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## Buying first or selling first in housing markets<sup>20</sup>

### 3.1 Introduction

A large number of households move within the same local housing market every year. Many of these moves are by owner-occupiers who buy a new property and sell their old housing unit. However, it takes time to transact in the housing market, so a homeowner that moves may end up either owning two units or being forced to rent for some period, depending on the sequence of transactions. Either of these two alternatives may be costly.<sup>21</sup> There is anecdotal evidence that the incentives to “buy first” (buy the new property before selling the old property) or “sell first” (sell the old property before buying the new one) may depend on the state of the housing market.<sup>22</sup> If the transaction sequence decisions of moving owner-occupiers in turn affect housing

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<sup>20</sup>This chapter is based on Moen et al. (2015)

<sup>21</sup>The following quote from Realtor.com, an online real estate broker, highlights this issue: “If you sell first, you may find yourself under a tight deadline to find another house, or be forced in temporary quarters. If you buy first, you may be saddled with two mortgage payments for at least a couple months.” (Dawson (2013))

<sup>22</sup>A common realtor advice to homeowners that have to move is to “buy first” in a “hot” market, when there are more buyers than sellers and prices are high or expected to increase, and “sell first” in a “cold” market, when there are more sellers than buyers and house prices are depressed or expected to fall. Anundsen and Larsen (2014) provides evidence on the response of the intentions of owner-occupiers to buy first or sell first to the state of the housing market using survey data for Norway. In Section 3.2 we provide direct evidence for this link using data for the Copenhagen housing market.

market conditions, there could be powerful equilibrium feedbacks with important consequences for housing market dynamics.

In this chapter we study a tractable equilibrium model of the housing market, which explicitly features trading delays and a transaction sequence decision for moving owner-occupiers. We show that the transaction sequence choices of moving homeowners can have powerful effects on the housing market and can lead to large fluctuations in the stock of houses for sale, time-on-market, transaction volume, and prices.

In the model, agents continuously enter and exit a local housing market. They have a preference for owning housing over renting, and consequently, search for a housing unit to buy. The market is characterized by a frictional trading process in the form of search-and-matching frictions. This leads to a positive expected time-on-market for buyers and sellers, which is affected by the tightness in the market – the ratio of buyers to sellers. Once an agent becomes an owner-occupier, he may be hit by an idiosyncratic preference shock over his life cycle. In that case he becomes “mismatched” with his current house and wants to move internally in the same housing market. To do that, the mismatched owner has to choose optimally the order of transactions – whether to buy a new housing unit first and then sell his old unit (buy first), or sell his old unit first and then buy (sell first). Given trading delays, this may lead to the agent becoming a double owner (owning two housing units) or a forced renter (owning no housing unit) for some time, which is costly. The expected time of remaining in such a state depends on the time-on-market for sellers and buyers, respectively.

If the costs incurred by a double owner or a forced renter are high relative to the costs of a mismatch, the mismatched owner prefers buying first over selling first whenever there are *more* buyers than sellers in the market, or more generally, when the buyer-seller ratio is high. The intuition for this behavior is the following. First, whenever it is more costly to be a double owner or a forced renter compared to being mismatched, a moving owner wants to minimize the delay between the two transactions. Second, when there are more buyers than sellers, the expected time-on-market is low for a seller and high for a buyer. Consequently, if a mismatched owner buys first he expects to spend a longer time as a buyer, and hence to remain mismatched longer. However, once he buys, he expects to stay with two houses for a short time while searching for a buyer for his old property. Conversely, choosing to sell first in that case implies a short time-to-sell and a short time of remaining mismatched but a longer time of searching to buy a new unit afterwards. Since the flow costs in between the two transactions are higher than during mismatch, buying first clearly dominates selling first in that case.

However, the order of transactions by moving owner-occupiers affects the buyer-seller ratio. Specifically, when mismatched owner-occupiers buy first, they crowd the buyer side of the market, and so, the market ends with more buyers than sellers in steady state. Nevertheless, this high buyer-seller ratio is consistent with the incentives of mismatched owners to buy first. Conversely, when all mismatched owners sell first, there are more sellers than buyers in steady state. However, a low buyer-seller ratio is consistent with the incentives of mismatched owners to sell first. Therefore, the interaction between the behavior of mismatched owners and the buyer-seller composition of the housing market creates a *strategic complementarity* in their transaction sequence decisions, which in turn may lead to multiple steady state equilibria. In one steady state equilibrium (a “Sell first” equilibrium), mismatched owners prefer to sell first, the market tightness is low and the expected time-on-market for sellers is high. In the other steady state equilibrium (a “Buy first” equilibrium), mismatched owners prefer to buy first, the market tightness is high and the expected time-on-market for sellers is low.<sup>23</sup>

To illustrate this strategic complementarity more clearly, we first assume that prices are fixed across steady states, or alternatively, that the rental price is equal to the house price times the discount rate, in which case prices do not influence the transaction sequence decision. After explaining this channel and its implications, in a separate section, we endogenize house prices. First, we assume that the steady state price level is an increasing function of the buyer-seller ratio. We show that even with a rental price that is constant, multiplicity exists as long as the responsiveness of the house price to the buyer-seller ratio is not too high. After clarifying this countervailing effect, we show that there can exist multiple equilibria when house prices are (endogenously) determined by Nash bargaining, and hence, both differ across trading pairs and respond to changes in the buyer-seller ratio. Specifically, the main channel that drives equilibrium multiplicity in our benchmark model – the strategic complementarity resulting from the interplay between mismatched owners’ transaction sequence decisions and the stock-flow conditions that determine the equilibrium market tightness – is still present in that environment. We also show that there can be equilibrium multiplicity even in an environment with competitive search where agents can trade off prices and time-on-market (queue length).

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<sup>23</sup>Note that we derive this multiplicity under the assumption of a constant returns to scale matching function. Therefore, the strategic complementarity does not arise from increasing returns to scale in matching as in Diamond (1982).

We also analyze switches between the “Buy first” and “Sell first” equilibria. Such switches lead to fluctuations in the housing market. Specifically, moving from the “Buy first” to the “Sell first” equilibrium is associated with an increase in the for-sale stock and time-on-market for sellers, and a drop in transactions. This behavior is broadly consistent with evidence on the housing cycle. In particular, explaining the negative comovement between the for-sale stock and transactions has been a challenge for search-based models of the housing market (Diaz and Jerez, 2013). As we show in a simple numerical example, the fluctuations generated by these switches can be substantial. Also, when prices are determined by Nash bargaining, we show that there can be substantial house price fluctuations arising from these equilibrium switches.

Finally, we show that when house prices respond to changes in the buyer-seller ratio, there can exist equilibria with self-fulfilling fluctuations in prices and market tightness. Since mismatched owners are more likely to buy first (sell first) when they expect price appreciation (depreciation), they end up exerting a destabilizing force on the housing market. For example, if agents expect prices to depreciate, they are more likely to sell first. However, this decreases the buyer-seller ratio, which in turn drags down house prices, and thus, confirms the agents’ expectations.

**Related literature.** The chapter is related to the growing literature on search-based models of the housing market and fluctuations in housing market liquidity, initiated by the seminal work of Wheaton (1990). This foundational paper is the first to consider a frictional model of the housing market to explain the existence of a “natural” vacancy rate in housing markets and the negative comovement between deviations from this natural rate and house prices. In that model, mismatched homeowners must also both buy and sell a housing unit. However, the model implicitly assumes that the cost of becoming a forced renter with no housing is prohibitively large, so that mismatched owners always buy first. As we show in our chapter, allowing mismatched owners to endogenously choose whether to buy first or sell first has important consequences for the housing market.

The chapter is particularly related to the literature on search frictions and propagation and amplification of shocks in the housing market (Krainer (2001), Novy-Marx (2009), Caplin and Leahy (2011), Diaz and Jerez (2013), Head et al. (2014), Ngai and Tenreyro (2014), Guren and McQuade (2013), Anenberg and Bayer (2015), Ngai and Sheedy (2015)). This literature shows how search frictions naturally propagate aggregate

shocks due to the slow adjustment in the stock of buyers and sellers. Additionally, they can amplify price responses to aggregate shocks, which in Walrasian models would be fully absorbed by quantity responses.<sup>24</sup>

Diaz and Jerez (2013) calibrate a model of the housing market in the spirit of Wheaton (1990) where mismatched owners must buy first, as well as a model where they must sell first. They show that each model explains some aspects of the data on housing market dynamics, pointing to the importance of a model that contains both choices. Other models of the housing market assume that the sequence of transactions is irrelevant, which implicitly assumes that the intermediate step of a transaction sequence for a moving owner is costless (Caplin and Leahy (2011), Ngai and Tenreyro (2014), Head et al. (2014), Guren and McQuade (2013), Ngai and Sheedy (2015)).

Ngai and Sheedy (2015) model an endogenous moving decision based on idiosyncratic match quality as an amplification mechanism of sales volume. The paper shows how the participation decisions of mismatched owners in the housing market can explain why time-on-market for sellers can decrease while the stock of houses for sale increases at the same time, as was the case during the housing boom of the late 90s and early 2000s. In our model we assume that mismatched owners always participate and instead focus on their transaction sequence decisions. The implications we draw from our analysis are therefore complementary to the insights in their paper.

Anenberg and Bayer (2015) is a recent contribution that is close to our chapter, particularly in terms of motivation. The chapter studies a rich quantitative model of the housing market to explain the large volatility of internal movements by existing owners, which they argue is the main driver of fluctuations in housing transactions. The authors calibrate their model to data for Los Angeles and show how shocks to the flow of new buyers can be amplified through the decisions of existing owners and can lead to substantial fluctuations in prices and volume. Similar to our model, existing owners in their model also have to both buy and sell in the same market. Unlike our model, however, existing owners in their model simultaneously search both on the buyer and seller side, so they do not choose to bias their search decisions. With some probability, both a buy and a sell offer may arrive in the same period, in which case an owner has to choose to conduct one of the two transactions and forfeit the possibility of conducting the other. Otherwise, whether a buy offer arrives before a sell offer or

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<sup>24</sup>The chapter is also broadly related to the Walrasian literature on house price dynamics and volatility (Stein (1995), Ortalo-Magne and Rady (2006), Glaeser et al. (2014)).

vice versa is exogenous from the point of view of individual owners. In contrast, in our model, mismatched owners choose which side of the market to enter and whether to receive only offers from buyers or from sellers. This endogenous choice by existing owners to bias their search decisions influences market tightness and buyer and seller times-on-market, which in turn influence the choices of other existing owners. The strategic complementarity resulting from this feedback between market tightness and the decisions of mismatched owners leads to multiplicity, self-fulfilling fluctuations, and housing market volatility in our model. Therefore, the theoretical focus of our chapter and the different mechanism that we explore make our chapter complementary to this study.

The paper is also related to the literature on multiple equilibria and self-fulfilling fluctuations as the result of search frictions. Multiple equilibria in that literature arise mainly from increasing returns to scale in matching (Diamond (1982)) or from the interactions between several frictional markets (Howitt and McAfee (1988)).<sup>25</sup> In contrast, multiplicity in our model arises in a single market with constant returns to scale in matching. Other sources of multiplicity in models with search frictions include an indeterminacy in the division of the match surplus (Howitt and McAfee (1987), Farmer (2012), Kashiwagi (2014)) or the interaction between the outside option of matched market participants and their endogenous separation decisions (Burdett and Coles (1998), Coles and Wright (1998), Burdett et al. (2004), Moen and Rosén (2013), Eeckhout and Lindenlaub (2015)). In our paper, the division of the match surplus is determined by a fixed price, by Nash bargaining, or by competitive search, so that the indeterminacy of a bilateral monopoly is not exploited. Also, separation is exogenous in our framework.

Section 3.5 that extends our results to environments where prices are endogenously determined, relates the chapter to the literature on Nash bargaining and competitive search in the housing market. In particular, Albrecht et al. (2007) study a search model of the housing market where buyers and sellers may become “desperate” if they search unsuccessful for too long. Because prices in their model are determined by Nash bargaining, the presence of agents with heterogeneous flow values while searching results in compositional effects that also arise in the extension of our model with Nash

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<sup>25</sup>Similar papers include Drazen (1988), Diamond and Fudenberg (1989), Mortensen (1989), Howitt and McAfee (1992), Boldrin et al. (1993), Mortensen (1999), Kaplan and Menzio (2016), Chéron and Decreuse (2016), and the previous chapter, among others.

bargaining. However, in their model equal numbers of buyers and sellers enter the market at an exogenous rate, so that there is no transaction sequence decision.<sup>26</sup> Finally, our extension in Section 3.5.3 to a model of the housing market with competitive search relates the chapter to recent models of competitive search in housing and asset markets (Diaz and Jerez (2013), Lester et al. (2015), Albrecht et al. (2016), and Lester et al. (2013)).

The rest of the chapter is organized as follows. In the next section we present some motivating facts using individual level data from Denmark. We also explain why modeling the transaction sequence of moving owners as an explicit choice rather than a passive outcome of simultaneous search on both sides of the market is important for consistency with the data. Section 3.3 presents the basic model of the housing market, and Section 3.4 characterizes the decisions of mismatched owners and discusses the equilibrium multiplicity and the implications of equilibrium switches. Section 3.5 shows that there can be equilibrium multiplicity in an environment where prices are determined by Nash bargaining and also in an environment with competitive search, and discusses some additional extensions. Section 3.6 shows how the incentives of mismatched owners to buy first or sell first depend on price expectations and shows that there can exist equilibria with self-fulfilling fluctuations in house prices and tightness, while section 3.7 concludes.

## 3.2 Motivating facts

We start by providing some motivating facts about the transaction sequence decisions of owner-occupiers for Copenhagen, Denmark. We focus on the Copenhagen urban area for the period 1992-2010. We use the Danish ownership register, which records the property ownership of individuals and legal entities as of January 1st of a given year. We combine that with a record of property sales for each year. The unique owner and property identifiers give us a matched property-owner data set, which we use to keep track of the transactions of individuals over time. We focus on individual owners who are recorded as the primary owner of a property.

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<sup>26</sup>Maury and Tripier (2014) study a modification of the Wheaton (1990) model, in which mismatched owners can buy and sell simultaneously, which they use to study price dispersion in the housing market. However, they do not consider the feedback from buying and selling decisions on the stock-flow process and on market tightness. This feedback is key for the mechanisms we explore in our chapter.



We use the ownership records of individual owners over time to identify owner-occupiers who buy and sell in the Copenhagen housing market.<sup>27</sup> We then use the property sales record to determine the agreement dates (the dates the sale agreement is signed) and closing dates (the dates the property formally changes ownership) for the two transactions. Based on those, we construct a variable that measures the time difference between the sale of the old property and the purchase of the new property. If the difference is positive, the owner-occupier buys first, if it is negative he sells first.

Figure 8 shows the distribution of the time difference between the agreement dates (Panel 8a) and closing dates (Panel 8b) for owner-occupiers who both buy and sell in Copenhagen during our sample period. There is substantial dispersion in the time difference between agreement dates, which suggests that a large fraction of these homeowners cannot synchronize the two transactions on the same date. Specifically, there is substantial mass even in the tails of the distribution. Examining the difference in closing dates shows a similar picture. Even though the distribution is more compressed in that case, since homeowners try to a greater extent to synchronize the closing dates, so that they occur on the same day or in a close interval, a large fraction of homeowners face a time difference of a month or more in between closing the two transactions. Overall, these distributions suggest that for homeowners that buy and sell in the same housing market the time difference between transactions can be substantial, confirming the anecdotal evidence cited in the introduction.

Another important observation is that the two distributions are right skewed, so moving homeowners tend to buy first during our sample period. This is confirmed when we examine the time series behavior of the fraction of homeowners that are identified as buying first in a given year from 1993-2008, as Figure 9 shows. Similar to Figure 8, the left-hand panel (Panel 9a) is based on agreement dates, while the right-hand panel (Panel 9b) is based on closing dates. Both panels also contain a price index for single family homes for the Copenhagen housing market. As the figure shows, the fraction of owners that buy first is not constant over time but exhibits wide variations going from a low of around 0.3 in 1994 to a high of 0.8 in 2006 and then back to a low of around 0.4 in 2008. This fraction tracks closely the house price index increasing over most of the sample period and peaking in the same year. It is then followed by a substantial drop as

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<sup>27</sup>Appendix 3.8.A contains detailed information on the data used and on the procedure for identifying owner-occupiers that buy and sell. Given the way we identify these owner-occupiers, we have a consistent count for the number of owners who buy first or sell first in a given year for the years 1993 to 2008.

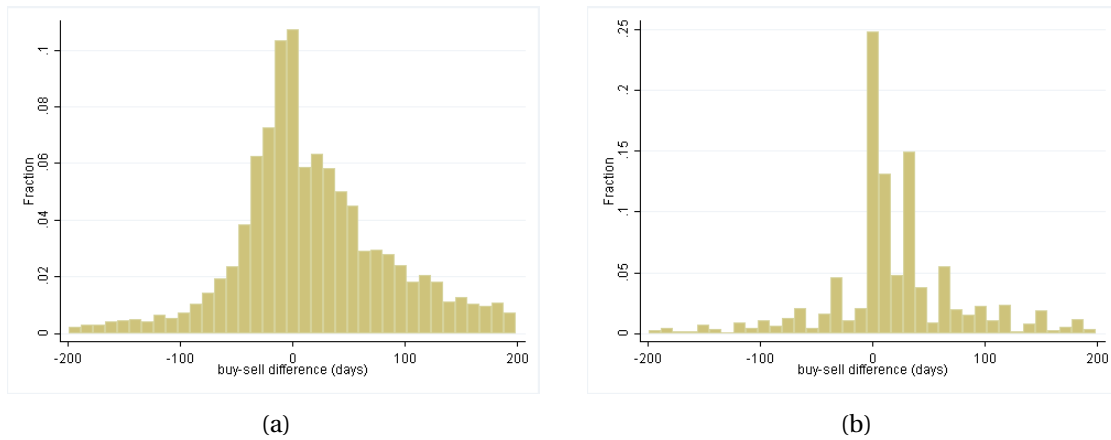


Figure 8: Distribution of the time difference between “sell” and “buy” agreement dates (a) and closing dates (b) for homeowners who both buy and sell in Copenhagen (1993-2008).

house prices start to decline after 2006. Therefore, Figure 9 suggests that the decisions to buy first may be related to the state of the housing market.

A closer examination of the period 2004-2008 strengthens this conjecture. Specifically, Figure 10 illustrates the fluctuations in key housing market variables like the for-sale stock, seller time-on-market, transaction volume and prices for Copenhagen in the period 2004-2008. It also includes our constructed fraction of buy first owners for Copenhagen in the period 2004-2008. During the first half of this period seller time-on-market (TOM), and the for-sale stock are low, while transaction volume and the fraction of buy first owners are high. There is a switch in all of these series around the 3rd quarter of 2006 and a quick reversal during which seller time-on-market and the for-sale stock increase rapidly, while the fraction of moving owners that buy first drops. Transaction volume is also lower during the second half of this period. Prices increase during the first half of the period and then decline.

We take these three exhibits as indication that there is a non-trivial transaction sequence choice for owner-occupiers that move in the same housing market, that the time difference between the two transactions can be substantial, and that the decision to buy first or sell first is related to the state of housing markets. These facts motivate our theoretical study below.

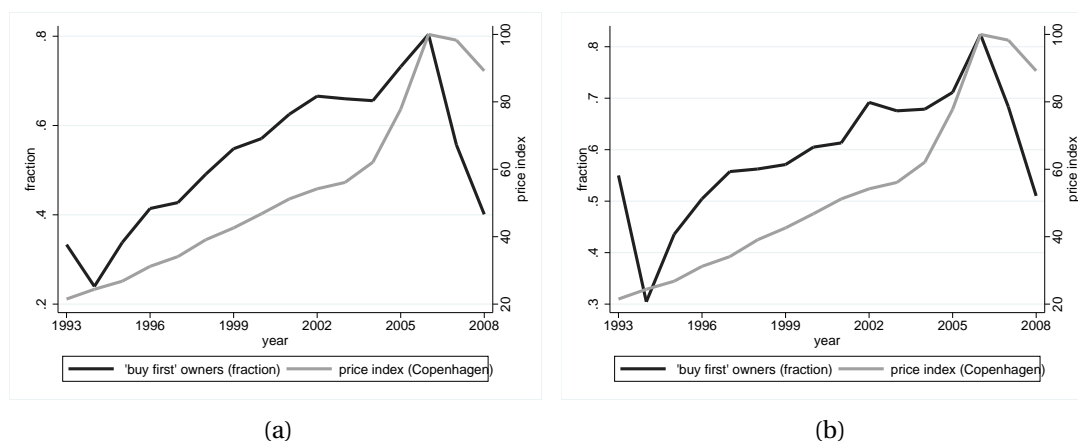


Figure 9: Fraction of owners who “buy first” and housing market conditions in Copenhagen (1993-2008). Panel a is based on agreement dates, and Panel b is based on closing dates.

Notes: The series on the fraction of “buy first” owners is from own calculations based on registry data from Statistics Denmark. See Appendix 3.8.A for a description on how we identify an owner that buys and sells in Copenhagen (a buyer-and seller) as a “buy first” (“sell first”) owner. We compute annual counts of the number of “buy first” and “sell first” owners by looking at the year of the first transaction for each of these owners. The fraction of “buy first” owners is then the proportion of buyer-and-seller owners that buy first. For Panel a the identification of an owner as buy first/sell first is based on the difference in the two agreement dates. For Panel b, it is based on the difference in the two closing dates. The price index is a repeat sales price index for single family houses for Copenhagen (Region Hovedstaden) constructed by Statistics Denmark.

### 3.2.1 Why an explicit transaction sequence choice?

Before proceeding with our model, we make the following important conceptual point. Suppose that rather than explicitly choosing how to conduct the sequence of transactions, moving owners always enter both sides of the market simultaneously. Then they simply take whichever trading opportunity comes first. Thus, they are *observed* to “buy first” whenever they happen to meet a seller before a buyer and vice versa. We refer to this as a simultaneous search strategy.

Suppose that the market is frictional and there are trading delays. With standard assumptions on the matching technology, the rate at which a buyer meets a seller is decreasing in the buyer-seller ratio in the market, while the rate at which a seller meets a buyer is increasing in the buyer-seller ratio. Hence, a simultaneous search strategy

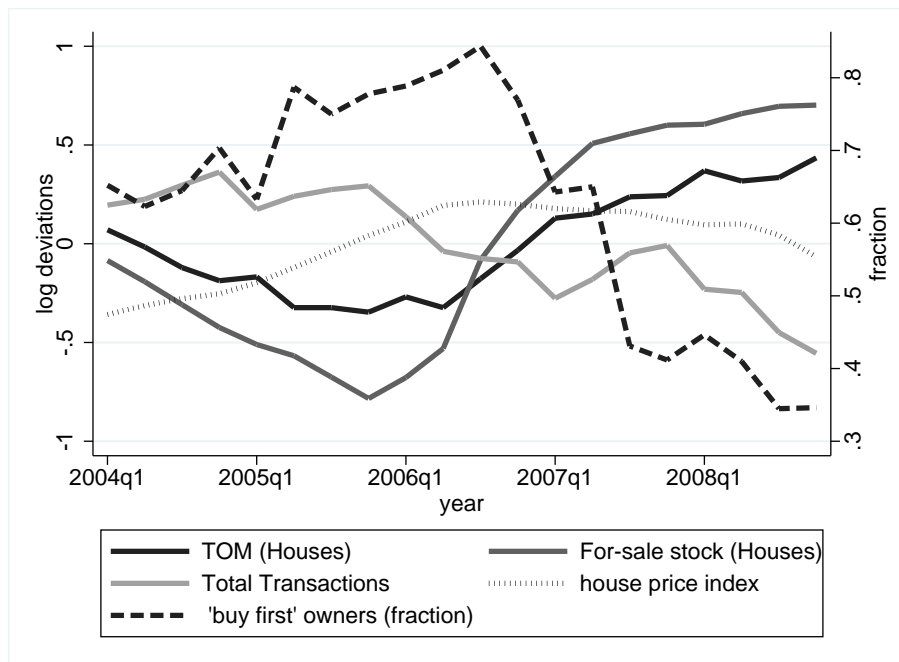


Figure 10: Housing market dynamics, Copenhagen 2004-2008

Notes: Data on seller time-on-market (TOM) and the for-sale stock is from the Danish Mortgage Banks' Federation (available at <http://statistik.realkreditforeningen.dk/BMSDefault.aspx>). These series are shown in log deviations from their sample mean. The total transaction volume is from Statistics Denmark. It is in log deviations from the sample mean after controlling for seasonal effects by quarter-in-year dummies. The fraction of buy first owners is from own calculations based on registry data from Statistics Denmark. See Appendix 3.8.A for a description on how we identify an owner that buys and sells in Copenhagen (a buyer-and-seller) as a “buy first” (“sell first”) owner. We compute quarterly counts of the number of “buy first” and “sell first” owners by looking at the quarter of the first transaction for each of these owners. The fraction of “buy first” owners is then the proportion of buyer-and-seller owners that buy first. The identification of an owner as buy first/sell first is based on the difference in the two agreement dates.

implies that the observed fraction of agents that buy first is decreasing in the buyer-seller ratio. The (steady state) average time-on-market is the inverse of the meeting rate of sellers, and hence is also decreasing in the buyer-seller ratio. It follows that if the agents use a simultaneous search strategy, the fraction of owners that are observed to buy first and the seller time-on-market should move in tandem – one should observe fewer

owners “buying first” whenever seller time-on-market is low and vice versa. However, this is counterfactual, in view of Figure 10.<sup>28</sup>

This simple example shows (without reference to the optimization decision of agents) that to be consistent with the data, mismatched owners must explicitly choose to (predominantly) search only on one side of the market, thus steering the sequence of their transactions, rather than to search simultaneously on both sides and having the sequence of their transactions be determined by the exogenous arrival of trading counterparties. Moreover, as we show in our model, when agents’ optimizing decisions are taken into account, under a naturally satisfied parametric assumption on preferences, mismatched owners rationally choose to bias their search towards one side of the market in a way that leads to aggregate behavior that is consistent with the data.

### 3.3 Model

In this section, we set up the basic model of a housing market characterized by trading frictions and re-trading shocks that will provide the main insights of our analysis.

