an annual average price (weighted by monthly volume). In the no internal movement model, upon selling, sellers in the starter market receive a time invariant and market conditions invariant lifetime utility. Percent buy-before-sell denotes the average share of internal movers who buy before selling over time in equilibrium. The different shares are achieved by adjusting the penalty for holding two positions, u_d.

Table 6: Welfare Analysis

	Change in Welfare per Transaction Relative to Decentralization: Equivalent Variation: in 2011 Dollars	as a share of average sales price	Equilibrium Price Volatility
Social Planner in Baseline Model	$7,453	1.52%	0.15
Social Planner in No Internal Movement Model	$2,019	0.41%	0.14
Optimal Policy in Baseline Model	$7,019	1.44%	0.13
Optimal Policy (Transaction Taxes Only) in Baseline Model	$1,030	0.21%	0.53

Notes: The social planner chooses match quality thresholds so as to maximize discounted social welfare, subject to the matching technology, the mismatch process, and the exogenous inflow process. In the no internal movement model, upon selling, sellers in the starter market receive a time invariant and market conditions invariant lifetime utility. The policy tools are a transaction tax (or subsidy) that is allowed to differ across submarkets, a per-period tax (or subsidy) to agents who hold two positions, and a per-period tax (or subsidy) to starter sellers who are mismatched with the metro area. The policy interventions are constrained to be invariant to time or market conditions and revenue neutral. To calculate price in the social planner equilibrium, we calculate the value functions associated with each pool assuming that matches are accepted/rejected according to the planner's transaction thresholds. Price is then calculated according to the equilibrium price equations in Section 3. Volatility is measured as the coefficient of variation over time.

Table 7: Comparison of Moments under Decentralization, Centralization, and Optimal Policy

	Decentralization		Social Planner		Optimal Policy	
	μ	(σ/μ)	μ	(σ/μ)	μ	(σ/μ)
Prob. of Transaction Conditional on Match (SB,SS)	0.13	0.49	0.30	0.20	0.30	0.09
Prob. of Transaction Conditional on Match (SB,D)	0.82	0.01	0.72	0.06	0.82	0.02
Prob. of Transaction Conditional on Match (SB,SSO)	0.91	0.05	0.69	0.09	0.77	0.04
Prob. of Transaction Conditional on Match (RB,RS)	0.77	0.01	0.49	0.11	0.58	0.01
Prob. of Transaction Conditional on Match (SS,RS)	0.05	1.05	0.09	0.99	0.05	0.37
Share of Internal Movers who buy first	0.29	0.33	0.29	0.24	0.35	0.41
Volume	0.08	0.07	0.08	0.09	0.08	0.08
Price		0.31	--	0.15		0.13

Notes: This table reports average of (μ) and volatility of (σ/μ) particular moments over time under the three equilibria listed above. The first five rows summarize transaction thresholds for the five types of housing transactions in the model economy. Transactions are differentiated by the types of agents who transact (abbreviated in parentheses). SB denotes starter buyer, SS denotes starter seller, D denotes an agent holding 2 positions, RB denotes a trade-up buyer, RS denotes a trade-up seller, SSO denotes a starter seller who is mismatched with the metro area.