#### 3.3.1 Preferences

Time is continuous. The housing market consists of a unit measure of durable housing units that do not depreciate, and a unit measure of households, which we refer to as agents. The agents are risk neutral and can borrow and lend freely at interest rate  $r > 0$ . When an agent buys a house and becomes a homeowner, he receives a flow utility of  $u > 0$ . We say that the homeowner is *matched*. With a Poisson rate  $\gamma$  the matched homeowner is hit by a taste shock, and becomes *mismatched* with his current housing unit. In that case the homeowner obtains a flow utility of  $u - \chi$ , for  $0 < \chi < u$ . A mismatched owner has to move to another housing unit in order to become matched

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<sup>28</sup>To show this formally, below we denote the buyer-seller ratio by  $\theta$ , the rate at which sellers meet buyers by  $\mu(\theta)$ , where  $\mu(\theta)$  is increasing in  $\theta$ , and the rate at which a buyer meets a seller by  $q(\theta) = \frac{\mu(\theta)}{\theta}$ , where  $q(\theta)$  is decreasing in  $\theta$ . If owners follow a simultaneous search strategy, in steady state, the ratio of owners observed to buy first relative to those observed to sell first is

$$\frac{q(\theta)}{\mu(\theta)} = \frac{1}{\theta}. \quad (3.1)$$

Therefore, this ratio is decreasing in  $\theta$ . Since  $\theta$  and sellers’ (average) time-on-market,  $\frac{1}{\mu(\theta)}$ , are negatively related, the fraction of owners observed to buy first and seller time-on-market should move in tandem as  $\theta$  changes.

again. Taste shocks of this form are standard in search models of the housing market (Wheaton, 1990), and create potential gains from trading.<sup>29</sup>

A mismatched owner can choose to *sell first* (and become a *mismatched seller*) – selling the housing unit he owns first and then buying a new one. Alternatively, he can choose to *buy first* (becoming a *mismatched buyer*) – buying a new housing unit first and then selling his old one. Finally, the mismatched owner may choose to not enter the housing market and stay mismatched.<sup>30</sup>

We also assume that a mismatched owner cannot synchronize the two transactions (the selling and buying). For example, he cannot exchange houses with another mismatched owner, as there is no double coincidence of housing wants among owners.<sup>31</sup> Instead, a mismatched owner has to conduct the two transactions in a sequence. A mismatched buyer ends up holding two housing units simultaneously for some period. In this case we say that he becomes a *double owner*. Similarly, a mismatched seller ends up owning no housing. In that case the agent becomes a *forced renter*.

The utility flows during the transaction period (when the agent is a double owner or a forced renter) are key for our results. We assume that a double owner receives a flow utility of  $u_2 < u$ , while a forced renter receives a flow utility of  $u_0 < u$ . These flows do not include the cost of renting a house for a forced renter, or rental income from renting out the second house for the double owner (as will be clear below, we assume that the double owner rents out the second housing unit). For the double owner,  $u_2$  includes

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<sup>29</sup>Rather than introducing segmentation in the housing stock, we treat all housing units as homogeneous, so that mismatched owners participate in one integrated market with other agents. Although in reality agents move across housing market segments (whether spatial or size-based) in response to a taste shock of the type we have in mind, modeling explicitly several types of housing would substantially reduce the tractability of the model. Furthermore, defining empirically distinct market segments is not straightforward as in reality households often search in several segments simultaneously (Piazzesi et al., 2015).

<sup>30</sup>See our discussion in Section 3.2.1 for why an explicit choice of buying first versus selling first is necessary for explaining the patterns we observe in the data. Also, in Section 3.5.4, we explicitly allow a mismatched owner to search as a buyer and seller simultaneously, subject to a fixed time endowment. We show that, given the preference assumptions we make, mismatched owners rationally choose to bias their search towards only one side of the market depending on the market tightness, so the restriction to either only buying first or selling first is without loss of generality in this case. Finally, notice that searching simultaneously as both a buyer and seller does not mean that the agent can synchronize the two transactions, only that he chooses to receive offers from both potential buyers and sellers.

<sup>31</sup>This is similar to the lack of double coincidence of wants used in money-search models (Kiyotaki and Wright (1993)). In reality, some moving homeowners may be able to synchronize the two transactions as is also evident from Figure 8. Allowing some mismatched owners to synchronize their buy and sell transactions would reduce the tractability of the model without changing its qualitative predictions.

maintenance costs, costs (pecuniary and non-pecuniary) associated with renting out the second house – reflecting unmodelled frictions in the rental market, costs associated with bridge loans (over and above the interest rate), reflecting unmodelled frictions in the financial market, and so on. For the forced renter,  $u_0$  includes relocation costs to a new temporary quarter, inconveniences and monetary costs associated with short-term renting, such as, for example, rent-back agreements, where a former owner rents his old house at a premium from the new owner, and other unmodelled frictions in the rental market, costs of storage of furniture, etc. As will be clear below, a driving assumption in our analysis is that  $u_2$  and  $u_0$  are less than  $u - \chi$ , i.e., the flow utilities to an agent during the transaction period are lower than when living as mismatched in his own house. For tractability, we also assume that a double owner does not experience mismatching shocks. This ensures that the maximum holdings of housing by an agent will not exceed two units in equilibrium.

Agents are born and die at the same rate  $g$ . New entrants start out their life without owning housing, and receive a flow utility  $u_n < u$ . Also, we assume that  $u_n \geq u_0$ , so that forced renters do not obtain a higher utility flow than new entrants. After a death/exit shock, an agent exits the economy immediately and obtains a reservation utility normalized to 0. If he owns housing, his housing units are taken over by a real-estate firm, which immediately places them for sale on the market.<sup>32</sup> Real-estate firms are owned by all the agents in the economy with new entrants receiving the ownership shares of exiting agents. Given the exit shock, agents effectively discount future flow payoffs at a rate  $\rho \equiv r + g$ . For notational convenience, we will directly use  $\rho$  later on.

Finally, agents without a house rent a dwelling. A landlord can simultaneously rent out a unit and have it up for sale. Hence double owners rent out one of their units, as do real-estate firms. The rental price is denoted by  $R$ .

### 3.3.2 Trading frictions and aggregate variables

The housing market is subject to trading frictions. These frictions are captured by a standard constant returns to scale matching function  $m(B(t), S(t))$ , mapping a stock  $B(t)$  of searching buyers and a stock  $S(t)$  of searching sellers to a flow  $m$  of new matches. We assume that there is random matching, so different types of agents meet with

<sup>32</sup>For simplicity, we assume that agents are not compensated for their housing upon exiting the economy. In Section 3.5.4, we discuss an extension to the a case where exiting agents are compensated for their housing by the real-estate firms.

probabilities that are proportional to their mass in the population of sellers or buyers. Directed search is discussed in Section 3.5.3. We define the market tightness in the housing market as the buyer-seller ratio,  $\theta(t) \equiv B(t)/S(t)$ . Additionally,  $\mu(\theta(t)) \equiv m(B(t)/S(t), 1) = m(B(t), S(t))/S(t)$  is defined as the Poisson rate with which a seller meets a buyer. Similarly,  $q(\theta(t)) \equiv m(B(t), S(t))/B(t) = \mu(\theta(t))/\theta(t)$  is the rate with which a buyer meets a seller.

Beside the market tightness,  $\theta(t)$ , which will be relevant for agents' equilibrium payoffs, we keep track of a number of stock variables. Specifically, those include the new entrants (denoted by  $B_n(t)$ ), matched owners ( $O(t)$ ), mismatched buyers ( $B_1(t)$ ), mismatched sellers ( $S_1(t)$ ), double owners ( $S_2(t)$ ), forced renters ( $B_0(t)$ ) and the housing units sold by real-estate firms ( $A(t)$ ). Therefore, the total measure of buyers is  $B(t) = B_n(t) + B_0(t) + B_1(t)$  and the total measure of sellers is  $S(t) = S_1(t) + S_2(t) + A(t)$ . Since the total population is constant and equal to 1 in every instant, it follows that

$$B_n + B_0 + B_1 + S_1 + S_2 + O = 1. \quad (3.2)$$

Also, since the housing stock does not shrink or expand over time, the following housing ownership condition holds in every instant,

$$O + B_1 + S_1 + A + 2S_2 = 1. \quad (3.3)$$

Summing up, the life-cycle of an agent in the model proceeds as follows. An agent begins his life as a new entrant. With rate  $q(\theta)$ , he becomes a matched owner. Once matched, he becomes mismatched with rate  $\gamma$ . A mismatched owner chooses to either buy first (mismatched buyer) or sell first (mismatched seller). A mismatched buyer becomes a double owner with rate  $q(\theta)$ , who in turn sells and reverts to being a matched owner with rate  $\mu(\theta)$ . A mismatched seller becomes a forced renter with rate  $\mu(\theta)$  and after that moves to being a matched owner with rate  $q(\theta)$ . In every stage of life an agent may exit the economy with rate  $g$ .

### 3.3.3 House price and rental price determination

We begin our analysis by assuming that the house price  $p$  is fixed and does not vary with the market tightness  $\theta$  (or, as a special case, that the rental price is equal to the house price times the discount rate  $\rho$ , see the end of this subsection). However, in the equilibria we consider, the price  $p$  lies in the bargaining set of all actively trading pairs.



We progressively relax this assumption by assuming that  $p$  varies with  $\theta$  in a reduced form-way in Section 3.5.1 and by assuming that prices are determined by symmetric Nash bargaining in Section 3.5.2 or in a competitive search equilibrium in Section 3.5.3. The main insights of our analysis hold in those environments as well, although at a significant reduction in tractability.<sup>33</sup>

In this paper, we do not explicitly model the rental market. Since there are equally many houses as there are agents in the economy, and all houses are either occupied by the owner or rented out, the supply of houses for rent is equal to the demand for houses for rent independently of the price (as long as all agents prefer to own rather than to rent) and independently of the transaction sequence of the agents. It follows that if the rental market is competitive, the rental price is indeterminate. In what follows, we assume that the rental price is constant, independently of  $\theta$ . Furthermore, given the assumption that a real-estate firm can rent out a housing unit without costs, we require that

$$\rho p \geq R, \tag{3.4}$$

as otherwise the real estate firms would want hold on to their houses forever.

As alluded to in the beginning of this subsection, an interesting special case, which is our benchmark case below, arises when  $R = \rho p$ . As we show below, in this case, the (steady state) house price does not influence the sequence of transactions. A higher price makes it more attractive to sell first due to discounting, while higher rental price makes it more attractive to buy first. If  $R = \rho p$ , the two effects cancel out.

### 3.4 Steady state equilibria

We start by characterizing steady state equilibria of this economy. We first discuss the value functions of different types of agents in a candidate steady state equilibrium.

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<sup>33</sup>Although the assumption that house prices are independent of  $\theta$  is made for convenience, it may also be an equilibrium outcome in some environments. Given that the price is assumed to lie in the bargaining sets of all trading pairs, it can be derived as the market clearing price in a competitive market with frictional entry of traders. In particular, as in Duffie et al. (2005) or Rocheteau and Wright (2005), the total measure of participants in that competitive market is determined by the matching function  $M(B, S)$ . The transaction price in our case will be indeterminate, and this opens up for a price that is independent of  $\theta$ . Also, under certain conditions, a unique fixed price that does not vary with tightness or across trading pairs can be microfounded as resulting from bargaining between heterogeneous buyers and sellers, in which the buyer has full bargaining power but does not know the type of the seller. As shown in Appendix 3.8.F, take-it-or-leave-it offers from buyers under private information about the seller's type can generate a fixed price that is equal to the present discounted value of rental income.

### 3.4.1 Value functions

We have a number of value functions for different agents in this economy. Specifically, we use the notation  $V^x$ , for the value function of a new entrant ( $x = Bn$ ), a forced renter ( $x = B0$ ), a mismatched buyer or seller ( $x = B1$  or  $x = S1$ ), a double owner ( $x = S2$ ) and real-estate firm holding one housing unit ( $x = A$ ). Finally, we denote the value function of a matched owner by  $V$ . Given these notations, we have a standard set of Bellman equations for the agents' value functions in a steady state equilibrium.

First of all, for a mismatched buyer we have

$$\rho V^{B1} = u - \chi + q(\theta) \max\{-p + V^{S2} - V^{B1}, 0\}, \quad (3.5)$$

where  $u - \chi$  is the flow utility from being mismatched. Upon matching with a seller, a mismatched buyer purchases a housing unit at price  $p$ , in which case he becomes a double owner, incurring a utility change of  $V^{S2} - V^{B1}$ .

A double owner has a flow utility of  $u_2 + R$  while searching for a counterparty. Upon finding a buyer, he sells his second unit and becomes a matched owner. Therefore, his value function satisfies the equation<sup>34</sup>

$$\rho V^{S2} = u_2 + R + \mu(\theta) (p + V - V^{S2}). \quad (3.6)$$

The value function of a mismatched seller is analogous to that of a mismatched buyer apart from the fact that a mismatched seller enters on the seller side of the market first and upon transacting becomes a forced renter. Therefore,

$$\rho V^{S1} = u - \chi + \mu(\theta) \max\{p + V^{B0} - V^{S1}, 0\}. \quad (3.7)$$

Finally, for a forced renter we have

$$\rho V^{B0} = u_0 - R + q(\theta) (-p + V - V^{B0}). \quad (3.8)$$

The remaining value functions are straightforward and are given in Appendix 3.8.B.

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<sup>34</sup>We present the value functions of double owners and forced renters assuming that they always trade at the price  $p$ , since that will always be the case in the steady state equilibria we consider. For example, for the case of a double owner we have  $V + p \geq (u_2 + R)/\rho$ . Appendix 3.8.B provides a set of sufficient conditions for this to hold.

### 3.4.2 Optimal choice of mismatched owners

In a steady state equilibrium, the optimal decision of mismatched owners depends on the simple comparison

$$V^{B1} \begin{matrix} \geq \\ < \end{matrix} V^{S1}. \quad (3.9)$$

We can substitute for  $V^{B0}$  and  $V^{S2}$  from equations (3.8) and (3.6) into the value functions for a mismatched buyer and seller to obtain

$$V^{B1} = \max \left\{ \frac{u - \chi}{\rho}, \frac{u - \chi}{\rho + q(\theta)} + \frac{q(\theta)(u_2 - (\rho p - R))}{(\rho + \mu(\theta))(\rho + q(\theta))} + \frac{q(\theta)\mu(\theta)}{(\rho + \mu(\theta))(\rho + q(\theta))} V \right\}, \quad (3.10)$$

and

$$V^{S1} = \max \left\{ \frac{u - \chi}{\rho}, \frac{u - \chi}{\rho + \mu(\theta)} + \frac{\mu(\theta)(u_0 + (\rho p - R))}{(\rho + \mu(\theta))(\rho + q(\theta))} + \frac{q(\theta)\mu(\theta)}{(\rho + \mu(\theta))(\rho + q(\theta))} V \right\}. \quad (3.11)$$

We define the effective utility flow for a forced renter as  $\tilde{u}_0 \equiv u_0 + \Delta$ , and for a double owner as  $\tilde{u}_2 \equiv u_2 - \Delta$ , where

$$\Delta \equiv \rho p - R. \quad (3.12)$$

In the special case in which  $R = \rho p$ ,  $\tilde{u}_0 = u_0$  and  $\tilde{u}_2 = u_2$ . Hence in this case, the housing price does not influence the flow value (including incomes/expenses from renting) of double owners or forced renters.

Our analysis focuses on the empirically relevant and realistic case, in which being mismatch gives a higher flow value than being a double owner or a forced renter:

**Assumption 3.A1:**  $u - \chi \geq \max\{\tilde{u}_0, \tilde{u}_2\}$ .

Anecdotal evidence points to the mismatch state as not particularly costly for the majority of homeowners. As Ngai and Sheedy (2015) argue, mismatch may be so small for many homeowners that they prefer not to move and save on the transaction costs. On the other hand, a comparison between the difference in agreement and closing dates from Figure 8 shows that moving homeowners tend to minimize the delay between the closing of the two transactions with many transactions either occurring simultaneously or within a short period. This suggests that delays between transactions are particularly costly for moving homeowners.

In the special case with  $R = \rho p$ , Assumption 3.A1 can be written as  $u - \chi > \max\{u_0, u_2\}$ . If, in addition,  $u_0 = u_2 = c$ , the assumption boils down to  $u - \chi \geq c$ .

Define  $D(\theta) \equiv V^{B1} - V^{S1}$  as the difference in value between buying first and selling first. Assuming that it is optimal for both a mismatched buyer and mismatched seller to transact, we have

$$D(\theta) = \frac{\mu(\theta)}{(\rho + q(\theta))(\rho + \mu(\theta))} \left[ \left(1 - \frac{1}{\theta}\right) (u - \chi - \tilde{u}_2) - \tilde{u}_0 + \tilde{u}_2 \right]. \quad (3.13)$$

In the case where  $\tilde{u}_0 = \tilde{u}_2 = c$ , equation (3.13) simplifies to

$$D(\theta) = \frac{(\mu(\theta) - q(\theta))(u - \chi - c)}{(\rho + q(\theta))(\rho + \mu(\theta))}. \quad (3.14)$$

Hence, in this simple case, buying first is preferred whenever  $\mu(\theta) > q(\theta)$ . The expected time on the market for a buyer and a seller are  $1/q(\theta)$  and  $1/\mu(\theta)$ , respectively. Hence buying first is preferred, if and only if, time-on-market is higher for a buyer than for a seller. The reason is that a mismatched owner has to undergo two transactions on both sides of the market before he becomes a matched owner. Given this, a mismatched owner wants to minimize the expected time in the situation that is relatively more costly. Since it is more costly to be a double owner or a forced renter than to be mismatched, a mismatched owner would care more about the expected time-on-market for the second transaction and would want to minimize the delay between the two transactions.

As an example, suppose that  $\theta < 1$  and consider the schematic representation of a mismatched owner's expected payoffs in Figure 11. If the agent buys first (top part of Figure 11), he has a short expected time-on-market as a buyer. However, he anticipates a long expected time-on-market in the next stage when he is a double owner and has to dispose of his old housing unit. In contrast, selling first (bottom part of Figure 11) implies a long expected time-on-market until the agent sells his property but a short time-on-market when the agent is a forced renter and has to buy a new property. Since  $u - \chi > c$ , it is more costly to remain in the second stage for a long time (as a double owner or forced renter) rather than to be mismatched and searching. Therefore, selling first is strictly preferred to buying first in that case.

We now formally characterize the optimal action of a mismatched owner given a steady state market tightness  $\theta$ . We adopt the notation  $\theta = \infty$  for the case where the buyer-seller ratio is unbounded. We define

$$\tilde{\theta} \equiv \frac{u - \chi - \tilde{u}_2}{u - \chi - \tilde{u}_0}. \quad (3.15)$$

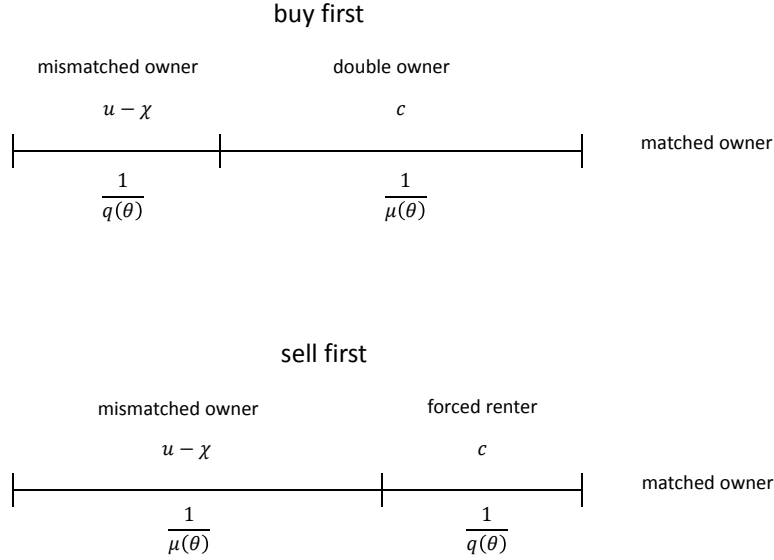


Figure 11: Buying first versus selling first when  $\theta < 1$ .

Note that if  $\tilde{u}_2 = \tilde{u}_0$ , then  $\tilde{\theta} = 1$ , while if  $\tilde{u}_2 > \tilde{u}_0$ , then  $\tilde{\theta} < 1$ , and vice versa if  $\tilde{u}_2 < \tilde{u}_0$ .<sup>35</sup> The following lemma fully characterizes the incentives of mismatched owners to buy first or sell first given a steady state market tightness  $\theta$ .

**Lemma 3.1.** *Let  $\tilde{\theta}$  be as defined in (3.15). Then for  $\theta \in (0, \infty)$ ,  $V^{B1} > V^{S1} \iff \theta > \tilde{\theta}$  and  $V^{B1} = V^{S1} \iff \theta = \tilde{\theta}$ . For  $\theta = 0$  and  $\theta = \infty$ ,  $V^{B1} = V^{S1} = (u - \chi) / \rho$ .*

*Proof.* See Appendix 3.8.C. □

Lemma 3.1 shows that, in general, as  $\theta$  increases, the incentives to buy first are strengthened. For high values of  $\theta$ , buying first dominates selling first. For low values of  $\theta$ , selling first dominates buying first.

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<sup>35</sup>In what follows we will additionally assume that at  $\theta = \tilde{\theta}$ , both  $V^{S1} > \frac{u - \chi}{\rho}$  and  $V^{B1} > \frac{u - \chi}{\rho}$ , so that a mismatched owner is strictly better off from transacting at  $\theta = \tilde{\theta}$ . This removes uninteresting steady state equilibria in which mismatched owners never transact. Assumption 3.A2 in Appendix 3.8.B gives a sufficient condition for this.

### 3.4.3 Steady state flows and stocks

We turn next to a description of the steady state equilibrium stocks and flows of this model. The full set of equations for these flows are included in Appendix 3.8.B. Here we just make some important observations on the stock-flow process in the model. First, combining the population and housing ownership conditions (3.2) and (3.3) we get that

$$B_n(t) + B_0(t) = A(t) + S_2(t). \quad (3.16)$$

Since there are equally many agents and houses, the stocks of agents without a house (forced renters and new entrants) must be equal to the stock of double owners and real-estate firms. This identity implies that in a candidate steady state equilibrium where all mismatched owners buy first (so that there are no forced renters), the market tightness, denoted by  $\bar{\theta}$  satisfies

$$\bar{\theta} = \frac{B_n + B_1}{A + S_2} = \frac{B_n + B_1}{B_n} > 1.$$

Similarly, if  $\underline{\theta}$  denotes the market tightness in a candidate steady state where all mismatched owners sell first (so that there are no double owners), we have that

$$\underline{\theta} = \frac{B_n + B_0}{A + S_1} = \frac{A}{A + S_1} < 1.$$

Therefore,  $\underline{\theta} < 1 < \bar{\theta}$ . This points to possibly wide variations in market tightness arising from changes in the behavior of mismatched owners. In Lemma 3.2 we show that  $\bar{\theta}$  solves

$$\left( \frac{1}{q(\bar{\theta}) + g} + \frac{1}{\gamma} \right) \bar{\theta} + \left( \frac{1}{q(\bar{\theta}) + g} - \frac{1}{\mu(\bar{\theta}) + g} \right) = \frac{1}{g} + \frac{1}{\gamma}, \quad (3.17)$$

and  $\underline{\theta}$  solves

$$\left( \frac{1}{\mu(\underline{\theta}) + g} + \frac{1}{\gamma} \right) \frac{1}{\underline{\theta}} = \frac{1}{g} + \frac{1}{\gamma}. \quad (3.18)$$

These two equations arise from the flow conditions and population and housing conditions if all mismatched owners buy first and sell first, respectively.

**Lemma 3.2.** *Let  $\bar{\theta}$  and  $\underline{\theta}$  denote the steady-state market tightness when all mismatched owners buy first and sell first, respectively. Then  $\bar{\theta}$  and  $\underline{\theta}$  are unique. Furthermore,  $\bar{\theta} > 1$ ,  $\underline{\theta} < 1$ , and  $\bar{\theta}$  is increasing in  $\gamma$  and  $\underline{\theta}$  is decreasing in  $\gamma$ .*

*Proof.* See Appendix 3.8.C. □

It is illustrative to consider a limit economy with small flows, where  $g \rightarrow 0$  and  $\gamma \rightarrow 0$  but the ratio  $\gamma/g = \kappa$  is kept constant in the limit. From equations (3.17) and (3.18), we have that

$$\lim_{\gamma \rightarrow 0, g \rightarrow 0, \frac{\gamma}{g} = \kappa} \bar{\theta} = 1 + \kappa, \quad (3.19)$$

and

$$\lim_{\gamma \rightarrow 0, g \rightarrow 0, \frac{\gamma}{g} = \kappa} \underline{\theta} = \frac{1}{1 + \kappa}. \quad (3.20)$$

Thus, the more important mismatched owners are in housing transactions (the higher is  $\kappa = \gamma/g$ ), the larger the variation in market tightnesses from changes in mismatched owners' actions.

### 3.4.4 Equilibrium characterization

We now combine the observations on the optimal choice of mismatched owners and the steady state stocks from the previous two sections to characterize equilibria of our model.

**Proposition 3.3.** *Consider the above economy. Let  $\tilde{\theta}$  be defined by condition (3.15), and  $\bar{\theta}$  and  $\underline{\theta}$  be defined by (3.17) and (3.18) with  $\bar{\theta}, \underline{\theta} \in (0, \infty)$ .*

1. *If  $\tilde{\theta} \in [\underline{\theta}, \bar{\theta}]$ , the model exhibits multiple steady state equilibria: an equilibrium with  $\theta = \bar{\theta}$ , in which mismatched owners buy first; an equilibrium with  $\theta = \underline{\theta}$ , in which mismatched owners sell first; and an equilibrium with  $\theta = \tilde{\theta}$ , in which the mismatched owners randomize between buying and selling.*
2. *If  $\tilde{\theta} < \underline{\theta}$ , there exists a unique steady state equilibrium in which all mismatched owners buy first.*
3. *If  $\tilde{\theta} > \bar{\theta}$ , there exists a unique steady state equilibrium in which all mismatched owners sell first.*

*Proof.* See Appendix 3.8.C. □

Therefore, depending on the flow payoffs  $\tilde{u}_0$  and  $\tilde{u}_2$ , there can exist multiple equilibria or a unique equilibrium. Note that the mixing equilibrium is unstable, in the sense that a small deviation from  $\tilde{\theta}$  implies that all mismatched owners want to buy first if the deviation is upwards, and to sell first if the deviation is downwards.

In the special case, with  $\tilde{u}_0 = \tilde{u}_2 = c$ , multiple equilibria always exists:

**Corollary 3.4.** *Consider the above economy and suppose that  $\tilde{u}_0 = \tilde{u}_2 = c$ . Then there exist three steady state equilibria: a sell first equilibrium with  $\theta = \underline{\theta}$ , in which mismatched owners sell first; a buy first equilibrium with  $\theta = \bar{\theta}$ , in which mismatched owners buy first; and an equilibrium with  $\theta = 1$ , in which the mismatched owners are indifferent between buying first and selling first, and half of them buy first.*

*Proof.* See Appendix 3.8.C. □

Intuitively, the equilibrium multiplicity arises because the feedback from the transaction sequence decisions of mismatched owners to the steady state equilibrium market tightness creates a form of *strategic complementarity* in their actions. When mismatched owners are buying first, the steady state buyer-seller ratio is high, so that it is individually rational for any mismatched owner to buy first. Conversely, when mismatched owners are selling first, the steady state buyer-seller ratio is low, and it is individually rational to sell first. Figure 12 illustrates this equilibrium multiplicity and the equilibrium value functions of mismatched owners.<sup>36</sup>

Figure 13 shows examples in which only one equilibrium may exist. In Panel 13a,  $\tilde{\theta} > \bar{\theta}$ , so that only a “Sell first” equilibrium exists with  $\theta = \underline{\theta}$ . Panel 13b shows the opposite case when  $\tilde{\theta} < \underline{\theta}$ , so that only a “Buy first” equilibrium exists with  $\theta = \bar{\theta}$ .

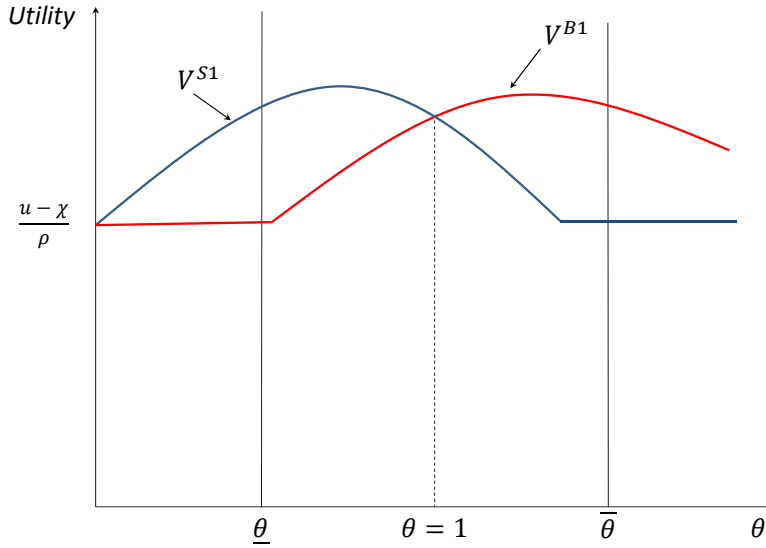
Since  $\tilde{\theta}$  depends on flow payoffs of mismatched owners, shocks to these payoffs can lead to equilibrium switches.<sup>37</sup> Apart from payoff shocks, equilibrium switches may also occur because of changes in agents’ beliefs. Next, we discuss the implications of such equilibrium switches for transaction volume, time-on-market, and the stock of houses for sale.

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<sup>36</sup>For illustrative purposes, in the figures below we assume that  $V^{B1}$  and  $V^{S1}$  as defined in (3.10) and (3.11) are single peaked, i.e. there is a  $\hat{\theta}^{B1}$ , s.t.  $V^{B1}$  is increasing for  $\theta < \hat{\theta}^{B1}$  and decreasing for  $\theta > \hat{\theta}^{B1}$  and similarly for  $V^{S1}$ .

<sup>37</sup>As an example of such a payoff shock, suppose that the payoff of a double owner,  $u_2$ , includes costs associated with obtaining a mortgage that allows him to finance the downpayment on his new property prior to the sale of his old property. When financial markets function normally, these costs are relatively low. Suppose that in that case  $\tilde{u}_2 > \tilde{u}_0$  and  $\tilde{\theta} < \underline{\theta}$ . Therefore, the “Sell first” equilibrium does not exist. Conversely, suppose that there is a shock to financial markets, so that obtaining a bridging mortgage becomes very costly, and thus  $\tilde{u}_2 < \tilde{u}_0$  and  $\tilde{\theta} > \bar{\theta}$ . As a result, after the shock, buying first is no longer optimal and the “Buy first” equilibrium no longer exists.



Figure 12: Equilibrium multiplicity with  $\tilde{u}_0 = \tilde{u}_2 = c$ .

### 3.4.5 Equilibrium switches

To simplify the analysis we consider the limit economy introduced in Section 3.4.3, where  $g \rightarrow 0$  and  $\gamma \rightarrow 0$  and  $\gamma/g = \kappa$ ,  $\bar{\theta} = 1 + \kappa$ , and  $\underline{\theta} = 1/(1 + \kappa) = 1/\bar{\theta}$ . Suppose that the economy starts in a “Buy first” equilibrium with market tightness  $\theta = \bar{\theta}$ . In that case

$$\bar{\theta} = \frac{\bar{B}}{\bar{S}} = \frac{B_n + B_1}{A + S_2} = \frac{B_n + B_1}{B_n}, \quad (3.21)$$

where  $\bar{B}$  and  $\bar{S}$  denote the stocks of buyers and sellers in the “Buy first” equilibrium. Suppose that the whole stock of mismatched owners,  $B_1$ , decide to sell first rather than buy first. In that case, the new market tightness becomes

$$\theta' = \frac{B'}{S'} = \frac{B_n}{B_n + B_1} = \underline{\theta},$$

where  $B'$  and  $S'$  denote the stocks of buyers and sellers immediately after the switch. Hence, the tightness jumps directly to its new steady state equilibrium value with no dynamic adjustment in  $\theta$ .

What are the implications of this switch? First of all, clearly average time-on-market for sellers,  $1/\mu(\theta)$ , increases. Second, consider the ratio of the stock of sellers before

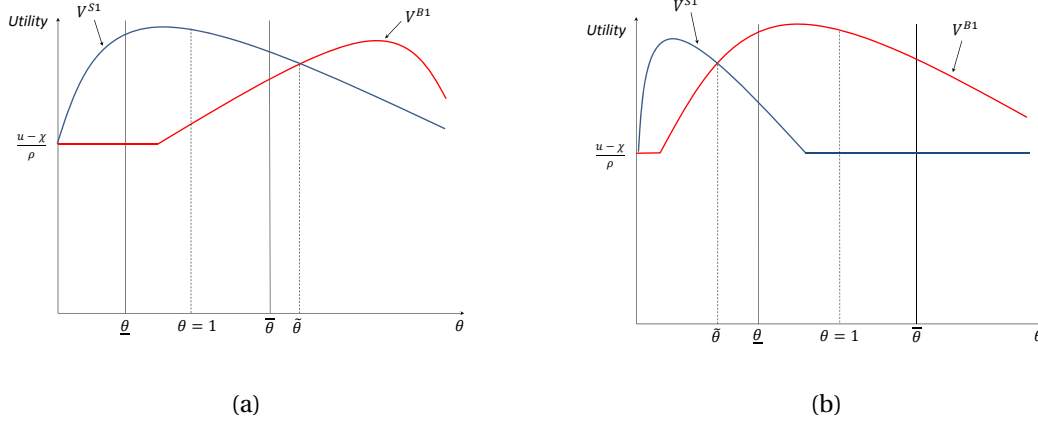


Figure 13: Examples with unique equilibria in the case of  $\tilde{\theta} > \bar{\theta}$  (a) and  $\tilde{\theta} < \bar{\theta}$  (b).

and after the switch. That ratio is exactly  $\underline{\theta}$ , which is less than 1. Therefore, there is an increase in the stock of houses for sale since some of the previous buyers become sellers. Finally, transaction volume may also fall depending on the shape of the matching function. Specifically, suppose that we have a Cobb-Douglas matching function, so  $m(B, S) = \mu_0 B^\alpha S^{1-\alpha}$ , for  $0 < \alpha < 1$ , and consider the ratio of transaction volumes before and after the switch

$$\frac{\mu(\bar{\theta})}{q(\underline{\theta})} = \frac{\mu_0 \bar{\theta}^\alpha}{\mu_0 \underline{\theta}^{\alpha-1}} = (1 + \kappa)^{2\alpha-1}.$$

Hence, transaction volume falls after the equilibrium switch if  $\alpha > 1/2$  and increases if  $\alpha < 1/2$ . The reason is that for  $\alpha > 1/2$  buyers are more important than sellers in generating transactions. When mismatched owners switch from buying first to selling first this leads to a reduction in the number of buyers and an increase in the number of sellers, and hence, to a fall in the transaction rate. Genesove and Han (2012) estimate a value of  $\alpha = 0.84$ . At that value, transaction volume would drop after the switch from a “Buy first” equilibrium to a “Sell first” equilibrium.

Consequently, a switch from a “Buy first” equilibrium to a “Sell first” equilibrium implies behavior for key housing market variables – the for-sale stock, average time-to-sell, and transaction volume – that is broadly consistent with evidence on housing cycles (Diaz and Jerez (2013), Guren (2014)). This behavior is also consistent with the evidence on the housing cycle in Copenhagen as shown in Figure 10. The negative comovement between the for-sale stock and transactions is of particular interest since search-based

models of the housing market usually have trouble generating this comovement (Diaz and Jerez, 2013).

### 3.4.6 Quantitative relevance

In this section we provide a simple numerical example to assess the quantitative relevance of our mechanism. Specifically, we examine the switch from the “Buy first” to the “Sell first” equilibrium in the limit economy.

We use the calibration of Head et al. (2014) to determine plausible values for the rate of mismatch,  $\gamma$ , and the entry and exit rate,  $g$ . We use the annual fraction of owners that move across U.S. counties, which according to the Census Bureau is around 3.2 percent, to determine  $g$ . The fraction of owners that stay in the same county conditional on moving is 60 percent, or around 1.5 times more owners move within the same county than across counties. Therefore, we set  $g = 0.035$  and  $\gamma = 0.0525$ . This implies an average duration for homeowners of around 11.4 years and an annual turnover rate of 8%. These flows give us values of the market tightness in the limit economy of  $\lim \bar{\theta} = 2.5$  and  $\lim \underline{\theta} = 0.4$ , respectively. Finally, we assume that the matching function is Cobb-Douglas so that  $\mu(\theta) = \mu_0 \theta^\alpha$ . We choose  $\alpha = 0.84$ , following Genesove and Han (2012).<sup>38</sup>

With these numbers, switching from the “Buy first” to the “Sell first” equilibrium in the limit economy leads to a decrease in the market tightness by around 85%. This is associated with a 150% increase in the for-sale stock, and a 350% increase in average time-to-sell. In addition, the transaction rate falls by around 50% immediately after the switch.

## 3.5 Endogenous prices

In this section we relax the assumption that prices are fixed, and analyze the existence of multiple equilibria with endogenous prices. First we impose an exogenous relationship between the steady state market tightness and the housing and rental prices in that

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<sup>38</sup>The small values of  $\gamma$  and  $g$  suggest that the focus on the limit economy in Section 3.4.5 is reasonable. See the working paper version of this chapter (Moen et al. (2015)) for a comparison of tightnesses in the limit economy and away from the limit. Also note that the value of  $\mu_0$  is irrelevant for the numerical results in this section. In Section 3.5.2, where we discuss the quantitative implications for house prices, we use a value of  $\mu_0 = 4$ , which gives a seller time-on-market of 6 weeks in a “Buy first” equilibrium.

market, and derive conditions for equilibrium multiplicity. Then we go one step further, and show that there can be multiple equilibria in an environment where prices are determined by Nash bargaining, and even in an environment with competitive search where agents can trade-off prices and time-on-market. With endogenous price formation, the model becomes algebra-intensive, as we have to keep track of which agent types trade with one another. For that reason, the details of the analysis are deferred to Appendix 3.8.D.

### 3.5.1 Prices depend on market tightness

When deriving conditions for multiplicity, we assumed that prices were exogenous, and hence unaltered by the transaction sequence decision of the agents. Now, we allow housing prices in steady state to depend on  $\theta$ . We thus write  $p = p(\theta)$ , with  $p'(\theta) > 0$ . We may also write the rent  $R$  as a function of  $\theta$ ,  $R = R(\theta)$ , with  $R'(\theta) \geq 0$ . Recall that the flow values of double owners and forced renters depend on  $\Delta = \rho p - R$ . Thus, we can write  $\Delta = \Delta(\theta)$ . It seems reasonable to assume that  $\Delta'(\theta) \geq 0$  (otherwise, there is no countervailing effect from endogenous prices).

As we already pointed out in Section 3.4.1, in the case with  $R = \rho p$ ,  $\Delta'(\theta) = 0$ , and so, assuming that house prices are exogenous is without loss of generality, since different (steady state) prices do not influence the flow value of double owners or forced renters. However, a countervailing effect arises if  $\Delta'(\theta) > 0$ . Specifically, from Equation (3.13), the decision whether to buy or to sell first depends on the sign of the following expression:

$$\tilde{D}(\theta) = \frac{\theta - 1}{\theta} (u - \chi - u_2 + \Delta(\theta)) + u_2 - u_0 - 2\Delta(\theta).$$

We normalize  $u_2 - u_0$  so that  $\tilde{D}(1) = 0$ , which requires that  $u_2 - u_0 = 2\Delta(1)$ . In order for the “Buy first” and “Sell first” equilibria to exist, we must have that (recall that  $\bar{\theta}$  and  $\underline{\theta}$  denote the steady state tightness in the “Buy first” and “Sell first” equilibria, respectively):

$$\frac{\bar{\theta} - 1}{\bar{\theta}} [u - \chi - u_2 + \Delta(\bar{\theta})] \geq 2(\Delta(\bar{\theta}) - \Delta(1)),$$

and

$$\frac{1 - \underline{\theta}}{\underline{\theta}} [u - \chi - u_2 + \Delta(\underline{\theta})] \geq 2(\Delta(1) - \Delta(\underline{\theta})).$$

In the two conditions above, the left-hand side broadly reflects the strategic complementarity effect identified in Section 3.4. A higher  $\theta$  makes buying more time-consuming

and selling less time-consuming, and since the agent's utility flow is higher whenever mismatched compared to being a double owner or a forced renter, this favors buying first.

The right-hand side reflects how a higher value of  $\theta$  changes the difference in the flow values of being a forced renter compared with a double owner. Note that if  $R \leq \rho p$ , it is beneficial for the agent, everything else equal, to buy late and sell early. We refer to this as a discounting effect. A higher  $\theta$  increases  $p$ , and unless  $R$  increases at the same rate, this strengthens the discounting effect and makes it more attractive to sell first. Due to our normalization, at  $\theta = 1$  the discounting effect is exactly balanced by a difference in the income flows  $u_2$  and  $u_0$ . However, for  $\theta > 1$ , the discounting effect becomes stronger, which favors selling first to buying first. Similarly, for  $\theta < 1$ , the discounting effect becomes weaker, which favors buying first to selling first.

Therefore, our multiple equilibrium result requires that the house price (or more generally,  $\Delta$ ) should not be too sensitive to changes in  $\theta$ , so that the discounting effect is weaker than the strategic complementarity effect. Notice that the two conditions always hold if  $u_2$  (and also  $u_0$  given the normalization) is sufficiently low. In that case the strategic complementarity effect always dominates for values of  $\theta$  that are consistent with a steady state equilibrium.

In this subsection the relationship between price and tightness is assumed to be exogenous. Next, we demonstrate that our results still hold in a model with Nash bargaining.

### 3.5.2 Prices determined by Nash bargaining

In this section we assume that prices are determined by symmetric Nash bargaining, so that buyers and sellers split the surplus of a match equally between them, as in Pissarides (2000). Therefore, there is no longer a single transaction price  $p$ , but prices depend on the types of the trading counterparties. To simplify the stock-flow conditions, we again consider a limit economy with small flows, where  $g \rightarrow 0$  and  $\gamma \rightarrow 0$  but the ratio  $\frac{\gamma}{g} = \kappa$  is constant, and where  $\bar{\theta} = 1 + \kappa$  and  $\underline{\theta} = 1/(1 + \kappa)$ . Additionally, and for analytical tractability, we consider parameter restrictions which ensure that all trading surpluses are positive in both a “Buy first” and “Sell first” candidate equilibrium, except for the surplus between a mismatched buyer and a mismatched seller. We give the relevant parameter restrictions in Appendix 3.8.B.

Note that the real-estate firms are different from the other agents in the economy, as they receive no utility from owning a house, and their gain from transacting is the price, which is a transfer and hence does not influence the match surplus. As a result, the equilibrium allocation becomes asymmetric, and tilts towards the “Buy first” equilibrium even with  $u_2 = u_0$ . It turns out that symmetry, in the sense that mismatched owners are indifferent between buying first and selling first if  $\theta = 1$ , is re-established if  $u_n - u_0 = u - u_2$ . In what follows we, therefore, assume that this is the case.

### “Buy first” equilibrium

Consider a “Buy first” steady state equilibrium candidate with a market tightness of  $\theta = \bar{\theta} > 1$ . In that candidate equilibrium, the sellers with positive measure are the double owners and real-estate firms, while the buyers with positive measure are the mismatched owners and new entrants. In the limit economy, the outflow rate of mismatched agents is equal to the outflow rate of new entrants, so  $B_1/B_n = \gamma/g = \kappa$ . Hence, the shares of new entrants and mismatched buyers in the pool of buyers are  $1/\bar{\theta}$  and  $1 - 1/\bar{\theta}$ , respectively. Furthermore, in the limit, as there is no death, the shares of real-estate firms and double owners in the pool of sellers are also  $1/\bar{\theta}$  and  $1 - 1/\bar{\theta}$ , respectively.

Given these shares and since buyers and sellers split the match surplus evenly, it follows that the value function of a mismatch buyer is (given  $\rho \rightarrow r$  in the limit)

$$rV^{B1} = u - \chi + \frac{1}{2}q(\bar{\theta}) \left[ \frac{1}{\bar{\theta}}\Sigma_{AB1} + \left(1 - \frac{1}{\bar{\theta}}\right)\Sigma_{S2B1} \right],$$

where  $\Sigma_{AB1} = V^{S2} - V^{B1} - V^A$  is the match surplus when a mismatched buyer meets a real-estate firm, and  $\Sigma_{S2B1} = V - V^{B1}$  is the match surplus when a mismatched buyer meets a double owner.

Consider a mismatched owners who deviates (permanently) and sells first.<sup>39</sup> Since a meeting between a mismatched buyer and a mismatched seller is assumed to lead to negative surplus, it follows that the value function of a deviator is simply

$$rV^{S1} = u - \chi + \frac{1}{2}\mu(\bar{\theta}) \frac{1}{\bar{\theta}}\Sigma_{S1Bn}.$$

<sup>39</sup>Examining permanent deviations here is without loss of generality, since a temporary deviation can only dominate a permanent deviation if and only if no deviation dominates the permanent deviation.

It follows that the difference between the value of buying first and selling first,  $D(\bar{\theta}) = V^{B1} - V^{S1}$ , can be written as

$$D(\bar{\theta}) = \frac{\frac{1}{2}q(\bar{\theta})}{r + \frac{1}{2}q(\bar{\theta})} \left( \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})} - \frac{1}{\bar{\theta}} \frac{u - u_2}{r + \frac{1}{2}\mu(\bar{\theta})} \right). \quad (3.22)$$

Given our assumptions on utility flows,  $D(\bar{\theta} = 1) = 0$  for  $\kappa = 0$ . An increase in  $\bar{\theta}$  (equivalently, an increase in  $\kappa$ ) leads to an increase in  $D(\bar{\theta})$  since the expression in parenthesis, increases. This increase comes from two effects. First,  $\mu(\bar{\theta})$  increases and  $q(\bar{\theta})$  decreases, so the second term in the parenthesis decreases (given that  $u_2 < u - \chi < u$ ) and the first term increases (since then  $u_n > u_0$ ). This effect is tightly linked to the strategic complementarity effect in our benchmark model in Section 3.4. Specifically, as before, an increase in  $\bar{\theta}$  increases the value of buying first given a lower expected time-on-market for double owners, while it decreases the value of selling first, given a higher expected time-on-market for forced renters.

Second, the fraction of new entrants and real-estate firms,  $1/\bar{\theta}$ , decreases. Therefore, buyers are more likely to meet double owners and sellers are more likely to meet mismatched buyers. However, the trading surplus for a buyer is higher when matched with a double owner compared to a match with a real-estate firm. Similarly, the trading surplus is lower for a seller when matched with a mismatched buyer compared to a new entrant. This compositional effect on both the buyer and seller sides of the market additionally strengthens the incentives to buy first.

### “Sell first” equilibrium

Consider a “Sell first” steady state equilibrium candidate with a market tightness of  $\theta = \underline{\theta} < 1$ . In that candidate equilibrium, the sellers with positive measure are the mismatched owners and real-estate firms, while the buyers are the forced renters and new entrants. In the limit economy, we have that the shares of forced renters and new entrants in the pool of buyers are  $\underline{\theta}$  and  $1 - \underline{\theta}$ , respectively. These are also the respective shares of real-estate firms and mismatched owners.

In this equilibrium candidate, the gain from deviating to (permanently) buying first for a mismatched owner is  $D(\underline{\theta}) = V^{B1} - V^{S1}$ , which is given by

$$D(\underline{\theta}) = \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} \left( \frac{\theta}{r + \frac{1}{2}q(\underline{\theta})} \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} - \frac{u - u_2}{r + \frac{1}{2}\mu(\underline{\theta})} \right). \quad (3.23)$$

Given our assumptions on the utility flows,  $D(\underline{\theta} = 1) = 0$  for  $\kappa = 0$ . A decrease in  $\underline{\theta}$  (increasing  $\kappa$ ) decreases  $D$ , and hence, makes it more attractive to sell first.

We conclude that the model with Nash bargaining exhibits multiple equilibria, as stated in the following proposition.

**Proposition 3.5.** *Consider the limit economy with prices determined by symmetric Nash bargaining. Suppose that conditions 3.B1-3.B4 given in Appendix 3.8.D hold. Then there exists a steady state equilibrium, in which all mismatched owners buy first and the equilibrium market tightness converges to  $\bar{\theta} = 1 + \kappa$ . Also, there exists a steady state equilibrium, in which all mismatched owners sell first and the equilibrium market tightness converges to  $\underline{\theta} = 1/(1 + \kappa)$ .*

*Proof.* See Appendix 3.8.D. □

As already mentioned, we have to make restrictions on the parameter set (conditions 3.B2-3.B4 in Appendix 3.8.D), to ensure that our assumptions regarding the matching sets are satisfied in equilibrium. These restrictions are only sufficient and the same matching sets may emerge for more general parameter values. Also, we conjecture that if these restrictions are not satisfied, and other matching sets emerge, these may also have multiple steady state equilibria with the structure described in Proposition 3.5.<sup>40</sup>

### Numerical example

To gain some additional insight into when multiple equilibria are possible with endogenously determined prices, and to show that conditions 3.B2-3.B4 are only sufficient for multiple equilibria, we consider a simple numerical example, in which conditions 3.B2-3.B4 need not be satisfied.<sup>41</sup> Figure 14 plots the difference  $D(\theta) = V^{B1} - V^{S1}$  in a

<sup>40</sup>Simulations confirm that multiple equilibria exist also for parameter values that do not satisfy conditions 3.B1-3.B4.

<sup>41</sup>One can also relax the symmetry condition 3.B1. Relaxing 3.B1 changes the value of  $\theta$  for which a mismatched owner is indifferent between buying first and selling first. Thus, it essentially shifts the curve in Figure 14 to the left or to the right.



candidate “Sell first” equilibrium for  $\theta \leq 1$  and a candidate “Buy first” equilibrium for  $\theta > 1$ . The figure illustrates several important points.

First, multiple steady state equilibria can be sustained even if the steady state market tightness fluctuates substantially between the candidate “Buy first” and “Sell first” equilibria. Using the stock-flow calibration from Section 3.4.6 produces substantial variation in market tightness across the two steady state equilibria as illustrated by the red and blue vertical lines on the Figure. This in turn means that there can be substantial price effects from switches across the two steady state equilibria. Specifically, for the numerical example that produces the figure, average house prices decline by around 32% between the “Buy first” and the “Sell first” equilibrium. Therefore, our mechanism can also lead to quantitatively significant fluctuations in house prices when those are endogenously determined.

Second, unlike the benchmark case with exogenously fixed prices, endogenously determined prices imply that for sufficiently low (sufficiently high) market tightness, buying first starts to dominate selling first (and vice versa). This reflects the discounting effect discussed in section 3.5.1, which can outweigh the strategic complementarity effect, so that multiple equilibria cease to exist. Nevertheless, as the numerical example illustrates, with Nash bargaining, the price response must be very large for the discounting effect to start dominating. Specifically, in the example in Figure 14, average house prices must decline by (approximately) more than 50% between a candidate “Buy first” and “Sell first” equilibria for the discounting effect to dominate.

### 3.5.3 Competitive search

In competitive search equilibrium, the sellers post prices, and buyers direct their search towards the sellers they find most attractive, taking into account that better terms of trade mean a longer expected waiting time before trade occurs. The market splits up in submarkets, and the different agents choose which submarket to enter. As shown in Garibaldi et al. (2016), the most patient buyers (who are most willing to trade off a short waiting time for a low price) will search for the most impatient sellers (who are most willing to trade off a low price for a short waiting time). Analogously, the least patient buyers search for the most patient sellers.

In Appendix 3.8.E we derive sufficient conditions on parameter values for multiple competitive search equilibria to exist. The economic mechanisms play out in a slightly

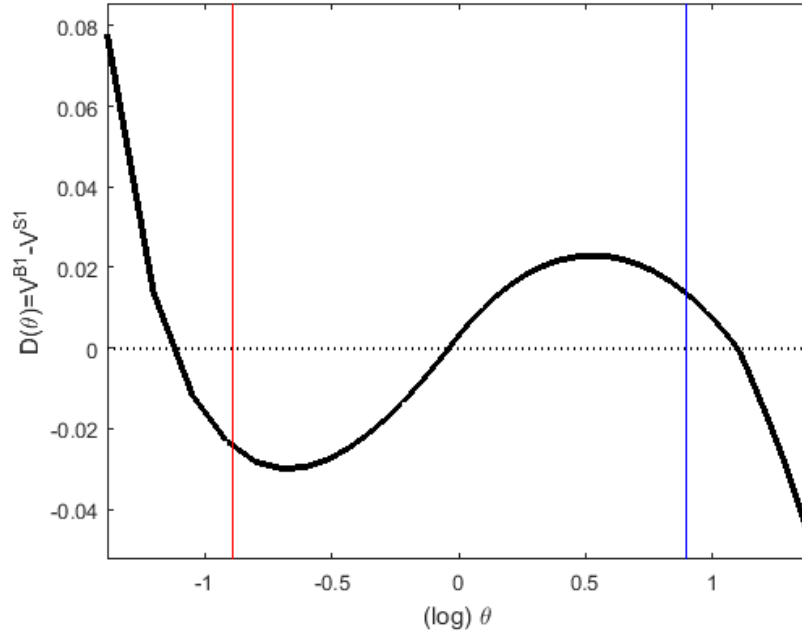


Figure 14: A plot of  $D(\theta)$  (solid black) against  $(\log) \theta$ .

Notes: Preference parameters used for the example:  $u = 2$ ,  $u_0 = 1.55$ ,  $u_2 = 1.85$ ,  $u_n = 1.7$ ,  $\chi = 0.14$ . Rental price  $R = 0.1$ . Vertical red and blue lines denote steady state market tightnesses in “Buy first” and “Sell first” equilibria using the stock-flow calibration from Section 3.4.6.

different way with competitive search than with wage bargaining. With wage bargaining, the strategic complementarity works through the market tightness: if more agents buy first, this increases the buyer-to-seller ratio in the market, and makes it more attractive to buy first. In competitive search equilibrium, the strategic complementarities are more involved. Single agents trade off waiting time and terms of trade. At market level, more buy-first agents will influence the buyer-to-seller ratio in the submarket(s) for mismatched buyers. This will not directly affect the sell-first agents, as they search in different submarkets. However, the asset values of all agents will change, thereby influencing the value of selling first and the speed at which sell-first agents transact.

In Appendix 3.8.E we derive the competitive search equilibrium allocation when the cost of being mismatched,  $\chi$ , is low, the flow utility of being a double owner,  $u_2$ , and as in 3.5.2 we assume that new entrants enjoy a strictly higher flow utility than forced renters:  $u_n > u_0$ . In the market constellations we study, a submarket with new entrants and real estate firms always operates.

In the “Buy first” equilibrium, the buyers are mismatched owners and new entrants, while the sellers are real estate firms and double owners as in Panel 15a of Figure 15, where blue indicates sellers and red buyers. The most patient buyer is the mismatched owner, while the most impatient sellers are the double owners. Hence these agents always transact. The least patient buyers are the new entrants, while the most patient sellers are the real estate firms. Hence submarkets for real estate firms and new entrants will always exist. In addition, a market for new entrants and double owners will also open.

Note that the match surplus  $\Sigma_{B1S2}$  between a mismatched buyer and a double owner is given by

$$\Sigma_{B1S2} = V + V^{S2} - V^{B1} - V^{S2} = V - V^{B1} > 0,$$

so that there is trade in this market.

Now consider a mismatched owner that deviates and sells first. For a small  $\chi$ , this seller will be more patient than both the real estate firms and the double owners, and will, therefore, transact with the most impatient buyers among the non-deviating buyers, the new entrants. It will then become a new buyer type – a forced renter – that is even more impatient than the new entrant because  $u_n > u_0$ . It will, therefore, transact with the most patient sellers, which are the real estate firms. Given that a forced renter is more impatient than a new entrant, real estate firms are willing to open a new submarket for the deviating agent. In particular, the value from being a forced renter,  $V^{B0}$ , maximizes his gain from search given the value of the real estate firm.

The match surplus between the deviating mismatched owner and the new entrant,  $\Sigma_{BnS1}$ , can be written as

$$\Sigma_{BnS1} = V + V^{B0} - V^{Bn} - V^{S1}.$$

Note that also  $\lim_{\chi \rightarrow 0} V^{S1} = \lim_{\chi \rightarrow 0} V$ . Moreover, for  $u_0 < u_n$ ,  $V^{B0}$  is strictly lower than  $V^{Bn}$ , also in the limit as  $\chi \rightarrow 0$ . As a result, the match surplus  $\Sigma_{BnS1}$  is negative for small values of  $\chi$ , so that the mismatched owner cannot gain by deviating and the “Buy first” equilibrium exists.

In the “Sell first” equilibrium, the sellers are mismatched homeowners and real estate firms, while the buyers are new entrants and forced renters. The most patient buyers are the new entrants, and the most patient sellers - the mismatched owners. The active submarkets will be between new entrants and real estate firms, mismatched buyers and forced renters, and forced renters and real estate firms. The markets (together with a deviating agent) are illustrated in Panel 15b of Figure 15.

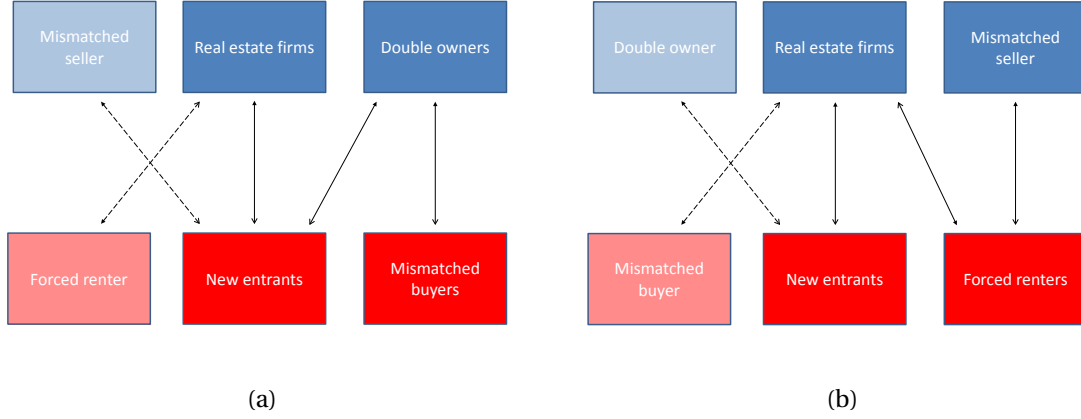


Figure 15: Equilibrium market segments (solid colors) and deviators (weaker colors) for “Buy first” (a) and “Sell first” (b) competitive search equilibria.

The asset values in the real-estate-new agents are as in the “Buy first” equilibrium, so that this market is active. For a real estate agent, the surplus of a transaction with a (more impatient) forced renter is even larger than with a new entrant, so that there are benefits of trade in this market as well. Hence, a forced renter obtains the same value  $V^{B0}$  as the (deviating) forced renter in the “Buy first” equilibrium. The match surplus between a forced renter and a mismatched seller,  $\Sigma_{B0S1}$ , is given by

$$\Sigma_{B0S1} = V + V^{B0} - V^{S1} - V^{B0} = V - V^{S1} > 0.$$

Now, consider a mismatched agent that deviates and buys first. This buyer will be more patient than both new entrants and forced renters, and will thus transact with the real estate firm, the most impatient seller. He will then become a double owner, thus, becoming more impatient than the real estate firm, and will therefore transact with the new entrants. A new submarket will open up, and the expression for the asset value  $V^{S2}$  is the same as for the double owner in the “Buy first” equilibrium. However, for the same reasons as in the “Buy first” equilibrium, the match surplus between the mismatched buyer and the real estate firm,  $\Sigma_{B1A}$ , is negative for low values of  $u_2$ . It follows that the deviation is unprofitable. We conclude that the model still exhibits multiple equilibria, as stated in the following proposition.

**Proposition 3.6.** *Consider the economy with competitive search, and suppose that  $\chi$  and  $u_2$  are small and that  $u_0 < u_n$ . Then the economy exhibits multiple equilibria. In one*

*equilibrium, all mismatched owners buy first. In another equilibrium, all mismatched owners sell first.*

*Proof.* See Appendix 3.8.E. □

We have no reason to believe that the condition on  $\chi$  is necessary to obtain multiple equilibria. However, without this assumption the model becomes less tractable, as it is not clear from the outset what market constellations will then be realized.

### 3.5.4 Additional extensions

Our benchmark model assumes that a mismatched owner has to choose to enter the housing market either as a buyer or as a seller. In Appendix F, we examine the optimal behavior of a mismatched owner that can choose to be both a buyer and a seller at the same time. We show that a mismatched owner strictly prefers to either only enter as a buyer or as a seller for any  $\theta \neq \tilde{\theta}$ , where  $\tilde{\theta}$  is defined as in Equation (3.15). Intuitively, since the decision to enter as both a buyer and seller depends ultimately on the value from entering as a buyer only and the value from entering as a seller only, whenever entering as a buyer only is dominated by entering as a seller only, then entering as both a buyer and seller is also dominated by entering as a seller only, and vice versa.

Additionally, we show that our main results continue to hold even assuming that homeowners are compensated for the value of their housing units when they exit the economy when  $g$  is sufficiently small. As can be seen in Appendix 3.8.F, in that case a modified version of Equation (3.15) determines the critical value of  $\tilde{\theta}$  below which a mismatched owner is better off selling first. In the limit, as  $g \rightarrow 0$ , that modified version converges to the value of  $\tilde{\theta}$  from Equation (3.15).

## 3.6 House price fluctuations

In this section, we first examine the implications of expected changes in the house price for the behavior of mismatched owners. We then construct dynamic equilibria with self-fulfilling fluctuations in prices and tightness. In the entire section we study our benchmark case, in which  $R = \rho p$ .

### 3.6.1 Exogenous house price movements

We first show that expected future changes in the house price affect the incentives of mismatched owners to buy first or sell first. Consider a simple, exogenous process for the price  $p$ . With rate  $\lambda$  the house price  $p$  changes to a permanent new level  $p_N$ .<sup>42</sup> We compare the utility from buying first relative to selling first for a mismatched owner before the price change. If the price change occurs between the two transactions, the mismatched owner will make a capital gain of  $p^N - p$  if he buys first and a capital loss of the same amount if he sells first. If the shock happens before the first transaction or after the second transaction, it will not influence the decision to buy first or sell first. To simplify the exposition we assume that  $u_0 = u_2 = c$ .<sup>43</sup>

The price risk associated with the transaction sequence decision creates asymmetry in the payoff from buying first or selling first. Specifically, at  $\theta = 1$ , the difference between the two value functions  $D(\theta) = V^{B1} - V^{S1}$  takes the form

$$D(1) = \frac{\mu(1)}{(\rho + q(1) + \lambda)(\rho + \mu(1) + \lambda)} 2\lambda(p_N - p). \quad (3.24)$$

An expected price decrease, leads to a higher value of  $V^{S1}$  relative to  $V^{B1}$ , even if matching rates for a buyer and a seller are the same. Consequently,  $V^{S1} > V^{B1}$  even for some values of  $\theta > 1$ . If the expected price decrease is sufficiently large, so that even at  $\theta = \bar{\theta}$ ,  $D(\bar{\theta}) < 0$ , then selling first will dominate buying first for any value of  $\theta$  that is consistent with equilibrium. Similarly, a sufficiently large expected price increase, will imply that  $D(\underline{\theta}) > 0$ , so buying first will dominate selling first for any value of  $\theta$  that is consistent with equilibrium. We summarize these observations in the following

**Proposition 3.7.** *Consider the modified economy with an exogenous house price change. Then for every  $\lambda > 0$  and  $\theta \in [\underline{\theta}, \bar{\theta}]$ , a mismatched owner prefers to sell first for sufficiently low values of  $p_N$ . Analogously, a mismatched owner prefers to buy first for sufficiently high values of  $p^N$ .*

*Proof.* See Appendix 3.8.C. □

<sup>42</sup>Since we assume that  $p = \frac{R}{\rho}$ , one can think of a permanent change in the equilibrium rental rate to  $R_N$ , which leads to a house price change to  $p_N = R_N/\rho$ .

<sup>43</sup>We assume that  $\theta$  remains constant over time, so the only change occurs in the house price  $p$ . Also, for this exercise, we implicitly assume that  $\gamma \rightarrow 0$ , so that  $V$  is independent of the house price  $p$ .

### 3.6.2 Self-fulfilling house price fluctuations

In the steady-state analysis, we showed that the model may exhibit multiple equilibria, with different market tightnesses. If a high market tightness is associated with a high price, this may lead to a destabilizing effect on housing prices. In this subsection we assume that the housing price depends on the buyer-seller ratio as in section 3.5.1 and on expected future prices, and show that this may lead to self-fulfilling house price fluctuations.

Suppose that  $X(t) \in \{0, 1\}$  follows a two-state Markov chain.  $X(t)$  starts in  $X(t) = 0$  and with Poisson rate  $\lambda$  transitions permanently to  $X(t) = 1$ . The realization of  $X(t)$  plays the role of a sunspot variable. The price in state 1 is assumed to be given by a smooth function  $p_1 = f(\theta_1)$ . The price in state 0 is assumed to be implicitly given by a smooth function  $p_0 = f(\theta_0, \lambda(p_1 - p_0))$ , increasing in both arguments, and with  $f(\theta, 0) \equiv f(\theta)$ . We take these relationships as exogenous and reduced form to illustrate the equilibrium consequences of the interaction of housing prices and market liquidity conditions with the transaction decisions of mismatched owners. Again we look at a limit economy as  $\gamma$  and  $g$  go to zero, keeping  $\kappa = \gamma/g$  fixed.

We consider an equilibrium in which the economy starts out in a “Buy first” regime ( $X(t) = 0$ ) in which 1) mismatched owners prefer to buy first and the market tightness is  $\theta_0 = \bar{\theta}$ , and 2) agents expect that with rate  $\lambda$ , the economy permanently switches to a “Sell first” regime with market tightness  $\theta_1 = \underline{\theta}$ . In that second regime, 1) mismatched owners strictly prefer to sell first, and 2) agents expect that the economy will remain in the “Sell first” regime forever. Since  $\bar{\theta} > \underline{\theta}$ , it follows that  $p_0 > p_1$ .<sup>44</sup> It is straightforward to show that as  $\lambda \rightarrow 0$ , the pay-offs when buying first and selling first converge to the pay-offs without regime switching. Hence, in the limit, buying first in state 0 is an equilibrium strategy if  $\bar{\theta} > \tilde{\theta}$ , while selling first is an equilibrium strategy in state 1 if  $\underline{\theta} < \tilde{\theta}$ , where  $\tilde{\theta}$  is defined by proposition 3.3. Hence, multiple equilibria exists whenever

$$1 + \kappa > \frac{u - \chi - u_2}{u - \chi - u_0} > \frac{1}{1 + \kappa}. \quad (3.25)$$

This equation is clearly satisfied when  $u_2 = u_0$ .

**Proposition 3.8.** *Consider the limit economy with  $g \rightarrow 0$ ,  $\gamma \rightarrow 0$  and  $\gamma/g = \kappa$ , and with the sunspot process described above. Suppose further that equation (3.25) is satisfied.*

<sup>44</sup>Suppose  $p_0 \leq p_1$ . Then  $p_0 = f(\bar{\theta}, \lambda(p_1 - p_0)) \geq f(\bar{\theta})$ . But then  $p_0 \geq f(\bar{\theta}) > f(\underline{\theta}) = p_1$ , a contradiction.

*Then there is a  $\bar{\lambda}$ , such that for  $\lambda < \bar{\lambda}$ , there exists a dynamic equilibrium characterized by two regimes  $x \in \{0, 1\}$ . In the first regime,  $\theta_0 = \bar{\theta}$  and mismatched owners buy first. In the second regime,  $\theta_1 = \underline{\theta}$ ,  $p_1 < p_0$ , and mismatched owners sell first. The economy starts in regime 0 and transitions to regime 1 with rate  $\lambda$ .*

*Proof.* Follows from the discussion above. □

Intuitively, if agents expect the change in regimes to occur sufficiently soon ( $\lambda$  is high), then it can be optimal for mismatched owners to sell first in the first regime despite the high market tightness, speculating on regimes changing in between their two transactions. This, however, is inconsistent with equilibrium. Therefore, an equilibrium with a transition between the two regimes exists only for a sufficiently low regime switching rate  $\lambda$ .

## 3.7 Institutional details and conclusion

In this section we compare the process of housing sales in several countries, and then provide brief concluding comments.

### 3.7.1 Institutional details

Actual housing markets in different countries differ in their institutional characteristics. Naturally, our model of the housing market abstracts from many of these peculiarities. As a result, the fit between the model and the way that houses are bought and sold may vary across countries. Nonetheless, we think our model captures essential elements of housing transactions for many countries, including Denmark, Norway, the Netherlands, and the United States. In these countries, the institutional set-up for the process of housing transactions is such that homeowners are concerned about the order of buying and selling, at least to some extent. In principle, the same issue occurs in the United Kingdom, but there the phenomenon of housing chains (see Rosenthal (1997)) may provide a way to accommodate the risks associated with moving in the owner-occupied housing market. Because of the widespread usage of housing chains in the UK, our model may be less suited for capturing the way houses are bought and sold in that



country. Instead it describes more closely the housing markets of countries where housing chains are rare or non-existent.<sup>45</sup>

Additionally, in England and Wales buyers and sellers are not legally bound to an agreed transaction until late in the process, so that both sides easily renege on offers (Rosenthal, 1997). As a result, if a household is not able to complete a second transaction as fast as desired, it may just withdraw from a first transaction in order to avoid the costly period in between. As shown in Appendix G, in Table 9 for buyers and Table 10 for sellers, commitment to an agreed transaction is significantly larger outside the UK. The tables show whether the law requires a grace period, what the penalty is for renegeing during and after this grace period, which conditions that allow to dissolve a contract are usually included in the contract, and for what period parties can still refer to these conditions. In Denmark (where our transactions data are from) for instance, only buyers enjoy a grace period of 6 days, in which they can cancel the transaction at a cost of one percent of the transaction price. Afterwards, buyers are liable for the full amount, while sellers can be taken to court if they do not transfer the house. Sometimes purchase offers allow for contingencies such as the ability to secure financing or the approval of one's own lawyer, but referral to these conditions requires proof and is restricted in time. The picture that emerges from the tables is that in Denmark, Norway, the Netherlands, and the United States it may be very costly to renege on a transaction once a purchase offer has been made or a conditional contract has been signed.

### 3.7.2 Conclusion

The transaction sequence decision of moving owner-occupiers depends on housing market conditions, such as the expected time-on-market for buyers and sellers and expectations about future house price appreciation. However, these decisions in turn exert important effects on the buyer-seller ratio of the housing market. This creates a coordination problem for moving owner occupiers, resulting in multiple equilibria. Equilibrium switches are associated with large fluctuations in the stock of units for sale, average time-on-market, transactions, and prices.

The tractable equilibrium model that we study in this paper to show these effects is deliberately simplified, and so lacks heterogeneity in many important dimensions.

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<sup>45</sup>There is anecdotal evidence that innovations in mortgage financing in recent years may have decreased the importance of housing chains in the UK market as well.

In particular, there is no heterogeneity in the costs of being a double owner versus a forced renter, which are likely to vary substantially across households and also to vary over time in response to aggregate shocks. In addition, we assumed constancy of the rate of mismatch and entry into and exit from the market. Nevertheless, endogenous fluctuations in  $\gamma$  and  $g$  are likely to additionally amplify and propagate aggregate shocks. Enriching the model along these dimensions will allow for a detailed quantitative model of the housing market, which can be taken to the data. We view this as an important step for future research.

## 3.8 Appendix

### 3.8.A Data Description

We use two data sets. The first (EJER) is an ownership register which contains the owners (private individuals and legal entities) of properties in Denmark as of the end of a given calendar year. The data set contains unique identifiers for owners (which, unfortunately, cannot be matched with other datasets beyond EJER for different years). It also contains unique identifiers for each individual property. The second data set (EJSA) contains a record of all property sales in a given calendar year. The majority of transactions include information on the sale price, sale (agreement), and takeover (closing) dates. Furthermore, they contain the property identifiers used in the EJER data-set, which allows for linking of the two datasets. The first data set is available from 1986 (recording ownership in 1985) until 2010 (recording ownership at the end of 2009), while the second is available from 1992 to 2010. Therefore, we effectively use data from 1991 (for ownership as of January 1, 1992) to 2009 (for ownership as of January 1, 2010).

We focus on the Copenhagen urban area (Hovedstadsområdet). We take the definition of the Copenhagen urban area as containing the following municipalities (by number): 101, 147, 151, 153, 157, 159, 161, 163, 165, 167, 173, 175, 183, 185, 187, 253, 269.<sup>46</sup>

We restrict attention to private owners and also to the primary owner of a property in a given year (whenever a property has more than one owners). Furthermore, we examine transactions where the new owner is a private individual and which have a

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<sup>46</sup>Due to a reform in 2007, which merged some municipalities and created a new one, we omit municipality 190 for consistency.

non-missing agreement date. We drop properties that are recorded to transact more than once in a given year. We also remove property-year observations for which no owner is recorded. This leaves us with a total of 3312520 property-year observations. These comprise 199812 unique properties and 345943 unique individual owners over our sample period.

To identify an individual owner as a buyer-and-seller we rely on the information from the ownership register across consecutive years. First of all, we use the information on ownership over consecutive years to determine the counterparties for each recorded transaction in our sample. We then identify an individual owner as a buyer-and-seller if he is recorded to buy a new property and sell an old property within the same year or over two consecutive years. An old property is defined as a property which an individual is registered as owning over at least 2 consecutive years.<sup>47</sup> Also, we do not count individuals that are recorded as holding two properties for two or more consecutive years, which we treat as purchases for investment purposes.

We conduct this for individuals that are recorded as owning at most 2 properties at the end of any calendar year in our sample. This comprises the large majority of individual owners in our sample. In particular, in a given year in our sample from 1991-2009 there are on average only around 0.4% of individual owners who own more than two properties in the Copenhagen. Therefore, the majority of individuals hold at most 1 or 2 properties over that period. In particular, on average, around 1.6% of individual owners hold two properties at the end of a calendar year in our sample. Interestingly, around 5% of the recorded owners of two properties at the end of a calendar year are also identified as a buyer-and-seller according to our identification procedure described above with that number going up to almost 14% at the peak of the housing boom in 2006.

For each individual owner that has been identified as buyer-and-seller, we compute the time period (in days) between the agreement data for sale of the old property and the agreement date for the purchase of the new property. Similarly, we compute the time period (in days) between the closing date that of the buyer-and-seller's old property by the new owner and the closing date for his new property. We then denote a buyer-and-seller for which the time period between agreement dates is negative (sale date

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<sup>47</sup>We make this restriction in order not to misclassify as a buyer-and-seller an individual who acquires a house, for example as a bequest (which is not recorded as a transaction), which he ends up selling quickly and then buys a new house with the proceeds from the sale. Adding back those agents has a very small effect on the pattern we uncover.

is before purchase date) as “selling first” and a buyer-and-seller for which the time period is positive (sale date is after purchase date) as “buying first”. We also do the same classification but based on closing dates rather than agreement dates. Given the way we identify a buyer-and-seller, we have a consistent count for the number of owners who “buy first” vs. “sell first” in a given year for the years 1993 to 2008.

In principle, and as Figures 8 and 9 show, working with either of the two identifications produces similar results. This is not surprising given that the time difference between the agreement dates and closing dates are highly correlated with a correlation coefficient of 0.9313. Figure 16 visualizes this strong correlation by plotting a scatter plot of the two time differences.

### 3.8.B Equilibrium concept and parameter restrictions for the basic model

First of all, the steady state value functions for a new entrant, a matched owner, and a real estate firm satisfy the following equations:

$$\rho V^{Bn} = u_n - R + q(\theta)(-p + V - V^{Bn}), \quad (3.26)$$

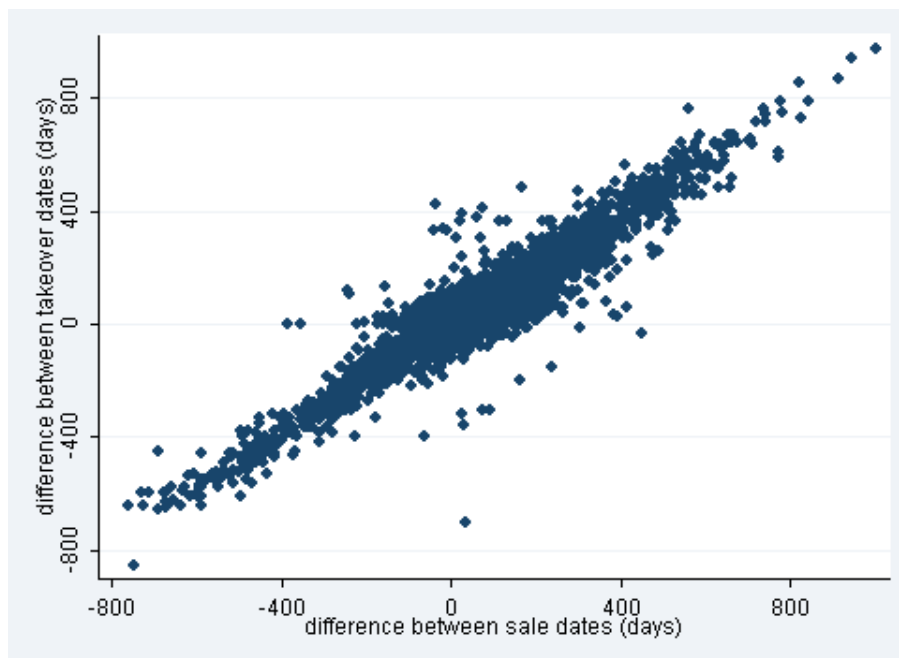


Figure 16: Difference in agreement dates vs. difference in closing dates, Copenhagen (1993-2008)

$$\rho V = u + \gamma (\max\{V^{B1}, V^{S1}\} - V), \quad (3.27)$$

and

$$\rho V^A = R + \mu(\theta) (p - V^A). \quad (3.28)$$

Importantly, in every steady state equilibrium,  $V$  satisfies  $V \geq \tilde{V}$ , where  $\tilde{V} = \frac{u}{\rho + \gamma} + \frac{\gamma}{\rho + \gamma} V^m$ , with  $V^m = \frac{u - \chi}{\rho}$ . Hence,  $\tilde{V}$  is the value of a matched owner who never transacts. Therefore,  $V \geq \tilde{V} = \frac{u}{\rho} - \frac{\gamma}{\rho + \gamma} \frac{\chi}{\rho}$  in any steady state equilibrium.

### Parameter restrictions

Sufficient conditions for new entrants, forced renters and double owners to prefer transacting and becoming matched owners are given by

$$\frac{u_n - R}{\rho} \leq \tilde{V} - p, \quad (3.29)$$

$$\frac{u_0 - R}{\rho} \leq \tilde{V} - p, \quad (3.30)$$

and

$$\frac{u_2 + R}{\rho} \leq \tilde{V} + p. \quad (3.31)$$

Since  $u_n \geq u_0$ , we can disregard (3.30), as it is implied by (3.29). Conditions (3.29) and (3.31) imply restrictions for the values of the house price,  $p$ , that are sufficient for these agents to be willing to transact at  $p$ , namely  $p \in \left[ \frac{u_2}{\rho} - \tilde{V} + \frac{R}{\rho}, \tilde{V} - \frac{u_n}{\rho} + \frac{R}{\rho} \right]$ .

From (3.28) a real estate firm is willing to transact if and only if  $p \geq \frac{R}{\rho}$ . Therefore, equilibrium is defined for a house price  $p$ , that satisfies

$$p \in \left[ \max\left\{ \frac{u_2}{\rho} - \tilde{V}, 0 \right\} + \frac{R}{\rho}, \tilde{V} - \frac{u_n}{\rho} + \frac{R}{\rho} \right]. \quad (3.32)$$

For  $u - \chi \geq \max\{u_0, u_2\}$ , which is the condition we will use to characterize equilibria, it follows that  $\frac{u_2}{\rho} - \tilde{V} < 0$  and so the set for prices is given by

$$p \in \left[ \frac{R}{\rho}, \tilde{V} - \frac{u_0}{\rho} + \frac{R}{\rho} \right]. \quad (3.33)$$

Finally, a sufficient condition for  $V^{S1} > \frac{u - \chi}{\rho}$  and  $V^{B1} > \frac{u - \chi}{\rho}$  at  $\theta = \tilde{\theta}$ , with  $\tilde{\theta}$  as defined in (3.15) is

**Assumption 3.A2:**  $\frac{u-\chi}{\rho} < \frac{u-\chi}{\rho+\mu(\tilde{\theta})} + \frac{\mu(\tilde{\theta})}{(\rho+\mu(\tilde{\theta}))(\rho+q(\tilde{\theta}))} \tilde{u}_0 + \frac{\mu(\tilde{\theta})q(\tilde{\theta})}{(\rho+\mu(\tilde{\theta}))(\rho+q(\tilde{\theta}))} \left( \frac{u}{\rho} - \frac{\gamma}{\rho+\gamma} \frac{\chi}{\rho} \right).$

Note that  $\frac{u}{\rho} - \frac{\gamma}{\rho+\gamma} \frac{\chi}{\rho} \leq V, \forall \theta$ , so the right hand side of this expression is lower than the value of  $V^{S1}$  at  $\theta = \tilde{\theta}$ .

### Steady state flow conditions

Before moving to our formal definition, it is necessary to describe the flow conditions that the aggregate stock variables defined in Section 3.3.2 must satisfy. We have that in a steady state equilibrium, given a market tightness  $\theta$ , the steady state values of  $B_n, B_0, B_1, S_1, S_2, O$ , and  $A$  must satisfy the following system of flow conditions:

$$g = (q(\theta) + g) B_n, \quad (3.34)$$

$$\mu(\theta) S_1 = (q(\theta) + g) B_0, \quad (3.35)$$

$$\mu(\theta) S_2 + q(\theta) (B_n + B_0) = (\gamma + g) O, \quad (3.36)$$

$$\gamma x_b O = (q(\theta) + g) B_1, \quad (3.37)$$

$$\gamma x_s O = (\mu(\theta) + g) S_1, \quad (3.38)$$

$$q(\theta) B_1 = (\mu(\theta) + g) S_2, \quad (3.39)$$

$$g(O + B_1 + S_1 + 2S_2) = \mu(\theta) A, \quad (3.40)$$

$$x_b + x_s = 1, \quad (3.41)$$

where  $x_b$ , and  $x_s$  are the equilibrium fractions of mismatched buyers and sellers, respectively. Apart from these conditions, the aggregate variables must satisfy the population constancy and housing ownership conditions (3.2) and (3.3). Finally, the equilibrium market tightness  $\theta$ , satisfies

$$\theta = \frac{B}{S} = \frac{B_n + B_0 + B_1}{S_1 + S_2 + A}. \quad (3.42)$$

### Equilibrium definition

We define a steady state equilibrium for this economy in the following way:

**Definition 3.9.** A steady state equilibrium consists of a house price  $p$ , equilibrium rental rate  $R$ , value functions  $V^{Bn}$ ,  $V^{B0}$ ,  $V^{B1}$ ,  $V^{S2}$ ,  $V^{S1}$ ,  $V$ ,  $V^A$ , market tightness  $\theta$ , fractions of mismatched owners that choose to buy first and sell first,  $x_b$ , and  $x_s$ , and aggregate stock variables,  $B_n$ ,  $B_0$ ,  $B_1$ ,  $S_1$ ,  $S_2$ ,  $O$ , and  $A$  such that:

1. The house price  $p \in \left[ \frac{R}{\rho}, \tilde{V} - \frac{u_0}{\rho} + \frac{R}{\rho} \right]$ ;
2. The equilibrium rental rate  $R \in [0, u_0]$ ;
3. The value functions satisfy equations (3.5)-(3.8) and (3.26)-(3.28) given  $\theta$ ,  $p$ , and  $R$ ;
4. Mismatched owners choose  $x \in \{b, s\}$ , to maximize  $\bar{V} = \max\{V^{B1}, V^{S1}\}$  and the fractions  $x_b$ , and  $x_s$  reflect that choice, i.e.

$$x_b = \int_i I\{x_i = b\} di,$$

where  $i \in [0, 1]$  indexes the  $i$ -th mismatched owner, and similarly for  $x_s$ ;

5. The market tightness  $\theta$  solves (3.42) given  $B_n$ ,  $B_0$ ,  $B_1$ ,  $S_1$ ,  $S_2$ ,  $O$ , and  $A$ ;
6. The aggregate stock variables  $B_n$ ,  $B_0$ ,  $B_1$ ,  $S_1$ ,  $S_2$ ,  $O$ , and  $A$ , solve (3.34)-(3.40) given  $\theta$  and mismatched owners' optimal decisions reflected in  $x_b$  and  $x_s$ .

### 3.8.C Proofs

#### Proof of Lemma 3.1

First of all, note that the function  $D(\theta)$ , defined in (3.13) crosses zero only at  $\theta = \tilde{\theta}$ . To see this, notice that

$$\lim_{\theta \rightarrow 0} D(\theta) = \frac{\tilde{u}_2 - (u - \chi)}{\rho} < 0,$$

and

$$\lim_{\theta \rightarrow \infty} D(\theta) = \frac{u - \chi - \tilde{u}_0}{\rho} > 0.$$

Away from these two limiting values,  $D(\theta) > 0$ , whenever

$$\left(1 - \frac{1}{\theta}\right)(u - \chi - \tilde{u}_2) - \tilde{u}_0 + \tilde{u}_2 > 0,$$

which is equivalent to  $\tilde{\theta} < \theta$ . Therefore,  $D(\theta) > 0$  if and only if  $\theta \in (\tilde{\theta}, \infty)$  and  $D(\theta) < 0$  if and only if  $\theta \in (0, \tilde{\theta})$ . Therefore,  $D(\theta) = 0$ , if and only if

$$\left(1 - \frac{1}{\theta}\right)(u - \chi - \tilde{u}_2) - \tilde{u}_0 + \tilde{u}_2 = 0,$$

or  $\theta = \tilde{\theta}$ . Note that  $D(\theta)$  fully summarizes the incentives of a mismatched owner to buy first/sell first apart from at  $\theta = 0$  and  $\theta = \infty$ . To see this, let

$$\begin{aligned} \tilde{V}^{B1} &= \frac{u - \chi}{\rho + q(\theta)} + \frac{q(\theta) \tilde{u}_2}{(\rho + \mu(\theta))(\rho + q(\theta))} + \frac{q(\theta) \mu(\theta)}{(\rho + \mu(\theta))(\rho + q(\theta))} V - \frac{u - \chi}{\rho} \\ &= \frac{q(\theta)}{\rho + q(\theta)} \left( \frac{\tilde{u}_2}{\rho + \mu(\theta)} + \frac{\mu(\theta)}{\rho + \mu(\theta)} V - \frac{u - \chi}{\rho} \right), \end{aligned}$$

and

$$\begin{aligned} \tilde{V}^{S1} &= \frac{u - \chi}{\rho + \mu(\theta)} + \frac{\mu(\theta) \tilde{u}_0}{(\rho + \mu(\theta))(\rho + q(\theta))} + \frac{q(\theta) \mu(\theta)}{(\rho + \mu(\theta))(\rho + q(\theta))} V - \frac{u - \chi}{\rho} \\ &= \frac{\mu(\theta)}{\rho + \mu(\theta)} \left( \frac{\tilde{u}_0}{\rho + q(\theta)} + \frac{q(\theta)}{\rho + q(\theta)} V - \frac{u - \chi}{\rho} \right). \end{aligned}$$

The functions  $\tilde{V}^{B1}$  and  $\tilde{V}^{S1}$  give the difference between the value of transacting and never transacting for a buyer first and seller first, respectively.

By Assumption 3.A2, at  $\tilde{\theta}$ ,  $V^{S1} > \frac{u - \chi}{\rho}$  and  $V^{B1} > \frac{u - \chi}{\rho}$ , so at  $\theta = \tilde{\theta}$ ,  $\tilde{V}^{B1} > 0$ , and  $\frac{\tilde{u}_2}{\rho + \mu(\theta)} + \frac{\mu(\theta)}{\rho + \mu(\theta)} V - \frac{u - \chi}{\rho} > 0$ . Furthermore, this latter inequality holds for any  $\theta > \tilde{\theta}$ , and so  $\tilde{V}^{B1} > 0$  for any  $\theta > \tilde{\theta}$ . Therefore, for any  $\theta > \tilde{\theta}$ , a mismatched buyer is better off transacting than not transacting. Similarly, for  $\theta < \tilde{\theta}$  the mismatched seller is better off transacting than not transacting.

Therefore, for  $\theta \in (0, \infty)$ , if  $D(\theta) > 0$ , a mismatched owners is better off buying first (and transacting) compared to selling first (and transacting or not transacting) and similarly, if  $D(\theta) < 0$ , a mismatched owner is better off selling first (and transacting) compared to buying first (and transacting or not transacting). At  $D(\theta) = 0$ , he is indifferent between buying first (and transacting) and selling first (and transacting).

Finally, clearly if  $\theta \rightarrow \infty$ ,  $\tilde{V}^{B1} \rightarrow 0$ , so  $V^{B1} \rightarrow \frac{u - \chi}{\rho} = V^{S1}$ . Similarly, if  $\theta \rightarrow 0$ ,  $\tilde{V}^{S1} \rightarrow 0$ , and so  $V^{S1} \rightarrow \frac{u - \chi}{\rho} = V^{B1}$ .  $\square$



**Proof of Lemma 3.2**

For the case where mismatched owners buy first ( $x_s = 0$ ), the stock-flow conditions are

$$g = (q(\theta) + g) B_n,$$

$$\gamma O = (q(\theta) + g) B_1,$$

$$q(\theta) B_1 = (\mu(\theta) + g) S_2,$$

$$g = (\mu(\theta) + g) A,$$

$$B_n + B_1 + S_2 + O = 1,$$

and

$$B_n = A + S_2.$$

It follows that  $B_n = \frac{g}{q(\theta)+g}$  and  $A = \frac{g}{\mu(\theta)+g}$ , or  $A = \frac{q(\theta)+g}{\mu(\theta)+g} B_n$ , so  $S_2 = \frac{g}{q(\theta)+g} - \frac{g}{\mu(\theta)+g}$ . Therefore, from the equation for  $\theta$ , we have that  $B_1 = (\theta - 1) B_n$  and  $O = \frac{1}{\gamma} (q(\theta) + g) (\theta - 1) B_n$ . Substituting into the population constancy condition, we have that

$$\theta B_n + B_n - \frac{q(\theta) + g}{\mu(\theta) + g} B_n + \frac{1}{\gamma} (q(\theta) + g) (\theta - 1) B_n = 1,$$

which, after substituting for  $B_n$  and re-arranging we can write as

$$\left( \frac{1}{q(\theta) + g} + \frac{1}{\gamma} \right) \theta + \left( \frac{1}{q(\theta) + g} - \frac{1}{\mu(\theta) + g} \right) = \frac{1}{g} + \frac{1}{\gamma}.$$

This is exactly equation (3.17). At  $\theta = 1$ , the left-hand side equals

$$\frac{1}{q(1) + g} + \frac{1}{\gamma} < \frac{1}{g} + \frac{1}{\gamma}.$$

Furthermore, note that  $\left( \frac{1}{q(\theta)+g} + \frac{1}{\gamma} \right) \theta$  is strictly increasing in  $\theta$  and also unbounded. Similarly,  $\left( \frac{1}{q(\theta)+g} - \frac{1}{\mu(\theta)+g} \right)$  is strictly increasing in  $\theta$  as well. Therefore, the left-hand side of (3.17) is strictly increasing in  $\theta$ , unbounded, and lower than the right-hand side for  $\theta = 1$ . Therefore, it has a unique solution for  $\theta > 1$ . We call this solution  $\bar{\theta}$ . Furthermore, by the Implicit Function Theorem, it immediately follows that  $\bar{\theta}$  is increasing in  $\gamma$ .

For the case where mismatched owners sell first ( $x_s = 1$ ) the stock-flow conditions become

$$\begin{aligned} g &= (q(\theta) + q) B_n, \\ \mu(\theta) S_1 &= (q(\theta) + g) B_0, \\ \gamma O &= (\mu(\theta) + g) S_1, \\ g &= (\mu(\theta) + g) A, \\ B_n + B_0 + S_1 + O &= 1, \end{aligned}$$

and

$$B_n + B_0 = A.$$

It follows that  $A = \frac{g}{\mu(\theta) + g} = B_0 + B_n$ ,  $S_1 = \frac{1-\theta}{\theta} A$  and  $O = \frac{1}{\gamma} (\mu(\theta) + g) \frac{1-\theta}{\theta} A$ . Therefore, substituting for these in the population constancy condition, we have that

$$\frac{1}{\theta} A + \frac{1}{\gamma} (\mu(\theta) + g) \frac{1-\theta}{\theta} A = 1.$$

Substituting for  $A$ , we obtain an equation for  $\theta$  of the form

$$\left( \frac{1}{\mu(\theta) + g} + \frac{1}{\gamma} \right) \frac{1}{\theta} = \frac{1}{g} + \frac{1}{\gamma},$$

which is equation (3.18). At  $\theta = 1$ , the left-hand side equals

$$\frac{1}{\mu(1) + g} + \frac{1}{\gamma} < \frac{1}{g} + \frac{1}{\gamma}.$$

Note also that  $\left( \frac{1}{\mu(\theta) + g} + \frac{1}{\gamma} \right) \frac{1}{\theta}$  is strictly decreasing in  $\theta$  and goes to 0 as  $\theta \rightarrow \infty$ . Also it asymptotes to  $\infty$  as  $\theta \rightarrow 0$ . Therefore, the equation has a unique solution for  $\theta < 1$ . We call this solution  $\underline{\theta}$ . By the Implicit Function Theorem, it immediately follows that  $\underline{\theta}$  is decreasing in  $\gamma$ .  $\square$

### Proof of Proposition 3.3

Clearly, Lemma 3.2 that determines the values of  $\bar{\theta}$  and  $\underline{\theta}$  is independent of the agents' payoffs. With regard to Item 1, a direct application of Lemma 3.1 shows that if  $\tilde{\theta} \in [\underline{\theta}, \bar{\theta}]$ , then at  $\theta = \underline{\theta}$  a mismatched owner is (weakly) better off selling first, at  $\theta = \bar{\theta}$  he is (weakly) better off buying first, and at  $\theta = \tilde{\theta}$  he is indifferent. If mismatched owners are

indifferent, they can randomize, such that  $\theta = \tilde{\theta} \in [\underline{\theta}, \bar{\theta}]$ . This follows since the stock-flow conditions ensure a continuous relation between the fraction of agents buying first,  $x_b$ , and  $\theta$ , and observing that  $\theta = \underline{\theta}$ , if and only if  $x_b = 0$  and,  $\theta = \bar{\theta}$ , if and only if  $x_b = 1$ , so that for  $\theta \in [\underline{\theta}, \bar{\theta}]$ ,  $x_b \in [0, 1]$ . Also, by Assumption 3.A2, they are strictly better off from transacting than not transacting. Consequently, agents' actions are optimal given  $\theta$  and the steady state value of  $\theta$  is consistent with agents' actions. Considering Item 2, by the same logic a steady state equilibrium in which mismatched owners buy first and  $\theta = \bar{\theta}$  exists. To see that it is the only symmetric steady state equilibrium, remember from Lemma 3.1 that mismatched owners only sell first for  $\theta < \tilde{\theta}$ , which contradicts  $\tilde{\theta} < \underline{\theta}$ . The same logic applies to Item 3.  $\square$

#### Proof of Corollary 3.4

For  $\tilde{u}_0 = \tilde{u}_2 = c$ ,  $\tilde{\theta} = 1$ . Because Lemma 3.2 shows that  $\bar{\theta} > 1$  when all mismatched owners buy first, and  $\underline{\theta} < 1$  if they sell first,  $\tilde{\theta} \in [\underline{\theta}, \bar{\theta}]$ . Then an application of Proposition 3.3 gives the buy first equilibrium and the sell first equilibrium. To see that  $\theta = 1$  if half of the mismatched owners buy first, take  $x_s = x_b = \frac{1}{2}$ . We have

$$\gamma \frac{1}{2} O = (q(\theta) + g) B_1, \quad (3.43)$$

and

$$\gamma \frac{1}{2} O = (\mu(\theta) + g) S_1. \quad (3.44)$$

At  $\theta = 1$ ,  $\mu(\theta) = q(\theta) = \mu(1)$ , so  $B_1 = S_1$ . Also,  $B_n = A = \frac{g}{\mu(1)+g}$  and  $B_0 = S_2 = S_1 \frac{\mu(1)}{\mu(1)+g}$ . Finally, population constancy implies that

$$2S_1 \frac{\mu(1)}{\mu(1)+g} + 2S_1 + 2S_1 \frac{\mu(1)+g}{\gamma} = \frac{\mu(1)}{\mu(1)+g},$$

which is satisfied for some  $S_1 \in (0, \frac{1}{2})$ . Because mismatched owners are indifferent at  $\theta = 1$  for  $\tilde{u}_0 = \tilde{u}_2 = c$  by Lemma 3.1, an equilibrium in which half of the mismatched owners buy first exists at  $\theta = 1$ .  $\square$

### Proof of Proposition 3.7

Consider the difference between the two value functions,  $D(\theta) = V^{B1} - V^{S1}$  assuming that the mismatched owner transacts in both cases.

$$D(\theta) = \frac{\mu(\theta) \left(1 - \frac{1}{\theta}\right) \left(u - \chi - c + \lambda \left(\bar{V}_N - v^{B0}\right)\right)}{(\rho + q(\theta) + \lambda)(\rho + \mu(\theta) + \lambda)} + \frac{\frac{\lambda \mu(\theta) \left(1 - \frac{1}{\theta}\right) q(\theta)}{(r + \mu(\theta))(r + q(\theta))} [\rho V - c] + \mu(\theta) \left(1 + \frac{1}{\theta}\right) \lambda (p_N - p)}{(\rho + q(\theta) + \lambda)(\rho + \mu(\theta) + \lambda)}. \quad (3.45)$$

Consider the case of  $1 < \theta \leq \bar{\theta}$ , so  $\bar{V}_N = V_N^{B1}$ . If  $\bar{V}_N = V_N^{B1}$ , where  $V_N^{B1}$  denotes the value of buying first after the price change, this difference simplifies further to

$$D(\theta) = \frac{\mu(\theta) \left[ \left(1 - \frac{1}{\theta}\right) \left(1 + \frac{\lambda}{\rho + q(\theta)}\right) (u - \chi - c) + \left(1 + \frac{1}{\theta}\right) \lambda (p_N - p) \right]}{(\rho + q(\theta) + \lambda)(\rho + \mu(\theta) + \lambda)}. \quad (3.46)$$

Suppose that  $p_N < p$  and define  $\theta_{B1}^{PR}$  as the solution to

$$\frac{\theta_{B1}^{PR} - 1}{\theta_{B1}^{PR} + 1} \left( 1 + \frac{\lambda}{\rho + q(\theta_{B1}^{PR})} \right) = \frac{\lambda(p - p_N)}{(u - \chi - c)}. \quad (3.47)$$

Therefore,  $\theta_{B1}^{PR}$  is the value of  $\theta$  that leaves a mismatched owner indifferent between buying first and selling first he anticipates a price change of  $p_N - p$  and a market tightness of  $\theta > 1$  after the price change. Note that  $\theta_{B1}^{PR}$  is increasing in  $p - p_N$  if  $\theta_{B1}^{PR} \geq 1$ . Therefore, a sufficient condition for mismatched owners to prefer to sell first, given  $1 < \theta \leq \bar{\theta}$ , is that  $\theta_{B1}^{PR} > \bar{\theta}$ .

Similarly, consider the case of  $\underline{\theta} \leq \theta < 1$ , so  $\bar{V}_N = V_N^{S1}$ , where  $V_N^{S1}$  denotes the value of selling first after the price change. In that case the difference in value functions can be written as

$$D(\theta) = \frac{\mu(\theta) \left[ \left(1 - \frac{1}{\theta}\right) \left(1 + \frac{\lambda}{\rho + \mu(\theta)}\right) (u - \chi - c) + \left(1 + \frac{1}{\theta}\right) \lambda (p_N - p) \right]}{(\rho + q(\theta) + \lambda)(\rho + \mu(\theta) + \lambda)}. \quad (3.48)$$

Suppose that  $p_N > p$  and define  $\theta_{S1}^{PR}$  as the solution to

$$\frac{\theta_{S1}^{PR} - 1}{\theta_{S1}^{PR} + 1} \left( 1 + \frac{\lambda}{\rho + \mu(\theta_{S1}^{PR})} \right) = \frac{\lambda(p - p_N)}{(u - \chi - c)}. \quad (3.49)$$

Similarly, to the case of  $\theta_{B1}^{PR}$ ,  $\theta_{S1}^{PR}$  is increasing in  $p - p_N$  if  $\theta_{S1}^{PR} \leq 1$ . Then, a sufficient condition for mismatched owner to prefer to buy first, given  $\underline{\theta} \leq \theta < 1$  is that  $\theta_{S1}^{PR} < \underline{\theta}$ .  $\square$

### 3.8.D A model with prices determined by Nash bargaining

We show our main analytical result for the model with Nash bargaining under the following parametric assumptions:

**Assumption 3.B1:**  $u_2 - u_0 = u - u_n$ .

**Assumption 3.B2:**  $r(u_2 - (u - \chi)) + \frac{1}{2}\mu_0\chi > 0$ .

**Assumption 3.B3:**  $r(u_2 - u_0) \geq 2[r(u_2 - (u - \chi)) + \frac{1}{2}\mu_0\chi]$ .

**Assumption 3.B4:**  $\frac{\gamma}{g} \leq \kappa^*$ ,

where  $\kappa^* > 0$  is determined below. The first assumption ensures that buying first and selling first are equally attractive at  $\theta = 1$ . Assumptions 3.B2-3.B4 ensure that the trading pattern described in the main text emerges in equilibrium.

#### Proof of Proposition 3.5

Below, we use the notation  $\Sigma_{ij}$  to denote the surplus from trade between agents of type  $i$  and type  $j$ .

**“Sell first” equilibrium existence.** We first show that a “Sell first” equilibrium exists with  $\theta = \underline{\theta} < 1$ . We proceed in two steps. First, we show that no mismatched owner has an incentive to deviate and buy first when  $\theta = \underline{\theta} < 1$ . This is verified under the conjecture that  $\Sigma_{ij} \geq 0$  for all buyer-seller pairs except for  $\Sigma_{S1B1}$ . Second, we verify the conjecture on the different surpluses.

**Step 1.** In the limit economy with small flows of a “Sell first” equilibrium candidate, the fraction of buyers who are forced renters is given by

$$\lim_{g \rightarrow 0, \gamma \rightarrow 0, \frac{g}{\gamma} = \kappa} \frac{B_0}{B} = \lim_{g \rightarrow 0, \gamma \rightarrow 0, \frac{g}{\gamma} = \kappa} \frac{q(\underline{\theta}) - \mu(\underline{\theta})}{g + q(\underline{\theta})} = 1 - \underline{\theta},$$

where  $\underline{\theta} = \frac{1}{1+\kappa}$ . Similarly,

$$\lim_{g \rightarrow 0, \gamma \rightarrow 0, \frac{g}{\gamma} = \kappa} \frac{A}{S} = \underline{\theta}.$$

Thus,

$$\begin{aligned}
rV^{B0} &= u_0 - R + \frac{1}{2}q(\underline{\theta}) \left( \frac{A}{S} \Sigma_{AB0} + \frac{S_1}{S} \Sigma_{S1B0} \right) \\
&= u_0 - R + \frac{1}{2}q(\underline{\theta}) (\underline{\theta} \Sigma_{AB0} + (1 - \underline{\theta}) \Sigma_{S1B0}),
\end{aligned}$$

and similarly,

$$rV^{Bn} = u_n - R + \frac{1}{2}q(\underline{\theta}) (\underline{\theta} \Sigma_{ABn} + (1 - \underline{\theta}) \Sigma_{S1Bn}),$$

so

$$V^{Bn} - V^{B0} = \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})}. \quad (3.50)$$

Also,

$$\begin{aligned}
rV^A &= R + \frac{1}{2}\mu(\underline{\theta}) \left( \frac{B_n}{B} (V - V^{Bn} - V^A) + \frac{B_0}{B} (V - V^{B0} - V^A) \right) \\
&= R + \frac{1}{2}\mu(\underline{\theta}) (\underline{\theta} (V - V^{Bn} - V^A) + (1 - \underline{\theta}) (V - V^{B0} - V^A)),
\end{aligned}$$

or

$$V^A = \frac{R}{r + \frac{1}{2}\mu(\underline{\theta})} + \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} \left( V - V^{B0} - \underline{\theta} \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} \right).$$

Analogous to Equation 3.50

$$V^{S2} - V^A = \frac{u_2 + \frac{1}{2}\mu(\underline{\theta})V}{r + \frac{1}{2}\mu(\underline{\theta})}.$$

This in turn implies that

$$V - V^{S2} = \frac{rV - u_2}{r + \frac{1}{2}\mu(\underline{\theta})} - V^A = \frac{u - u_2}{r + \frac{1}{2}\mu(\underline{\theta})} - V^A.$$

Turning to the value functions of mismatched owners, a mismatched seller has a value function given by

$$rV^{S1} = u - \chi + \frac{1}{2}\mu(\underline{\theta}) \left( V - V^{S1} - \underline{\theta} \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} \right),$$

which can be re-written as

$$V^{S1} = \frac{u - \chi}{r + \frac{1}{2}\mu(\underline{\theta})} + \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} V - \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} \frac{\theta}{r + \frac{1}{2}q(\underline{\theta})} \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})}.$$

For the value function of a deviating mismatched buyer, assuming that trade takes place when he meets a real-estate firm but not when he meets a mismatched seller, writes

$$rV^{B1} = u - \chi + \frac{1}{2}q(\underline{\theta})\theta\Sigma_{AB1}.$$

Or

$$\left(r + \frac{1}{2}\mu(\underline{\theta})\right)V^{B1} = u - \chi + \frac{1}{2}\mu(\underline{\theta})(V^{S2} - V^A).$$

Consider the difference between the utilities from buying first compared to selling first. In the limit we consider, we have that

$$\left(r + \frac{1}{2}\mu(\underline{\theta})\right)(V^{B1} - V^{S1}) = \frac{1}{2}\mu(\underline{\theta})\left(V^{S2} - V^A - V + \frac{\theta}{\rho + \frac{1}{2}q(\underline{\theta})} \frac{u_n - u_0}{\rho + \frac{1}{2}q(\underline{\theta})}\right).$$

Substituting for  $V^{S2} - V^A - V$ , we get that

$$V^{B1} - V^{S1} = \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} \left( \frac{u_2 - u}{r + \frac{1}{2}\mu(\underline{\theta})} + \theta \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} \right).$$

Note that at  $\underline{\theta} = 1$  (i.e. for  $\kappa = 0$ ),

$$\frac{u_2 - u}{r + \frac{1}{2}\mu(\underline{\theta})} + \theta \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} = 0,$$

given Assumption 3.B1. As  $\underline{\theta}$  moves away from 1 toward 0 ( $\kappa$  increases), we have that  $\frac{u_2 - u}{r + \frac{1}{2}\mu(\underline{\theta})} + \theta \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})}$  decreases, so  $V^{B1} < V^{S1}$  for  $\underline{\theta} < 1$ . Therefore, it is not optimal for a mismatched owner to deviate and buy first in an equilibrium in which mismatched owners sell first and  $\theta < 1$ .

**Step 2.** We verify that our conjectures for the surpluses are correct. It is clear given our assumptions that  $\Sigma_{S2B1} = V - V^{B1} > 0$  and  $\Sigma_{S1B0} = V - V^{S1} > 0$ . Also,  $\Sigma_{ABn} \geq 0$ . Next, we show that  $\Sigma_{S1Bn} > 0$ . In the limit we consider,

$$\begin{aligned}
\Sigma_{S1Bn} &= V - V^{Bn} + V^{B0} - V^{S1} = V - V^{S1} - \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} \\
&= \frac{\chi}{r + \frac{1}{2}\mu(\underline{\theta})} + \frac{\frac{1}{2}\mu(\underline{\theta})(\underline{\theta} - 1) - r}{r + \frac{1}{2}\mu(\underline{\theta})} \frac{u_n - u_0}{r + \frac{1}{2}q(\underline{\theta})} \\
&= \frac{r(\chi + u_0 - u_n) + \frac{1}{2}q(\underline{\theta})\chi + \frac{1}{2}\mu(\underline{\theta})(\underline{\theta} - 1)(u_n - u_0)}{(r + \frac{1}{2}q(\underline{\theta}))(r + \frac{1}{2}\mu(\underline{\theta}))}.
\end{aligned}$$

Therefore, at  $\underline{\theta} = 1$ ,  $\Sigma_{S1Bn} > 1$  if

$$r(\chi + u_0 - u_n) + \frac{1}{2}\mu_0\chi > 0.$$

Note that given Assumption 3.B1, this is equivalent to

$$r(u_2 - (u - \chi)) + \frac{1}{2}\mu_0\chi > 0,$$

which holds by Assumption 3.B2. Therefore, by continuity of the value functions with respect to  $\theta$ , it follows that there is a  $\kappa_1 > 0$ , such that for  $\kappa < \kappa_1$ ,  $\Sigma_{S1Bn} > 0$ . Next, we show that  $\Sigma_{ABn} > 0$ . To show, this suppose, toward a contradiction, that  $\Sigma_{ABn} < 0$ . Then

$$rV^{Bn} + rV^A \leq u_n + \frac{1}{2}q(\underline{\theta})\Sigma_{ABn} + \frac{1}{2}\mu(\underline{\theta})\Sigma_{ABn},$$

where the inequality comes from  $\Sigma_{ABn} < 0 < \Sigma_{S1Bn}$  and  $\Sigma_{ABn} < \Sigma_{AB0}$ , since  $V^{Bn} > V^{B0}$ . Therefore,

$$\Sigma_{ABn} \geq \frac{rV - u_n}{r + \frac{1}{2}q(\underline{\theta}) + \frac{1}{2}\mu(\underline{\theta})} > 0,$$

so we arrive at a contradiction.  $\Sigma_{ABn} > 0$  also implies that  $\Sigma_{AB0} > 0$ , since  $V^{Bn} > V^{B0}$ . Next notice that

$$\Sigma_{S2Bn} = \Sigma_{ABn} + V - V^{S2} + V^A = \Sigma_{ABn} + \frac{rV - u_2}{r + \frac{1}{2}\mu(\underline{\theta})} > 0.$$

Again, this also implies that  $\Sigma_{S2B0} > 0$ . Next, we show that  $\Sigma_{AB1} > 0$ . In the limit we consider,

$$\begin{aligned}
\Sigma_{AB1} &= V^{S2} - V^{B1} - V^A = V^{S2} - V^A - \frac{u - \chi}{r + \frac{1}{2}\mu(\underline{\theta})} - \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})} (V^{S2} - V^A) \\
&= \frac{r(V^{S2} - V^A) - (u - \chi)}{r + \frac{1}{2}\mu(\underline{\theta})} = \frac{\frac{r}{r + \frac{1}{2}\mu(\underline{\theta})}u_2 + \frac{\frac{1}{2}\mu(\underline{\theta})}{r + \frac{1}{2}\mu(\underline{\theta})}u - (u - \chi)}{r + \frac{1}{2}\mu(\underline{\theta})} \\
&= \frac{r(u_2 - (u - \chi)) + \frac{1}{2}\mu(\underline{\theta})\chi}{(r + \frac{1}{2}\mu(\underline{\theta}))^2}.
\end{aligned}$$



At  $\underline{\theta} = 1$ ,  $\Sigma_{AB1} > 0$  if  $r(u_2 - (u - \chi)) + \frac{1}{2}\mu_0\chi > 0$ , which is our parametric Assumption 3.B2. Therefore, by continuity of the value functions with respect to  $\underline{\theta}$ , it follows that there is a  $\kappa_2 > 0$ , such that for  $\kappa < \kappa_2$ ,  $\Sigma_{AB1} > 0$ . Finally, in the limit we consider

$$\begin{aligned}\Sigma_{S1B1} &= V^{S2} - V^{B1} + V^{B0} - V^{S1} \\ &= V^{S2} - V^{B1} + \frac{rV^{B0} - (u - \chi) + R}{r + \frac{1}{2}\mu(\underline{\theta})} - V^A \\ &= \Sigma_{AB1} + \frac{rV^{B0} - (u - \chi) + R}{r + \frac{1}{2}\mu(\underline{\theta})}.\end{aligned}$$

At  $\underline{\theta} = 1$ ,

$$\begin{aligned}\frac{rV^{B0} - (u - \chi) + R}{r + \frac{1}{2}\mu_0} &= \frac{\frac{r}{r + \frac{1}{2}\mu_0}(u_0 - R) + \frac{\frac{1}{2}\mu_0}{r + \frac{1}{2}\mu_0}u - \frac{\frac{1}{2}\mu_0}{r + \frac{1}{2}\mu_0}rV^A - (u - \chi) + R}{r + \frac{1}{2}\mu_0} \\ &= \frac{ru_0 + \frac{1}{2}\mu_0u - \frac{1}{2}\mu_0(rV^A - R) - (r + \frac{1}{2}\mu_0)(u - \chi)}{(r + \frac{1}{2}\mu_0)^2}.\end{aligned}$$

Substituting for  $\Sigma_{AB1}$ , we get

$$\Sigma_{S1B1} = \frac{r(u_0 + u_2 - 2(u - \chi)) + \mu\chi - \frac{1}{2}\mu_0(rV^A - R)}{(r + \frac{1}{2}\mu_0)^2}.$$

Therefore, a sufficient condition for  $\Sigma_{S1B1} < 0$  at  $\underline{\theta} = 1$  is

$$r(u_0 + u_2 - 2(u - \chi)) + \mu_0\chi \leq 0,$$

or

$$r(u_2 - u_0) \geq 2 \left[ r(u_2 - (u - \chi)) + \frac{1}{2}\mu_0\chi \right],$$

which is our parametric assumption 3.B3. Again by continuity of the value functions with respect to  $\underline{\theta}$ , we have that there is a  $\kappa_3 > 0$ , s.t. for  $\kappa < \kappa_3$ ,  $\Sigma_{S1B1} < 0$ . Taking  $\underline{\kappa} = \min\{\kappa_1, \kappa_2, \kappa_3\}$ , we have that for  $\kappa < \underline{\kappa}$ , there is a ‘‘Sell first’’ equilibrium with a market tightness given by  $\underline{\theta} = \frac{1}{1 + \kappa}$ .

**‘‘Buy first’’ equilibrium existence.** We follow the same two steps to show the existence of a ‘‘Buy first’’ equilibrium with  $\theta = \bar{\theta} > 1$ . Again, we make the same conjectures on the

different surpluses as in the case of the “Sell first” equilibrium. In the limit economy, the fraction of buyers who are new entrants is

$$\lim_{g \rightarrow 0, \gamma \rightarrow 0, \frac{g}{\gamma} = \kappa} \frac{B_n}{B} = \frac{1}{\bar{\theta}},$$

where  $\bar{\theta} = 1 + \kappa$ . Also,

$$\lim_{g \rightarrow 0, \gamma \rightarrow 0, \frac{g}{\gamma} = \kappa} \frac{A}{S} = \frac{1}{\bar{\theta}}$$

as well. Therefore, similarly to the value functions in the “Sell first” equilibrium, we have that

$$\left(r + \frac{1}{2}\mu(\bar{\theta})\right)V^A = R + \frac{1}{2}\mu(\bar{\theta})\left(\frac{1}{\bar{\theta}}(V - V^{Bn}) + \frac{\bar{\theta} - 1}{\bar{\theta}}(V^{S2} - V^{B1})\right),$$

and

$$\left(r + \frac{1}{2}\mu(\bar{\theta})\right)V^{S2} = u_2 + \left(r + \frac{1}{2}\mu(\bar{\theta})\right)V^A + \frac{1}{2}\mu(\bar{\theta})V.$$

Therefore, as in the “Sell first” equilibrium,

$$V - V^{S2} = \frac{rV - u_2}{r + \frac{1}{2}\mu(\bar{\theta})} - V^A.$$

Also, as in the “Sell first” equilibrium,

$$V^{Bn} - V^{B0} = \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})}.$$

Turning to the value functions of a mismatched buyer, we have that

$$rV^{B1} = u - \chi + \frac{1}{2}q(\bar{\theta})\left(\frac{1}{\bar{\theta}}(V^{S2} - V^{B1} - V^A) + \left(1 - \frac{1}{\bar{\theta}}\right)(V - V^{B1})\right),$$

For the value function of a deviating agent who chooses to sell first, we have that

$$rV^{S1} = u - \chi + \frac{1}{2}\mu(\bar{\theta})\left(\frac{1}{\bar{\theta}}\Sigma_{S1Bn}\right),$$

since  $\Sigma_{S1B1} < 0$ . Then,

$$\left(r + \frac{1}{2}q(\bar{\theta})\right)V^{S1} = u - \chi + \frac{1}{2}q(\bar{\theta})V + \frac{1}{2}q(\bar{\theta})\frac{u_0 - u_n}{r + \frac{1}{2}q(\bar{\theta})}.$$

Therefore, the difference between  $V^{B1} - V^{S1}$  satisfies

$$\left(r + \frac{1}{2}q(\bar{\theta})\right)(V^{B1} - V^{S1}) = \frac{1}{2}q(\bar{\theta}) \left( \frac{1}{\bar{\theta}} \frac{u_2 - u}{r + \frac{1}{2}\mu(\bar{\theta})} + \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})} \right).$$

At  $\bar{\theta} = 1$ , we have that

$$\frac{1}{\bar{\theta}} \frac{u_2 - u}{r + \frac{1}{2}\mu(\bar{\theta})} + \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})} = 0,$$

by Assumption 3.B1. As  $\bar{\theta}$  increases, we have that  $\frac{1}{\bar{\theta}} \frac{u_2 - u}{r + \frac{1}{2}\mu(\bar{\theta})} + \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})}$  increases, so  $V^{B1} > V^{S1}$  for  $\bar{\theta} > 1$ . Therefore, it is not optimal for a mismatched owner to deviate and sell first in an equilibrium in which mismatched owners buy first and  $\theta > 1$ .

Finally, we verify that our conjectures for the surpluses are correct. As in the “Sell first” case,  $\Sigma_{S1B0} > 0$  and  $\Sigma_{S2B1} > 0$ . Also, as in the “Sell first” case, in the limit we consider,

$$\begin{aligned} \Sigma_{AB1} &= V^{S2} - V^{B1} - V^A \\ &= V^{S2} - V^A - V + V - \frac{u - \chi}{r + \frac{1}{2}q(\bar{\theta})} - \frac{\frac{1}{2}q(\bar{\theta})}{r + \frac{1}{2}q(\bar{\theta})} \left[ \frac{1}{\bar{\theta}} (V^{S2} - V^A - V) + V \right] \\ &= \frac{\left(r + \frac{1}{2}q(\bar{\theta})\right) \frac{\bar{\theta}-1}{\bar{\theta}}}{r + \frac{1}{2}q(\bar{\theta})} \frac{u_2 - u}{r + \frac{1}{2}\mu(\bar{\theta})} + \frac{\chi}{r + \frac{1}{2}q(\bar{\theta})} \\ &= \frac{r(u_2 - (u - \chi)) + \frac{1}{2}\mu(\bar{\theta})\chi + \frac{1}{2}q(\bar{\theta}) \frac{\bar{\theta}-1}{\bar{\theta}} (u_2 - u)}{\left(r + \frac{1}{2}\mu(\bar{\theta})\right) \left(r + \frac{1}{2}q(\bar{\theta})\right)}. \end{aligned}$$

Note that at  $\bar{\theta} = 1$ ,  $\Sigma_{AB1}$  in the “Buy first” case is the same as the “Sell first” case. Therefore, there is a  $\kappa_4 > 0$ , such that for  $\kappa < \kappa_4$  and  $\bar{\theta} = 1 + \kappa$ ,  $\Sigma_{AB1} > 0$ . Similarly,

$$\begin{aligned} \Sigma_{S1Bn} &= V - V^{Bn} + V^{B0} - V^{S1} = V - V^{S1} - \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})} \\ &= \frac{\chi}{r + \frac{1}{2}q(\bar{\theta})} - \frac{r}{r + \frac{1}{2}q(\bar{\theta})} \frac{u_n - u_0}{r + \frac{1}{2}q(\bar{\theta})} \\ &= \frac{r(\chi + u_0 - u_n) + \frac{1}{2}q(\bar{\theta})\chi}{\left(r + \frac{1}{2}q(\bar{\theta})\right)^2}, \end{aligned}$$

which at  $\bar{\theta} = 1$  is again the same as for the “Sell first” case. Therefore, there is a  $\kappa_5 > 0$ , such that for  $\kappa < \kappa_5$ ,  $\Sigma_{S1Bn} > 0$ . A similar argument to the one for the “Sell first” case also confirms that  $\Sigma_{ABn} > 0$ ,  $\Sigma_{AB0} > 0$ ,  $\Sigma_{S2Bn} > 0$  and  $\Sigma_{S2B0} > 0$ . Finally,

$$\begin{aligned}
\Sigma_{S1B1} &= V^{S2} - V^{B1} + V^{B0} - V^{S1} \\
&= V^{S2} - V^{B1} + \frac{rV^{B0} - (u - \chi) + R + \frac{1}{2}q(\bar{\theta})(\bar{\theta} - 1)(V^{S2} - V^{B1} - V^A)}{r + \frac{1}{2}q(\bar{\theta})} - V^A \\
&= \left(1 + \frac{\frac{1}{2}q(\bar{\theta})(\bar{\theta} - 1)}{r + \frac{1}{2}q(\bar{\theta})}\right) \Sigma_{AB1} + \frac{rV^{B0} - (u - \chi) + R}{r + \frac{1}{2}q(\bar{\theta})}.
\end{aligned}$$

At  $\bar{\theta} = 1$ , showing that  $\Sigma_{S1B1} < 0$  in the “Buy first” case therefore follows the “Sell first” case, so that  $\Sigma_{S1B1} < 0$  for  $\kappa < \kappa_6$ , for some  $\kappa_6 > 0$ . Taking  $\bar{\kappa} = \min\{\kappa_4, \kappa_5, \kappa_6\}$ , we have that for  $\kappa < \bar{\kappa}$ , there is a “Buy first” equilibrium with a market tightness given by  $\bar{\theta} = 1 + \kappa$ . Finally, taking  $\kappa^* = \min\{\bar{\kappa}, \underline{\kappa}\}$ , we arrive at the desired result.  $\square$

### 3.8.E A model with competitive search

We define a competitive search equilibrium for the economy described in Section 3.5.3. Let  $(\mathcal{P}, \Theta)$  denote the active market segments in the economy, i.e. segments that attract a positive measure of buyers and sellers. The following equations describe the steady state value functions of agents. For new entrants we have:

$$\rho V^{Bn} = u_n - R + \max_{(p, \theta) \in (\mathcal{P}, \Theta)} \{q(\theta)(-p + V - V^{Bn})\}. \quad (3.51)$$

Similarly, for a real estate firm, we have

$$\rho V^A = R + \max_{(p, \theta) \in (\mathcal{P}, \Theta)} \{\mu(\theta)(p - V^A)\}. \quad (3.52)$$

For mismatched owners that buy first, we have

$$\rho V^{B1} = u - \chi + \max\left\{0, \max_{(p, \theta) \in (\mathcal{P}, \Theta)} \{q(\theta)(-p + V^{S2} - V^{B1})\}\right\}, \quad (3.53)$$

where the value function takes into account the possibility that a mismatched buyer may be better off not searching. Similarly, if the mismatched owner sells first, we have

$$\rho V^{S1} = u - \chi + \max\left\{0, \max_{(p, \theta) \in (\mathcal{P}, \Theta)} \{\mu(\theta)(p + V^{B0} - V^{S1})\}\right\}. \quad (3.54)$$

A double owner solves

$$\rho V^{S2} = u_2 + R + \max_{(p,\theta) \in (\mathcal{P}, \Theta)} \{ \mu(\theta) (p + V - V^{S2}) \}, \quad (3.55)$$

while a forced renter solves

$$\rho V^{B0} = u_0 - R + \max_{(p,\theta) \in (\mathcal{P}, \Theta)} \{ q(\theta) (-p + V - V^{B0}) \}. \quad (3.56)$$

Finally, for a matched owner we have

$$\rho V = u + \gamma (\max \{ V^{B1}, V^{S1} \} - V). \quad (3.57)$$

Next, we describe the steady state stock-flow conditions. Let

$$(p^{Bn}, \theta^{Bn}) \in (\mathcal{P}^{Bn}, \Theta^{Bn}) \equiv \arg \max_{(p,\theta)} \{ q(\theta) (-p + V - V^{Bn}) \} \subset (\mathcal{P}, \Theta) \quad (3.58)$$

denote a market segment that maximizes the value of searching for a new entrant. We define  $(p^j, \theta^j)$  and  $(\mathcal{P}^j, \Theta^j)$  analogously for an agent type  $j \in \{A, B1, S1, B0, S2\}$ . For agents  $j \in \{B1, S1\}$ , we adopt the convention that  $\Theta^j = \emptyset$  if they choose not to search.

We have the following stock-flow conditions

$$g = \left( \sum_{\theta \in \Theta} x^{Bn}(\theta) q(\theta) + g \right) B_n, \quad (3.59)$$

$$\sum_{\theta \in \Theta} x^{S1}(\theta) \mu(\theta) S_1 = \left( \sum_{\theta \in \Theta} x^{B0}(\theta) q(\theta) + g \right) B_0, \quad (3.60)$$

$$\gamma x_b O = \left( \sum_{\theta \in \Theta} x^{B1}(\theta) q(\theta) + g \right) B_1, \quad (3.61)$$

$$\gamma x_s O = \left( \sum_{\theta \in \Theta} x^{S1}(\theta) \mu(\theta) + g \right) S_1, \quad (3.62)$$

$$\sum_{\theta \in \Theta} x^{B1}(\theta) q(\theta) B_1 = \left( \sum_{\theta \in \Theta} x^{S2}(\theta) \mu(\theta) + g \right) S_2, \quad (3.63)$$

$$g(O + B_1 + S_1 + 2S_2) = \sum_{\theta \in \Theta} x^A(\theta) \mu(\theta) A, \quad (3.64)$$

$$x_b + x_s = 1, \quad (3.65)$$

with

$$\sum_{\theta \in \Theta} x^j(\theta) = 1 \quad \forall j \in \{Bn, A, B0, S2\}, \quad (3.66)$$

where  $x^j(\theta) = 0$  if  $\theta \notin \Theta^j$  and, if a mismatched buyer/seller chooses to search,

$$\sum_{\theta \in \Theta} x^j(\theta) = 1 \quad \text{for } j \in \{B1, S1\}, \quad (3.67)$$

with  $x^j(\theta) = 0$  if  $\theta \notin \Theta^j$ . In the above expressions  $\mathbf{x}^j(\theta) \geq 0$  is the vector of mixing probabilities over segments in  $\Theta$  for an agent  $j \in \{Bn, A, B1, S1, B0, S2\}$ . Market tightnesses in each segment are given by

$$\theta = \frac{x^{Bn}(\theta) B_n + x^{B1}(\theta) B_1 + x^{B0}(\theta) B_0}{x^A(\theta) A + x^{S2}(\theta) S_2 + x^{S1}(\theta) S_1}, \quad (3.68)$$

where  $x^j(\theta) = 0$  if  $\theta \notin \Theta^j$ .

Finally, we have the population constancy and housing ownership conditions

$$B_n + B_0 + B_1 + S_1 + S_2 + O = 1, \quad (3.69)$$

and

$$O + B_1 + S_1 + A + 2S_2 = 1. \quad (3.70)$$

Following Moen (1997), we additionally require that the active market segments  $(\mathcal{P}, \Theta)$  are such that the equilibrium allocation is a “no-surplus allocation”. Formally, we make the following requirement.

**No-surplus allocation.** Let  $\mathcal{B} \subset \{Bn, B1, B0\}$  and  $\mathcal{S} \subset \{A, S1, S2\}$  denote the sets of *active* buyers and sellers in a steady state equilibrium, that is agents that have a strictly positive measure in steady state. Given the set of active segments  $(\mathcal{P}, \Theta)$  and agents’ steady state value functions  $\{V^{Bn}, V^{B1}, V^{B0}, V^A, V^{S1}, V^{S2}\}$ , there exists no pair  $(p, \theta) \notin (\mathcal{P}, \Theta)$ , such that  $V^i(p, \theta) > V^i$ , for some  $i \in \{Bn, B1, B0\}$ , and  $V^j(p, \theta) \geq V^j$  for some  $j \in \mathcal{S}$ , or  $V^i(p, \theta) > V^i$ , for some  $i \in \{A, S1, S2\}$ , and  $V^j(p, \theta) \geq V^j$  for some  $j \in \mathcal{B}$ , where  $V^i(p, \theta)$  denotes the steady state value function of an agent that trades in segment  $(p, \theta)$ , for  $i \in \{Bn, B1, B0, A, S1, S2\}$ .

Informally, the no-surplus allocation condition requires that in equilibrium there are no agents that would be strictly better off from deviating and opening a new market

segment that would be at least as attractive for some active agents (buyers or sellers) compared to their equilibrium values.

We can now define a symmetric steady state competitive search equilibrium of this economy as follows

**Definition 3.10.** A symmetric steady state competitive search equilibrium of this economy consists of a set of active market segments  $(\mathcal{P}, \Theta)$ , steady state value functions  $V^{Bn}, V^{B0}, V^{B1}, V^{S2}, V^{S1}, V, V^A$ , fractions of mismatched owners that choose to buy first and sell first,  $x_b$ , and  $x_s$ , aggregate stock variables,  $B_n, B_0, B_1, S_1, S_2, O$ , and  $A$ , distributions of agent types over active market segments  $\{\mathbf{x}^j\}_{j \in \{Bn, A, B1, S1, B0, S2\}}$ , and set of active buyers and sellers,  $\mathcal{B}$  and  $\mathcal{S}$ , such that

1. The value functions satisfy equations (3.51) - (3.57) and the mixing distributions  $\{\mathbf{x}^j\}_j$  are consistent with the agents' optimization problems.
2. Mismatched owners choose to buy first or sell first, in order to maximize  $\bar{V} = \max\{V^{B1}, V^{S1}\}$  and the fractions  $x_b$ , and  $x_s$  reflect that choice, i.e.

$$x_b = \int_i I\{x_i = b\} di,$$

where  $i \in [0, 1]$  indexes the  $i$ -th mismatched owner, and similarly for  $x_s$ ;

3. The aggregate stock variables  $B_n, B_0, B_1, S_1, S_2, O$ , and  $A$ , solve (3.59)-(3.64) and (3.69)-(3.70) given  $\Theta, \{\mathbf{x}^j\}_j$  and mismatched owners' optimal decisions, reflected in  $x_b$  and  $x_s$ .
4. Every  $\theta \in \Theta$  satisfies equation (3.68) given  $B_n, B_0, B_1, S_1, S_2, O, A$ , and  $\{\mathbf{x}^j\}_j$ ;
5. The set of active buyers and sellers,  $\mathcal{B}$  and  $\mathcal{S}$ , is consistent with mismatched owners' optimal decisions;
6.  $(\mathcal{P}, \Theta)$  and agents' steady state value functions satisfy the no-surplus allocation condition.

### Proof of Proposition 3.6

Consider first the "Buy first" equilibrium as described in section 3.5.3. In this "Buy first" equilibrium there are three active market segments characterized by prices  $p_1^{B1} > p_2^{B1} > p_3^{B1}$  and market tightnesses  $\theta_1^{B1} < \theta_2^{B1} < \theta_3^{B1}$ . New entrants trade with real estate agents in market 1 and with double owners in market 2, while the latter also trade with mismatched buyers in market 3. Let  $x^{Bn}$  denote the probability with which a new

entrant visits segment  $(p_1^{B1}, \theta_1^{B1})$ , and  $x^{S2}$  the probability with which a double owner visits segment  $(p_2^{B1}, \theta_2^{B1})$ . The stock-flow conditions for this equilibrium are

$$B_n = \frac{g}{x^{Bn} q(\theta_1^{B1}) + (1 - x^{Bn}) q(\theta_2^{B1}) + g}, \quad (3.71)$$

$$A = \frac{g}{\mu(\theta_1^{B1}) + g}, \quad (3.72)$$

$$B_1 = \frac{\gamma O}{q(\theta_3^{B1}) + g}, \quad (3.73)$$

$$S_2 = \frac{q(\theta_3^{B1}) B_1}{x^{S2} \mu(\theta_2^{B1}) + (1 - x^{S2}) \mu(\theta_3^{B1}) + g}, \quad (3.74)$$

$$B_n + B_1 + S_2 + O = 1, \quad (3.75)$$

and

$$B_n = A + S_2. \quad (3.76)$$

The market tightnesses in each active segment satisfy

$$\theta_1^{B1} = \frac{x^{Bn} B_n}{A}, \quad (3.77)$$

$$\theta_2^{B1} = \frac{(1 - x^{Bn}) B_n}{x^{S2} S_2}, \quad (3.78)$$

and

$$\theta_3^{B1} = \frac{B_1}{(1 - x^{S2}) S_2}. \quad (3.79)$$

Observe that (3.71), (3.72), (3.76), and (3.77) imply that  $x^{Bn} < 1$ , as otherwise, (3.71), (3.72) and (3.77) give

$$\theta_1^{B1} = \frac{B_n}{A} = \frac{\mu(\theta_1^{B1}) + g}{q(\theta_1^{B1}) + g}, \quad (3.80)$$

which has a unique solution at  $\theta_1^{B1} = 1$ . However, this is inconsistent with (3.76).

Let  $\Sigma_{ij}$ , for  $i \in \{B_n, B_0, B_1\}$  and  $j \in \{A, S_1, S_2\}$  denote the match surplus from trading between a buyer  $i$  and seller  $j$ . The no-surplus allocation condition determines the equilibrium prices in each segment as a function of the steady state values of agents. Define



$$\begin{aligned}\bar{V}^{Bn} &= q(\theta_1^{B1})(-p_1^{B1} + V - V^{Bn}) \\ &= q(\theta_2^{B1})(-p_2^{B1} + V - V^{Bn}), \\ \bar{V}^A &= \mu(\theta_1^{B1})(p_1^{B1} - V^A),\end{aligned}$$

$$\bar{V}^{B1} = q(\theta_3^{B1})(-p_3^{B1} + V^{S2} - V^{B1}),$$

and

$$\begin{aligned}\bar{V}^{S2} &= \mu(\theta_2^{B1})(p_2^{B1} + V - V^{S2}) \\ &= \mu(\theta_3^{B1})(p_3^{B1} + V - V^{S2}),\end{aligned}$$

as the maximized value of searching for each trader. The no-surplus allocation condition implies that

$$\begin{aligned}(p_1^{B1}, \theta_1^{B1}) &= \arg \max_{p, \theta} \mu(\theta)(p - V^A), \\ \text{s.t. } q(\theta)(-p + V - V^{Bn}) &\geq \bar{V}^{Bn}.\end{aligned}$$

Denote the elasticity of the matching function with respect to buyers by  $\alpha$  (which may depend on  $\theta$ ). Solving for  $p_1^{B1}$  and  $\theta_1^{B1}$  gives the well-known Hosios rule (Hosios (1990)),

$$p_1^{B1} - V^A = (1 - \alpha) \Sigma_{BnA},$$

or equivalently,

$$p_1^{B1} = (1 - \alpha)(V - V^{Bn}) + \alpha V^A.$$

Therefore,

$$\bar{V}^{Bn} = \alpha q(\theta_1^{B1}) \Sigma_{BnA} = \alpha q(\theta_2^{B1}) \Sigma_{BnS2},$$

or

$$q(\theta_1^{B1}) \Sigma_{BnA} = q(\theta_2^{B1}) \Sigma_{BnS2}. \quad (3.81)$$

We have similar surplus sharing rules between the other trading pairs, which determine  $p_2^{B1}$  and  $p_3^{B1}$ . There is one more indifference condition for a double owner that relates  $\theta_2^{B1}$  and  $\theta_3^{B1}$ . Specifically,

$$\mu(\theta_2^{B1}) \Sigma_{BnS2} = \mu(\theta_3^{B1}) \Sigma_{B1S2}. \quad (3.82)$$

These surplus sharing rules imply that the value functions of active agents satisfy the equations

$$\rho V^{Bn} = u_n - R + \alpha q(\theta_2^{B1}) \Sigma_{BnS2}, \quad (3.83)$$

$$\rho V^A = R + (1 - \alpha) \mu(\theta_1^{B1}) \Sigma_{BnA}, \quad (3.84)$$

$$\rho V^{B1} = u - \chi + \alpha q(\theta_3^{B1}) \Sigma_{B1S2}, \quad (3.85)$$

$$\rho V^{S2} = u_2 + R + (1 - \alpha) \mu(\theta_2^{B1}) \Sigma_{BnS2}, \quad (3.86)$$

and

$$\rho V = u + \gamma(V^{B1} - V). \quad (3.87)$$

Finally, use  $V^{Bn}$  and  $V^{S2}$  from (3.83) and (3.86) to solve for

$$\Sigma_{BnS2} = \frac{2\rho V - u_n - u_2}{\rho + \alpha q(\theta_2^{B1}) + (1 - \alpha) \mu(\theta_2^{B1})}. \quad (3.88)$$

Similarly, using  $V^{Bn}$  and  $V^A$  from (3.83) and (3.52), combined with indifference condition (3.81), to solve for

$$\Sigma_{BnA} = V - V^{Bn} - V^A = \frac{\rho V - u_n}{\rho + \alpha q(\theta_1^{B1}) + (1 - \alpha) \mu(\theta_1^{B1})}. \quad (3.89)$$

Solving for  $V^{B1}$  from equation (3.85), we get

$$V^{B1} = \frac{u - \chi}{\rho + \alpha q(\theta_3^{B1})} + \frac{\alpha q(\theta_3^{B1})}{\rho + \alpha q(\theta_3^{B1})} V,$$

so

$$\Sigma_{B1S2} = V - V^{B1} = \frac{\rho V - (u - \chi)}{\rho + \alpha q(\theta_3^{B1})}. \quad (3.90)$$

Therefore, equations (3.71)-(3.79), combined with the two indifference conditions (3.81) and (3.82), and the value function equations (3.83)-(3.87) with surpluses (3.88)-(3.90) jointly determine the equilibrium stocks of agents, market tightnesses, mixing probabilities  $x^{Bn}$  and  $x^{S2}$ , and active agent value functions in a “Buy first” equilibrium.

We now prove existence of this equilibrium when  $\chi$  and  $u_2$  are small, and  $u_0$  is strictly smaller than  $u_n$ . Note that  $\Sigma^{S2B1} = V - V^{B1} > 0$  for any  $u_2$ , but that  $\lim_{\chi \rightarrow 0} V = \lim_{\chi \rightarrow 0} V^{B1} = \frac{u}{\rho}$ , so that  $\lim_{\chi \rightarrow 0} \Sigma_{B1S2} = 0$ . This in turn implies that  $\lim_{\chi \rightarrow 0} \theta_3^{B1} = \infty$  and  $\lim_{\chi \rightarrow 0} x^{S2} = 1$ . To see this, suppose to the contrary that as  $\chi \rightarrow 0$ ,  $\theta_3^{B1}$  remains bounded and thus  $x^{S2}$  is strictly below one. Therefore,  $\mu(\theta_3^{B1}) \Sigma_{B1S2} \rightarrow 0$ , so indifference

condition (3.82) implies that  $\mu(\theta_2^{B1})\Sigma_{BnS2} \rightarrow 0$ . Given (3.88), this in turn means that  $\theta_2^{B1} \rightarrow 0$  and thus  $x^{Bn} \rightarrow 1$ . However,

$$\lim_{\theta_2^{B1} \rightarrow 0} q(\theta_2^{B1})\Sigma_{BnS2} = \frac{2\rho V - u_n - u_2}{\alpha},$$

which is inconsistent with  $x^{Bn} \rightarrow 1$ . To see this, remember from (3.80) that  $\theta_1^{B1} \rightarrow 1$  as  $x^{Bn} \rightarrow 1$ . Because

$$\lim_{\theta_1^{B1} \rightarrow 1} q(\theta_1^{B1})\Sigma_{BnA} = \frac{\rho V - u_n}{\frac{\rho}{q(1)} + 1} < \rho V - u_n < \frac{2\rho V - u_n - u_2}{\alpha},$$

in this case new entrants would be strictly better off participating in the second market segment. Thus, we arrive at a contradiction.

As  $\theta_3^{B1} \rightarrow \infty$ ,  $q(\theta_3^{B1}) \rightarrow 0$ , and mismatched owners do not buy to become double owners:  $S_2 \rightarrow 0$ . Without trading partners in market 2, all new entrants visit market 1:  $x^{Bn} \rightarrow 1$  and thus  $\theta_1^{B1} \rightarrow \frac{B_n}{A} \rightarrow 1$ . In this case,  $V^{Bn}$  from (3.83) is given by

$$\lim_{\chi \rightarrow 0} \rho V^{Bn} = u_n + \frac{\alpha q(1)}{\rho + q(1)}(u - u_n) - R, \quad (3.91)$$

which is strictly between 0 and  $\rho V$ , as long as  $R$  is not too large. Similarly, using that  $\mu(1) = q(1)$ ,  $V^A$  is given by

$$\lim_{\chi \rightarrow 0} \rho V^A = R + \frac{(1 - \alpha)q(1)}{\rho + q(1)}(u - u_n), \quad (3.92)$$

which is also strictly between 0 and  $\rho V$  if  $R$  is not too large. As a result,

$$\lim_{\chi \rightarrow 0} (V^A + V^{Bn}) = \frac{u_n}{\rho} + \frac{q(1)}{\rho + q(1)} \frac{u - u_n}{\rho},$$

which is strictly between 0 and  $V$ . By continuity, there exists a  $\bar{\chi}_1 > 0$  such that for  $\chi \in (0, \bar{\chi}_1)$ , it is the case that  $\Sigma_{BnA} > 0$ ,  $x^{Bn} \in (0, 1)$  and  $\theta_1^{B1} \in (0, 1)$ , but also  $\Sigma_{B1S2} > 0$ .

With  $V^{Bn}$  as defined in (3.91) above, it follows that  $V^{S2}$  is uniquely determined as

$$\rho V^{S2} = \max_{p, \theta} \{u_2 + R + \mu(\theta)(V + p - V^{S2})\},$$

subject to  $u_n - R + q(\theta)(V - p - V^{Bn}) = \rho V^{Bn}$ . Note that  $V^{S2}$  goes to negative infinity for any  $\chi > 0$  when  $u_2$  does. To see this, suppose to the contrary that  $V^{S2}$  remains bounded when  $u_2$  goes to negative infinity. Then  $\mu(\theta)$  must go to infinity, and hence  $\theta$  must go to infinity. But then  $q(\theta)$  goes to zero, and for the new entrants to get their

outside option,  $p$  must go to  $-\infty$ . In this case  $V^{S2}$  still goes to negative infinity, so that we arrive at a contradiction. Consequently, for any  $\chi > 0$  there exists a  $\bar{u}_2^{B1}$  such that for  $u_2 < \bar{u}_2^{B1}$ ,  $V^{S2}$  is sufficiently low such that both  $\Sigma_{B1A} = V^{S2} - V^A - V^{B1} < 0$  and  $\Sigma_{BnS2} = 2V - V^{Bn} - V^{S2} > \Sigma_{BnA} > 0$ . We can then conclude that there is trade in markets 1, 2, and 3, but that real estate agents and mismatched buyers do not open a fourth market.<sup>48</sup>

Furthermore, it follows that for any  $u_2 < \bar{u}_2^{B1}$  there exists a  $\bar{\chi}_2 > 0$  such that for  $\chi \in (0, \bar{\chi}_2)$ , it is the case that  $\Sigma_{BnS2} > \Sigma_{B1S2}$ . Given this ranking and the fact that  $\Sigma_{BnA} < \Sigma_{BnS2}$ , the ranking of tightnesses across segments then follows from the indifference conditions (3.81) and (3.82). Having established the ranking of tightnesses, the ranking of prices across segments immediately follows from the indifference conditions as well. Specifically, (3.81) implies that

$$q(\theta_1^{B1})(-p_1^{B1} + V - V^{Bn}) = q(\theta_2^{B1})(-p_2^{B1} + V - V^{Bn}),$$

or

$$\frac{q(\theta_1^{B1})}{q(\theta_2^{B1})} = \frac{-p_2^{B1} + V - V^{Bn}}{-p_1^{B1} + V - V^{Bn}}.$$

$\theta_1^{B1} < \theta_2^{B1}$  and  $q(\cdot)$  decreasing imply that  $p_1^{B1} > p_2^{B1}$ . Similarly, (3.82) implies that  $p_2^{B1} > p_3^{B1}$ . Finally, note that  $\Sigma_{BnS2} > \Sigma_{B1S2}$  implies that  $V - V^{Bn} > V^{S2} - V^{B1}$ , so a new entrant is more impatient than a mismatched buyer in the sense that the direct utility gain from transacting is higher for a new entrant compared to a mismatched buyer.<sup>49</sup>

Consider now a mismatched owner that deviates and sells first, and upon trade becomes a forced renter. We allow both a mismatched seller and a forced renter to open new market segments with active agents as counterparties. First, observe that  $V^{Bn} > V^{B0}$  for any  $\chi > 0$ , that is, a new entrant is always better off than a forced renter. This ranking comes from the assumption that  $u_0 < u_n$  and from a revealed preference argument. Specifically, suppose to the contrary that  $V^{B0} > V^{Bn}$ . Suppose also that it is optimal for a forced renter to trade with a real estate firm (the argument for the

<sup>48</sup>For market 2 to be active, it is sufficient for  $u_2$  to be low enough to ensure  $\Sigma_{BnS2} > 0$ , even if  $\Sigma_{BnS2} < \Sigma_{BnA}$ . However,  $u_2 < \bar{u}_2^{B1}$  ensures the ranking of tightnesses and prices proven next.

<sup>49</sup>This also implies that a new entrant has steeper sloped indifference curves in the  $\theta - p$  space, so he is willing to trade-off a higher price for the same decrease in market tightness compared to a mismatched buyer.

case where the forced renter trades with a double owner is analogous). The no-surplus allocation condition again implies that the Hosios condition holds, so

$$\rho V^{B0} = u_0 - R + \alpha q(\tilde{\theta})(V - V^{B0} - V^A),$$

where  $\tilde{\theta}$  is such that a real estate firm is indifferent between trading in this new segment and trading in the segment with a tightness of  $\theta_1^{B1}$  and a price of  $p_1^{B1}$ . In contrast, we have that

$$\rho V^{Bn} = u_n - R + \alpha q(\theta_1^{B1})(V - V^{Bn} - V^A).$$

Since  $u_0 < u_n$  but  $V^{B0} > V^{Bn}$ , we have  $q(\tilde{\theta})(V - V^{B0} - V^A) > q(\theta_1^{B1})(V - V^{Bn} - V^A)$  and so  $\tilde{\theta} < \theta_1^{B1}$ . But then a new entrant is better off deviating and trading in the segment with tightness  $\tilde{\theta}$ , since  $q(\tilde{\theta})(V - V^{Bn} - V^A) > q(\theta_1^{B1})(V - V^{Bn} - V^A)$ . Furthermore, given that  $V^{B0} > V^{Bn}$ ,  $\Sigma_{BnA} > \Sigma_{B0A}$ , so a real estate firm is in fact also strictly better off trading with a new entrant in the segment with tightness  $\tilde{\theta}$ . However, this is not consistent with  $(p_1^{B1}, \theta_1^{B1})$  not violating the no-surplus allocation condition. Therefore, in an equilibrium where  $(p_1^{B1}, \theta_1^{B1})$  are consistent with the no-surplus allocation, we must have  $q(\tilde{\theta}) < q(\theta_1^{B1})$ . However, this means that  $V^{B0} < V^{Bn}$ , and we arrive at a contradiction.

We conclude that  $V^{B0} > V^{Bn}$  and  $\Sigma_{BnA} < \Sigma_{B0A}$ , so that a forced renter is the most impatient of the buyers. The forced renter will therefore trade with a real estate agent, the most patient of the sellers. A new submarket opens up, and real estate firms flow into this submarket up to the point where they are indifferent between selling to the deviator and to a new agent. Now suppose the deviating mismatched owner sells to a new entrant. Then the match surplus reads

$$\Sigma_{BnS1} = V - V^{Bn} + V^{B0} - V^{S1} \leq V - V^{Bn} + V^{B0} - \frac{u - \chi}{\rho}.$$

Given that  $V^{Bn} - V^{B0}$  is bounded away from zero for any  $\chi > 0$ , there exists a  $\bar{\chi}_3 > 0$  such that for  $\chi \in (0, \bar{\chi}_3)$ , it is the case that  $\Sigma_{BnS1} < 0$ . Note, however, that  $\Sigma_{BnS1} > \Sigma_{B1S1}$  for  $\chi < \bar{\chi}_2$ , since, as shown above, in that case  $V - V^{Bn} > V^{S2} - V^{B1}$ , meaning that a new entrant is more impatient than a mismatched buyer. Therefore, for  $\chi < \min\{\bar{\chi}_1, \bar{\chi}_2, \bar{\chi}_3\}$ ,  $\Sigma_{B1S1} < \Sigma_{BnS1} < 0$  and  $\Sigma_{B1S2} > 0$ . In that case a mismatched owner that deviates and sells first is better off not trading. However, not trading is dominated by buying first since  $V^{B1} > \frac{u - \chi}{\rho}$ . Therefore, a mismatched owner is never better off deviating from buying first in a “Buy first” equilibrium.

Constructing a “Sell first” equilibrium follows similar steps. In this equilibrium there are three active market segments characterized by prices  $p_1^{S1} < p_2^{S1} < p_3^{S1}$  and market tightnesses  $\theta_1^{S1} > \theta_2^{S1} > \theta_3^{S1}$ . Real estate agents trade with new entrants in market 1 and with forced renters in market 2, while the latter also trade with mismatched sellers in market 3. Let  $x^A$  denote the probability with which a real estate firm visits segment  $(p_1^{S1}, \theta_1^{S1})$ , and  $x^{B0}$  the probability with which a forced renter visits segment  $(p_2^{S1}, \theta_2^{S1})$ . The stock-flow conditions in this case become

$$B_n = \frac{g}{q(\theta_1^{S1}) + g}, \quad (3.93)$$

$$A = \frac{g}{x^A \mu(\theta_1^{S1}) + (1 - x^A) \mu(\theta_2^{S1}) + g}, \quad (3.94)$$

$$S_1 = \frac{\gamma O}{\mu(\theta_3^{S1}) + g}, \quad (3.95)$$

$$B_0 = \frac{\mu(\theta_3^{S1}) S_1}{x^{B0} q(\theta_2^{S1}) + (1 - x^{B0}) q(\theta_3^{S1}) + g}, \quad (3.96)$$

$$B_n + B_0 + S_1 + O = 1, \quad (3.97)$$

and

$$B_n + B_0 = A. \quad (3.98)$$

The market tightnesses in each active segment satisfy

$$\theta_1^{S1} = \frac{B_n}{x^A A}, \quad (3.99)$$

$$\theta_2^{S1} = \frac{x^{B0} B_0}{(1 - x^A) A}. \quad (3.100)$$

and

$$\theta_3^{S1} = \frac{(1 - x^{B0}) B_0}{S_1}, \quad (3.101)$$

Similarly to before, observe that (3.93), (3.94), (3.98), and (3.101) imply that  $x^A < 1$ , as otherwise, (3.93), (3.94) and (3.101) give

$$\theta_1^{S1} = \frac{B_n}{A} = \frac{\mu(\theta_1^{S1}) + g}{q(\theta_1^{S1}) + g},$$

which has a unique solution at  $\theta_1^{S1} = 1$ . However, this is inconsistent with (3.98). As before, the no-surplus allocation implies that the match surpluses between trading

pairs are split according to the Hosios rule. Consequently, there are two indifference conditions for real estate firms and forced renters given by

$$\mu(\theta_1^{S1}) \Sigma_{BnA} = \mu(\theta_2^{S1}) \Sigma_{B0A}, \quad (3.102)$$

and

$$q(\theta_2^{S1}) \Sigma_{B0A} = q(\theta_3^{S1}) \Sigma_{B0S1}, \quad (3.103)$$

respectively. In addition, the surplus sharing rules imply that the value functions of active agents satisfy the equations

$$\rho V^{Bn} = u_n - R + \alpha q(\theta_1^{S1}) \Sigma_{BnA}, \quad (3.104)$$

$$\rho V^A = R + (1 - \alpha) \mu(\theta_1^{S1}) \Sigma_{BnA}, \quad (3.105)$$

$$\rho V^{S1} = u - \chi + (1 - \alpha) q(\theta_3^{S1}) \Sigma_{B0S1}, \quad (3.106)$$

$$\rho V^{B0} = u_0 - R + \alpha \mu(\theta_3^{S1}) \Sigma_{B0S1}, \quad (3.107)$$

and

$$\rho V = u + \gamma(V^{S1} - V). \quad (3.108)$$

Finally, the above value functions allow us to solve for the surpluses as follows:

$$\Sigma_{BnA} = V - V^{Bn} - V^A = \frac{\rho V - u_n}{\rho + \alpha q(\theta_1^{S1}) + (1 - \alpha) \mu(\theta_1^{S1})}. \quad (3.109)$$

$$\Sigma_{B0S1} = V - V^{S1} = \frac{\rho V - (u - \chi)}{\rho + (1 - \alpha) \mu(\theta_3^{S1})}, \quad (3.110)$$

and

$$\Sigma_{B0A} = \frac{\rho V - u_0}{\rho + \alpha q(\theta_2^{S1}) + (1 - \alpha) \mu(\theta_2^{S1})}. \quad (3.111)$$

The stock-flow and market tightness equations (3.93)-(3.101), combined with the two indifference conditions (3.102) and (3.103), and value functions and surpluses (3.104)-(3.111) fully characterize the equilibrium stocks of agents, market tightnesses, mixing probabilities  $x^A$  and  $x^{B0}$ , and active agent value functions in a ‘‘Sell first’’ equilibrium. We now prove existence of this equilibrium when  $\chi$  and  $u_2$  are small, and  $u_0$  is strictly smaller than  $u_n$ .

Note that  $\Sigma_{B0S1} = V - V^{S1} > 0$  for any  $u_0$ , but that  $\lim_{\chi \rightarrow 0} V = \lim_{\chi \rightarrow 0} V^{S1} = \frac{u}{\rho}$ , so that  $\lim_{\chi \rightarrow 0} \Sigma_{B0S1} = 0$ . Then, a set of arguments similar to the case of the ‘‘Buy first’’

equilibrium shows that  $\lim_{\chi \rightarrow 0} \theta_3^{B1} = 0$  and  $\lim_{\chi \rightarrow 0} x^{B0} = 1$ , so that  $\lim_{\chi \rightarrow 0} \mu(\theta_3^{B1}) = 0$  and  $\lim_{\chi \rightarrow 0} B_0 = 0$ , implying that  $\lim_{\chi \rightarrow 0} x^A = 1$  and  $\lim_{\chi \rightarrow 0} \theta_1^{B1} = 1$ . As a result,  $\lim_{\chi \rightarrow 0} V^{Bn}$  and  $\lim_{\chi \rightarrow 0} V^A$  are the same as in the “Buy first” equilibrium, and there exists a  $\bar{\chi}_4 > 0$  such that for  $\chi \in (0, \bar{\chi}_4)$ , it is the case that  $\Sigma_{BnA} > 0$ ,  $x^A \in (0, 1)$  and  $\theta_1^{S1} > 1$  but remains bounded, while  $\Sigma_{B0S1} > 0$ . As a result, markets 1 and 3 are active.

Following the same arguments as in the “Buy first” equilibrium, it is then the case that  $V^{Bn} > V^{B0}$ , also as  $\chi \rightarrow 0$ , so that  $0 < \Sigma_{BnA} < \Sigma_{B0A}$  and market 2 is active. Furthermore, there must exist a  $\bar{\chi}_5 > 0$  such that for  $\chi \in (0, \bar{\chi}_5)$ , it is the case that  $\Sigma_{B0A} > \Sigma_{B0S1}$ , since  $\lim_{\chi \rightarrow 0} \Sigma_{B0S1} = 0$ . This ranking implies that  $-V^A > V^{B0} - V^{S1}$ , so that a real estate firm is more impatient than a mismatched seller in the sense that the direct utility gain from transacting is higher for a real estate firm compared to a mismatched seller. The ranking of tightnesses and prices across segments then follows from the indifference conditions (3.102) and (3.103), similar to the case of a “Buy first” equilibrium. The fact that  $V^{Bn} - V^{B0}$  is bounded away from zero also implies that there exists a  $\bar{\chi}_6 > 0$  such that for  $\chi \in (0, \bar{\chi}_6)$ , a mismatched owner and a new entrant will not open a fourth market, because  $\lim_{\chi \rightarrow 0} V = \lim_{\chi \rightarrow 0} V^{S1} = \frac{u}{\rho}$  and thus  $\Sigma_{BnS1} = V - V^{S1} + V^{B0} - V^{Bn} < 0$  for a sufficiently small  $\chi$ .

Now consider a mismatched owner that deviates and buys first. Potential sellers are real estate firms and mismatched homeowners, and upon trade the deviator becomes a double owner, who can open up new market segments with new entrants and forced renters. Note that  $V^{S2}$  falls without bounds as  $u_2$  does, because a deviating double owner has to offer new entrants or forced renters their market value, following a similar argument as in the “Buy first” equilibrium. Then there exists a  $\bar{u}_2^{S1}$  such that for all  $u_2 < \bar{u}_2^{S1}$  it is the case that  $\Sigma_{B1A} = V^{S2} - V^A - V^m < 0$ , so that a deviating mismatched owner does not buy from a real estate agent. Note, however, that  $\Sigma_{B1S1} < \Sigma_{B1A} < 0$  for  $\chi < \bar{\chi}_5$  since, as shown above, in that case  $-V^A > V^{B0} - V^{S1}$ , meaning that a new entrant is more impatient than a mismatched buyer. As a result, a mismatched owner that deviates and buys first is better off not trading. However, not trading is dominated by selling first since  $V^{B1} > \frac{u-\chi}{\rho}$ . Therefore, a mismatched owner is never better off deviating from selling first in a “Sell first” equilibrium.

Finally, setting  $\bar{\chi} = \min \{\bar{\chi}_1, \bar{\chi}_2, \bar{\chi}_3, \bar{\chi}_4, \bar{\chi}_5, \bar{\chi}_6\}$  and  $\bar{u}_2 = \min \{\bar{u}_2^{B1}, \bar{u}_2^{S1}\}$ , we arrive at our result.  $\square$



### 3.8.F Additional extensions

#### Simultaneous Entry as Buyer and Seller

We assume that a mismatched owner can allocate a fixed amount of time (normalized to 1 unit) to search in the housing market as a buyer or a seller. A mismatched owner that chooses to enter as a buyer or seller only allocates all of his time to one activity. Otherwise, a mismatched owner that enters as both a buyer and a seller can allocate a fraction  $\phi \in (0, 1)$  of his time to searching as buyer, and searches the remaining  $1 - \phi$  of his time as seller. For a given market tightness  $\theta$ , the value function  $V^{SB}$  for a mismatched owner that enters as both buyer and seller satisfies the following equation in a steady state equilibrium:

$$\rho V^{SB} = u - \chi + (1 - \phi)\mu(\theta) \max\{0, p + V^{B0} - V^{SB}\} + \phi q(\theta) \max\{0, -p + V^{S2} - V^{SB}\}.$$

We then show the following

**Proposition 3.11.** *For  $\theta \in (0, \tilde{\theta})$ ,  $V^{S1} > V^{SB}$ , for any  $\phi \in (0, 1)$ . Also, for  $\theta \in (\tilde{\theta}, \infty)$ ,  $V^{B1} > V^{SB}$ , for any  $\phi \in (0, 1)$ .*

*Proof.* To show the first part, suppose the opposite, so  $V^{S1} \leq V^{SB}$ . Then

$$\begin{aligned} & \mu(\theta) \max\{0, p + V^{B0} - V^{S1}\} \leq \\ & (1 - \phi)\mu(\theta) \max\{0, p + V^{B0} - V^{SB}\} + \phi q(\theta) \max\{0, -p + V^{S2} - V^{SB}\}. \end{aligned}$$

Under the assumption that  $V^{S1} \leq V^{SB}$ , and since we know from Lemma 3.1 that  $V^{B1} < V^{S1}$  for  $\theta \in (0, \tilde{\theta})$ , it must then be the case that

$$\begin{aligned} & \mu(\theta) \max\{0, p + V^{B0} - V^{S1}\} \leq \\ & (1 - \phi)\mu(\theta) \max\{0, p + V^{B0} - V^{S1}\} + \phi q(\theta) \max\{0, -p + V^{S2} - V^{B1}\}, \end{aligned}$$

which does not hold because  $\mu(\theta)(p + V^{B0} - V^{S1}) > 0$  for  $\theta \in (0, \tilde{\theta})$  by Assumption 3.A2, and because  $\mu(\theta)(p + V^{B0} - V^{S1}) > q(\theta)(-p + V^{S2} - V^{B1})$  for  $\theta \in (0, \tilde{\theta})$ , as in Lemma 3.1.

To show the second part, suppose the opposite, so  $V^{B1} \leq V^{SB}$ . Then

$$q(\theta) \max\{0, p + V^{S2} - V^{B1}\} \leq (1 - \phi)\mu(\theta) \max\{0, p + V^{B0} - V^{SB}\} + \phi q(\theta) \max\{0, -p + V^{S2} - V^{SB}\}.$$

Under the assumption that  $V^{B1} \leq V^{SB}$ , and since we know from Lemma 3.1 that  $V^{S1} < V^{B1}$  for  $\theta \in (\tilde{\theta}, \infty)$ , it must then be the case that

$$q(\theta) \max\{0, p + V^{S2} - V^{B1}\} \leq (1 - \phi)\mu(\theta) \max\{0, p + V^{B0} - V^{S1}\} + \phi q(\theta) \max\{0, -p + V^{S2} - V^{B1}\},$$

which does not hold because  $q(\theta)(-p + V^{S2} - V^{B1}) > 0$  for  $\theta \in (\tilde{\theta}, \infty)$  by Assumption 3.A2, and because  $\mu(\theta)(p + V^{B0} - V^{S1}) < q(\theta)(-p + V^{S2} - V^{B1})$  for  $\theta \in (\tilde{\theta}, \infty)$ , as in Lemma 3.1.<sup>50</sup>  $\square$

Finally, note that under payoff symmetry (i.e.  $\tilde{u}_0 = \tilde{u}_2 = c$ ) the possibility to enter as both buyer and seller while allocating each an equal amount of time can result in an equilibrium with a market tightness of  $\theta = 1$ . Specifically, at  $\theta = 1$ ,  $\mu(\theta) = q(\theta) = \mu(1)$ . At these flow rates it can easily be seen that if  $\tilde{u}_0 = \tilde{u}_2 = c$ , then  $V^{B1} = V^{S1} = V^{SB}$  for any  $\phi$ . Finally, a tightness of  $\theta = 1$  can result from mismatched owners entering as buyers and sellers simultaneously and allocating each an equal amount of time (so  $\phi = 0.5$ ).

This is analogous to the equilibrium described in Proposition 3.4, with the only difference that now agents follow symmetric strategies compared to asymmetric strategies with one half of mismatched owners buying first and the other half selling first.

#### Homeowners compensated for their housing unit upon exit

Suppose that upon exit homeowners receive bids for their housing unit(s) from a set of competitive real estate firms. Therefore, given that the value of a housing unit to a real estate firm is  $V^A(\theta)$ , homeowners receive  $V^A(\theta)$  for each housing unit that they own. Again, we consider a steady state equilibrium with a fixed market tightness  $\theta$ . We define  $\tilde{u}_0(\theta, g) \equiv u_0 + \Delta - gV^A(\theta)$  and  $\tilde{u}_2(\theta, g) = u_2 - \Delta + gV^A(\theta)$ . Note that  $V^A(\theta)$  is (weakly) increasing in  $\theta$ , so  $\tilde{u}_2$  is increasing in  $\theta$  and  $\tilde{u}_0$  is decreasing in  $\theta$ ;

<sup>50</sup>Note also that for  $\theta = 0$  and  $\theta \rightarrow \infty$ , mismatched owners are indifferent between remaining mismatched and any search strategy, because  $V^{B1} = V^{S1} = V^{SB} = \frac{u - \chi}{\rho}$ , but that such tightnesses cannot occur in steady state by Lemma 2.

Given this definition, the difference between the values from buying first and selling first (assuming a mismatched owner transacts in both cases),  $D(\theta) \equiv V^{B1} - V^{S1}$ , can be written as

$$D(\theta) = \frac{\mu(\theta)}{(\rho + q(\theta))(\rho + \mu(\theta))} \left[ \left(1 - \frac{1}{\theta}\right) (u - \chi - \tilde{u}_2(\theta, g)) - \tilde{u}_0(\theta, g) + \tilde{u}_2(\theta, g) \right].$$

Let  $\tilde{\theta}$  be defined implicitly by

$$\tilde{\theta} \equiv \frac{u - \chi - \tilde{u}_2(\tilde{\theta}, g)}{u - \chi - \tilde{u}_0(\tilde{\theta}, g)},$$

whenever that equation has a solution.<sup>51</sup> Note that in the limit as  $g \rightarrow 0$ , assumption A1 will hold. Therefore, for  $g$  sufficiently close to zero, we will have that  $u - \chi > \max\{\tilde{u}_0(\theta, g), \tilde{u}_2(\theta, g)\}$ , for all  $\theta \in [\underline{\theta}, \bar{\theta}]$ , and so a version of Lemma 3.1 will hold in this case as well. Given this result one can then easily construct multiple steady state equilibria as in Proposition 3.3.

#### A fixed price as the outcome of take-it-or-leave-it offers under private information

In this section we show that a fixed price equal to the present discounted value of rental income can be microfounded as the outcome of bargaining under private information about types, with full bargaining power for buyers. Suppose therefore in this section that buyers make take-it-or-leave-it offers, but do not know the type of the seller. However, buyers do know the fractions of the types in the economy. Because of heterogeneity among sellers, their reservation prices vary. Matching is still random, so that buyers cannot direct their search to the seller type with the lowest reservation price but meet a particular seller type with a probability equal to their proportion in the population of sellers. The question is then whether buyers, upon meeting a seller, make an offer that only sellers with a low reservation price would accept (and thus trade only if they have met a seller of this type), or make an offer that all sellers would accept (and therefore trade for sure).

<sup>51</sup>Note that the above equation for  $\tilde{\theta}$ , whenever it has a solution, has a unique solution for any  $g \geq 0$ , since given the properties of  $\tilde{u}_0$  and  $\tilde{u}_2$ , it follows that the right hand side of this expression is (weakly) decreasing in  $\theta$ . Furthermore, the right hand side is strictly decreasing in  $g$  for any  $\theta > 0$ , so by the implicit function theorem,  $\tilde{\theta}$  is decreasing in  $g$ .

We consider the symmetric case with  $\tilde{u}_0 = \tilde{u}_2 = c$  (which for  $p = \frac{R}{\rho}$  amounts to  $u_0 = u_2 = c$ ), so that  $\tilde{\theta} = 1$ . In addition, we maintain Assumptions A1 and A2 and assume that  $u_n < u - \chi$ , so that both mismatched owners and new entrants are strictly better off to enter the market. As in the model with symmetric Nash bargaining, we focus on steady state equilibria with value functions, market tightness  $\theta$ , and the stocks of different agent types constant over time. Moreover, although results hold more generally, we again consider a limit economy with small flows where  $g \rightarrow 0$  and  $\gamma \rightarrow 0$  but the ratio  $\frac{\gamma}{g} = \kappa$  is kept constant in the limit. Remember that in this case  $\bar{\theta} \rightarrow 1 + \kappa$  and  $\underline{\theta} \rightarrow \frac{1}{1+\kappa}$ . We will show that under these conditions both in a “Buy first” and in a “Sell first” equilibrium no buyer has an incentive to deviate from targeting both types of sellers by demanding a lower price than the unique prevailing price  $p = \frac{R}{\rho}$ .

Still denoting the value of a matched owner that remains passive upon mismatch by  $\tilde{V}$ , note first that at  $\tilde{\theta} = 1$  Assumption A2 can be simplified to

$$\begin{aligned} \frac{u - \chi}{\rho} &< \frac{u - \chi}{\rho + \mu_0} + \frac{\mu_0}{(\rho + \mu_0)^2} c + \frac{\mu_0^2}{(\rho + \mu_0)^2} \tilde{V}, \\ &\Leftrightarrow \frac{u - \chi}{\rho} < \frac{c}{\rho + \mu_0} + \frac{\mu_0}{\rho + \mu_0} \tilde{V}, \\ &\Leftrightarrow 0 < \rho(c - (u - \chi)) + \mu_0(\rho \tilde{V} - (u - \chi)), \end{aligned}$$

which, for future reference, is not greater than  $\rho(c - (u - \chi)) + \mu_0(\rho V - (u - \chi))$ .

Under the unique price to be proven, the value functions are given by equations (3.5)-(3.8) and (3.26)-(3.28), given  $\theta$  and  $R$ . We first show that in an equilibrium in which mismatched owners “Buy first”, buyers have no incentive to demand a lower price than  $p = \frac{R}{\rho}$ . In such an equilibrium there are two types of sellers: double owners and real estate agents. As before, the lowest price that a real estate agent would be willing to accept is  $p^A = V^A = \frac{R}{\rho}$ . The lowest price that a double owner would be willing to accept is  $p^{S2} = V^{S2} - V$ . Substituting these prices in the value functions, in an equilibrium with price dispersion  $p^{S2} < p^A$ , since

$$\begin{aligned} \rho(V^{S2} - V - V^A) &= u_2 + R + \mu(\theta)(p^{S2} + V - V^{S2}) - \rho V - R - \mu(\theta)(p^A - V^A), \\ &\Leftrightarrow \rho(V^{S2} - V - V^A) = u_2 - \rho V < 0, \end{aligned}$$

$$\Leftrightarrow V^{S2} - V < V^A.$$

For that reason, under full information buyers would like to buy from a double owner, but the question is whether under private information they will make an offer that only double owners would accept. Note that for any  $p \geq p^{S2}$  double owners are willing to sell, while for  $p < p^{S2}$  they are not. As a result, since buying a house is preferred to being passive, among all possible deviations no offer is more profitable than demanding  $V^{S2} - V$ . The proof can therefore be restricted to this deviating offer. Note also that a deviating mismatched seller has zero mass, so that its presence doesn't affect the take-it-or-leave-it offers that buyers make.

First considering new entrants, for them to demand  $p^A$  it must be the case that

$$V - V^{Bn} - p^A \geq \frac{S_2}{S} (V - V^{Bn} - p^{S2}).$$

Substituting prices and using that  $S = S_2 + A$  yields

$$\frac{A}{S} \left( V - V^{Bn} - \frac{R}{\rho} \right) \geq \frac{S_2}{S} \left( V - V^{S2} + \frac{R}{\rho} \right). \quad (3.112)$$

From the value functions we have that

$$\begin{aligned} \rho \left( V - V^{Bn} - \frac{R}{\rho} \right) &= \rho V - u_n + R - q(\theta) \left( V - V^{Bn} - \frac{R}{\rho} \right) - R, \\ \Leftrightarrow (\rho + q(\theta)) \left( V - V^{Bn} - \frac{R}{\rho} \right) &= \rho V - u_n, \end{aligned}$$

and

$$\begin{aligned} \rho \left( V - V^{S2} + \frac{R}{\rho} \right) &= \rho V - u_2 - R - \mu(\theta) \left( V - V^{S2} + \frac{R}{\rho} \right) + R, \\ \Leftrightarrow (\rho + \mu(\theta)) \left( V - V^{S2} + \frac{R}{\rho} \right) &= \rho V - u_2. \end{aligned} \quad (3.113)$$

Moreover, in the limit we consider, we know from the section on Nash bargaining that  $\frac{A}{S} = \frac{1}{\bar{\theta}}$  and  $\frac{S_2}{S} = \frac{\bar{\theta}-1}{\bar{\theta}}$ , so that (3.112) amounts to

$$\frac{1}{\bar{\theta}} (\rho + \mu(\bar{\theta})) (\rho V - u_n) \geq \frac{\bar{\theta}-1}{\bar{\theta}} (\rho + q(\bar{\theta})) (\rho V - u_2).$$

where both sides are positive, but where the right-hand side can be made arbitrarily close to zero by moving closer to  $\bar{\theta} = 1$ . Therefore, it follows that there is a  $\kappa_7 > 0$ , such

that for  $\kappa < \kappa_7$ , new entrants in a “Buy first” equilibrium demand  $p = \frac{R}{\rho}$  upon meeting a seller. Substituting  $u_0$  for  $u_n$ , the same condition holds for a deviating mismatched seller, and then becomes a forced renter. Therefore, there is a  $\kappa_8 > 0$ , such that for  $\kappa < \kappa_8$ , forced renters in a “Buy first” equilibrium make the same offer.

For mismatched owners that buy first to demand  $p^A$  it must be the case that

$$\begin{aligned} V^{S2} - V^{B1} - p^A &\geq \frac{S_2}{S} (V^{S2} - V^{B1} - p^{S2}), \\ \Leftrightarrow \frac{A}{S} \left( V^{S2} - V^{B1} - \frac{R}{\rho} \right) &\geq \frac{S_2}{S} \left( V - V^{S2} + \frac{R}{\rho} \right). \end{aligned} \quad (3.114)$$

Rearranging the value functions yields

$$\begin{aligned} \rho \left( V^{S2} - V^{B1} - \frac{R}{\rho} \right) &= u_2 + R + \mu(\theta) \left( V - V^{S2} + \frac{R}{\rho} \right) - R - (u - \chi) - q(\theta) \left( V^{S2} - V^{B1} - \frac{R}{\rho} \right), \\ \Leftrightarrow (\rho + q(\theta)) \left( V^{S2} - V^{B1} - \frac{R}{\rho} \right) &= u_2 - (u - \chi) + \mu(\theta) \left( V - V^{S2} + \frac{R}{\rho} \right). \end{aligned} \quad (3.115)$$

Substituting the steady state fractions and (3.115) into (3.114), in the limit we consider we have that

$$\begin{aligned} \frac{1}{\bar{\theta}} \left( u_2 - (u - \chi) + \mu(\bar{\theta}) \left( \frac{R}{\rho} + V - V^{S2} \right) \right) &\geq \frac{\bar{\theta} - 1}{\bar{\theta}} (\rho + q(\bar{\theta})) \left( V - V^{S2} + \frac{R}{\rho} \right), \\ u_2 - (u - \chi) &\geq \left[ (\bar{\theta} - 1) (\rho + q(\bar{\theta})) - \mu(\bar{\theta}) \right] \left( V - V^{S2} + \frac{R}{\rho} \right). \end{aligned}$$

Substituting (3.113) yields

$$\begin{aligned} (\rho + \mu(\bar{\theta})) (u_2 - (u - \chi)) &\geq \left[ (\bar{\theta} - 1) (\rho + q(\bar{\theta})) - \mu(\bar{\theta}) \right] (\rho V - u_2), \\ \Leftrightarrow \rho (u_2 - (u - \chi)) + \mu(\bar{\theta}) (\rho V - (u - \chi)) &\geq (\bar{\theta} - 1) (\rho + q(\bar{\theta})) (\rho V - u_2). \end{aligned}$$

The left-hand side is positive for any  $\bar{\theta} \geq 1$  by Assumption 3.A2. Moving  $\bar{\theta}$  towards 1 can make the right-hand side arbitrarily close to zero, so that there exists a  $\kappa_9 > 0$ , such that for  $\kappa < \kappa_9$ , mismatched owners that buy first in a “Buy first” equilibrium demand  $p = \frac{R}{\rho}$  upon meeting a seller. Taking  $\bar{\kappa}' = \min\{\kappa_7, \kappa_8, \kappa_9\}$ , we have that for  $\kappa < \bar{\kappa}'$ , all buyers demand  $p = \frac{R}{\rho}$  upon meeting a seller in a “Buy first” equilibrium with a market tightness given by  $\bar{\theta} = 1 + \kappa$ .

Secondly, we show that in an equilibrium in which mismatched owners sell first, buyers have no incentive to demand a lower price than  $p = \frac{R}{\rho}$ . In such an equilibrium

there are two types of sellers: mismatched owners that sell first, and real estate agents. The lowest price that a real estate agent would be willing to accept is still  $p^A = V^A = \frac{R}{\rho}$ . The lowest price that a mismatched owner would be willing to accept is  $p^{S1} = V^{S1} - V^{B0}$ . It must be the case that  $V^{B0} - V^{S1} + p^A \geq 0$ , because mismatched owners don't remain passive by Assumption 3.A2. It follows that  $p^{S1} \leq p^A$ , so that with full information buyers would like to buy from a mismatched owner. Again the question is whether under private information buyers will make an offer that only mismatched owners would accept. Similar to the "Buy first" equilibrium, the proof can be restricted to the deviation of demanding  $V^{S1} - V^{B0}$ .

First considering forced renters, for them to demand  $p^A$  it must be the case that

$$\begin{aligned} V - V^{B0} - p^A &\geq \frac{S_1}{S} (V - V^{B0} - p^{S1}), \\ \Leftrightarrow \frac{A}{S} \left( V - V^{B0} - \frac{R}{\rho} \right) &\geq \frac{S_1}{S} \left( V^{B0} - V^{S1} + \frac{R}{\rho} \right). \end{aligned} \quad (3.116)$$

Rearranging the value functions yields

$$\begin{aligned} \rho \left( V - V^{B0} - \frac{R}{\rho} \right) &= \rho V - u_0 + R - q(\theta) \left( V - V^{B0} - \frac{R}{\rho} \right) - R, \\ \Leftrightarrow (\rho + q(\theta)) \left( V - V^{B0} - \frac{R}{\rho} \right) &= \rho V - u_0, \end{aligned} \quad (3.117)$$

and

$$\begin{aligned} \rho \left( V^{B0} - V^{S1} + \frac{R}{\rho} \right) &= u_0 - R + q(\theta) \left( -\frac{R}{\rho} + V - V^{B0} \right) - (u - \chi) - \mu(\theta) \left( \frac{R}{\rho} + V^{B0} - V^{S1} \right) + R, \\ \Leftrightarrow (\rho + \mu(\theta)) \left( V^{B0} - V^{S1} + \frac{R}{\rho} \right) &= u_0 - (u - \chi) + q(\theta) \left( V - V^{B0} - \frac{R}{\rho} \right). \end{aligned} \quad (3.118)$$

Substituting (3.118), (3.116) therefore amounts to

$$\begin{aligned} \frac{A}{S} (\rho + \mu(\theta)) \left( V - V^{B0} - \frac{R}{\rho} \right) &\geq \frac{S_1}{S} \left( u_0 - (u - \chi) + q(\theta) \left( V - V^{B0} - \frac{R}{\rho} \right) \right), \\ \Leftrightarrow \left[ \frac{A}{S} (\rho + \mu(\theta)) - \frac{S_1}{S} q(\theta) \right] \left( V - V^{B0} - \frac{R}{\rho} \right) &\geq \frac{S_1}{S} (u_0 - (u - \chi)). \end{aligned}$$

Substituting (3.117) yields

$$\begin{aligned} \left[ \frac{A}{S} (\rho + \mu(\theta)) - \frac{S_1}{S} q(\theta) \right] (\rho V - u_0) &\geq \frac{S_1}{S} (\rho + q(\theta)) (u_0 - (u - \chi)), \\ \Leftrightarrow \frac{A}{S} (\rho + \mu(\theta)) (\rho V - u_0) &\geq \frac{S_1}{S} \rho (u_0 - (u - \chi)) + \frac{S_1}{S} q(\theta) (\rho V - (u - \chi)). \end{aligned}$$

From the section on Nash bargaining we know that  $\frac{A}{S} = \underline{\theta}$  and  $\frac{S_1}{S} = 1 - \underline{\theta}$ . Substituting these steady state fractions, we have that

$$\underline{\theta}(\rho + \mu(\underline{\theta}))(\rho V - u_0) \geq (1 - \underline{\theta})[\rho(u_0 - (u - \chi)) + q(\underline{\theta})(\rho V - (u - \chi)).]$$

Again, by moving towards  $\underline{\theta} = 1$  the right-hand side can be made arbitrarily close to zero while the left-hand side remains positive. Therefore, there exists a  $\kappa_{10} > 0$ , such that for  $\kappa < \kappa_{10}$ , forced renters in a “Sell first” equilibrium demand  $p = \frac{R}{\rho}$  upon meeting a seller. Substituting  $u_n$  for  $u_0$  the same condition holds for a new entrant, so that there is a  $\kappa_{11} > 0$ , such that for  $\kappa < \kappa_{11}$ , new entrants make the same offer.

Finally, for a deviating mismatched buyer to demand  $p^A$  it must be the case that

$$\begin{aligned} V^{S2} - V^{B1} - p^A &\geq \frac{S_1}{S}(V^{S2} - V^{B1} - p^{S1}), \\ \Leftrightarrow \frac{A}{S}\left(V^{S2} - V^{B1} - \frac{R}{\rho}\right) &\geq \frac{S_1}{S}\left(V^{B0} - V^{S1} + \frac{R}{\rho}\right). \end{aligned} \quad (3.119)$$

Rearranging the value functions yields

$$\begin{aligned} \rho\left(V^{S2} - V^{B1} - \frac{R}{\rho}\right) &= u_2 + R + \mu(\theta)\left(\frac{R}{\rho} + V - V^{S2}\right) - u - \chi + q(\theta)\left(-\frac{R}{\rho} + V^{S2} - V^{B1}\right) - R, \\ \Leftrightarrow (\rho + q(\theta) + \mu(\theta))\left(V^{S2} - V^{B1} - \frac{R}{\rho}\right) &= u_2 - (u - \chi) + \mu(\theta)(V - V^{B1}), \end{aligned}$$

with

$$\mu(\theta)(V - V^{B1}) = \mu(\theta)\left(V - \frac{u - \chi}{\rho}\right) - \mu(\theta)q(\theta)\left(V^{S2} - V^{B1} - \frac{R}{\rho}\right).$$

From (3.118) we know that

$$\begin{aligned} (\rho + \mu(\theta))\left(V^{B0} - V^{S1} + \frac{R}{\rho}\right) &= u_0 - (u - \chi) + q(\theta)\left(V - V^{B0} - \frac{R}{\rho} + V^{S1} - V^{S1}\right), \\ \Leftrightarrow (\rho + q(\theta) + \mu(\theta))\left(V^{B0} - V^{S1} + \frac{R}{\rho}\right) &= u_0 - (u - \chi) + q(\theta)(V - V^{S1}), \end{aligned}$$

with

$$q(\theta)(V - V^{S1}) = q(\theta)\left(V - \frac{u - \chi}{\rho}\right) - \mu(\theta)q(\theta)\left(V^{B0} - V^{S1} + \frac{R}{\rho}\right).$$

Therefore, (3.119) simply amounts to

$$\frac{A}{S}\left(u_2 - (u - \chi) + \mu(\theta)\left(V - \frac{u - \chi}{\rho}\right)\right) \geq \frac{S_1}{S}\left(u_0 - (u - \chi) + q(\theta)\left(V - \frac{u - \chi}{\rho}\right)\right).$$

Substituting the steady state fractions, we have that

$$\underline{\theta}\left(u_2 - (u - \chi) + \mu(\underline{\theta})\left(V - \frac{u - \chi}{\rho}\right)\right) \geq (1 - \underline{\theta})\left(u_0 - (u - \chi) + q(\underline{\theta})\left(V - \frac{u - \chi}{\rho}\right)\right).$$

The left-hand side is positive for any  $0 < \underline{\theta} \leq 1$  by Assumption 3.A2. Moving  $\bar{\theta}$  towards 1 can make the right-hand side arbitrarily close to zero, so that there exists a  $\kappa_{12} > 0$ , such



that for  $\kappa < \kappa_{12}$ , deviating mismatched owners that buy first in a “Sell first” equilibrium demand  $p = \frac{R}{\rho}$  upon meeting a seller. Taking  $\underline{\kappa}' = \min\{\kappa_{10}, \kappa_{11}, \kappa_{12}\}$ , we have that for  $\kappa < \underline{\kappa}'$ , all buyers demand  $p = \frac{R}{\rho}$  upon meeting a seller in a “Sell first” equilibrium with a market tightness given by  $\underline{\theta} = \frac{1}{1+\kappa}$ . Finally, taking  $\kappa' = \min\{\bar{\kappa}', \underline{\kappa}'\}$ , we have that both in a “Buy first” and in a “Sell first” equilibrium, the take-it-or-leave-it offer that buyers make is equal to  $p = \frac{R}{\rho}$ .

### 3.8.G Institutional details

The information in Tables 9 and 10 is based on:

- <http://boligejer.dk/koebaftale/> for Denmark.
- <http://www.eiendomsrettsadvokaten.no/advokathjelp> for Norway.
- <http://www.eigenhuis.nl/juridisch/> for the Netherlands.
- <http://www.realtor.com> and <https://www.doorsteps.com/> for the U.S.
- <http://hoa.org.uk/advice/guides-for-homeowners> for England and Wales.

Table 9: Institutional details for buyers

Country	Grace period	Penalty for renegeing during grace period	Penalty for renegeing after grace period	Possible conditions to dissolve contract (requires proof)	Period to refer to dissolving conditions
Denmark	6 days	1% of price	Liabile for full amount	May include as conditions: <ul style="list-style-type: none"> <li>• Ability to secure financing</li> <li>• Lawyer reservation</li> </ul>	As specified in the purchase offer
Norway	None	N/A	Liabile for full amount	May include as condition: <ul style="list-style-type: none"> <li>• Ability to secure financing</li> </ul>	As specified in the purchase offer
Netherlands	3 days	None	Standard contract: <ul style="list-style-type: none"> <li>• End contract: &gt;10% price</li> <li>• Demand fulfillment: &gt;0.3% sale price per day</li> <li>• Court</li> </ul>	Standard contract: <ul style="list-style-type: none"> <li>• Ability to secure financing</li> <li>• Applicability for national mortgage insurance</li> <li>• Structural inspection</li> </ul>	As specified in the contract: usually not for more than a few weeks after signing it
United States	None (3 days in NJ only)	N/A	Losing the Earnest Money Deposit, ranging from \$500 to 10% of the price	Standard purchase offer: <ul style="list-style-type: none"> <li>• Ability to secure financing</li> <li>• Appraisal</li> <li>• Structural inspection</li> </ul>	Usually not for more than a few weeks after signing the offer, e.g. 17 days in CA
England & Wales	Pull out until exchange of (unconditional) contracts	Occasionally one loses holding deposit, ranging from £500 to £1000	10% price	None	N/A

Table 10: Institutional details for sellers

Country	Grace period	Penalty for renegeing during grace period	Penalty for renegeing after grace period	Possible conditions to dissolve contract
Denmark	None	N/A	Court	None
Norway	None	N/A	Court	None
			Standard contract:	
Netherlands	None	N/A	<ul style="list-style-type: none"> <li>• End contract: &gt;10% price</li> <li>• Demand fulfillment: &gt;0.3% sale price per day</li> <li>• Court</li> </ul>	None
United States	None (3 days in NJ only)	N/A	Court	None
England & Wales	Pull out until exchange of contracts	None	Court	None