Search and Credit Frictions in the Housing Market*

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August 6, 2020

Abstract

This paper develops a model of the housing market with search and credit frictions. The interaction between the two sources of friction gives rise to a novel channel through which the financial sector affects prices and liquidity in the housing market and leads to multiple equilibria. In a numerical exercise, we gauge the relative contribution of credit market shocks to the observed patterns in housing prices, time-to-sell, and mortgage debt-to-price ratio in the U.S. data prior to the 2007 housing market crash. Our results suggest that shocks associated with the credit frictions channel had a relatively larger impact on the observed build-up in mortgage debt and lack of change in time-to-sell than on the increase in prices.

JEL Classification: E2, E32, R21, R31.

Keywords: Housing market; Credit Frictions; Search and Matching; Multiple Equilibria; Mortgages.

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*We are grateful to the Editor Peter Rupert, an anonymous Associate Editor, two anonymous referees, Richard Arnott, Pablo Fajgelbaum, Thanasis Geromichalos, Jang-Ting Guo, Berthold Herrendorf, Ayse Imrohoroglu, Timothy Kam, Ioannis Kospentaris, Jeffrey Lacker, Kevin Lansing, Junsang Lee, Iourii Manovskii, Vincenzo Quadrini, Romain Rancière, Guillaume Rocheteau, Henry Siu, Alwyn Young and Anthony L. Zhang for their insightful comments and suggestions. We also thank seminar participants at UH Manoa, UC Irvine, UC Riverside, Virginia Commonwealth University, the 14th Urban Economics Association (Federal Reserve Bank of Philadelphia) and the Fall 2019 Midwest Macro Meetings (Michigan State University) for helpful discussions. Part of this research was conducted while the second author was visiting the University of Southern California, Marshall School of Business, whose hospitality is greatly appreciated.

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1. Introduction

A predominant feature of the housing market is that it is subject to search frictions. Empirically, it takes time both to sell a house and find a suitable home. The large fluctuations in the time-to-sell and time-to-buy over the business cycle provide further evidence that search frictions are prevalent in the housing market. Another salient feature of the housing market is the presence of credit frictions. The vast majority of households are liquidity constrained and need to finance their home purchase.[1] Further, finding a mortgage lender is a costly and time consuming process. With these characteristics of the housing market in mind, this paper tries to understand the main channels through which financial markets affect the equilibrium in the housing market, with a particular focus on prices, liquidity and mortgage debt.

To this end, we develop a tractable dynamic model of the housing market with search and credit frictions. Search and matching frictions in the housing market capture the fact that it takes time for buyers to find a suitable home and for sellers to sell a house. In addition, buyers are liquidity constrained in our framework. They must be pre-approved for a mortgage by a financier before they can purchase a house. Given that this process is costly and time consuming, the credit market is also subject to search and matching frictions, a friction that we capture in the spirit of Wasmer and Weil (2004) and Petrosky-Nadeau and Wasmer (2017).[2] If households choose to participate in the housing market and search for a home, their first step is to search for a financier. Matching between households and financiers is costly and time consuming for both the buyer and the financier. Upon forming a match, they negotiate a mortgage contract and the household begins searching for a suitable home. During this search process, the financier continues to incur search and screening costs related to marketing and servicing mortgage applicants. These costs may also include costs associated with holding relatively liquid assets, so that the financier can deliver the funds once the buyer finds a home, similar to the overhead costs of loan commitments due to liquid-asset holding in Kashyap, Rajan and Stein (2002).[3] When the buyer finds a home, she pays the downpayment and begins

[1]The National Association of Realtors reports that, during 2016, 88% of all buyers financed their homes. In addition, according to the 2001 US Census, nearly all home-occupied houses without a mortgage are the results of homeowners paying off a mortgage loan, see Alexandrov and Koulayev (2018).

[2]There is a large amount of empirical evidence of homebuyers' search in mortgage markets, see Alexandrov and Koulayev (2018), Allen, Clark and Houde (2014a), (2014b) and (2019), Bhutta, Fuster and Hizmo (2019), Lee and Hogarth (2000), Woodward and Hall (2012) and the references therein.

[3]However, it is worth stressing that our results do not rely on these liquidity costs, i.e. with screening and

repaying the mortgage, whereas the financier finances the rest of the purchase. The other key features that determine housing market dynamics in our environment include free entry of buyers, sellers and financiers, and that both house prices and mortgage contracts are the result of bargaining—see Allen *et al.* (2014a), (2014b), (2019) and the references therein for evidence of bargaining in mortgage markets. Entry of buyers and sellers allows the model to account for the observed housing market dynamics, especially the observed correlation between buyers and vacancies in the housing market, see Gabrovski and Ortego-Marti (2019).

Understanding house prices and liquidity in the housing market is important, given that most households in the US hold most of their wealth in the form of housing equity. The frictions in our environment give rise to a novel channel through which the financial market affects prices and liquidity in the housing market. Because of bargaining, mortgage payments depend on housing market conditions, in particular house prices and liquidity in the housing market. In turn, when buyers meet a seller and bargain over the house price, the mortgage contract affects buyers' bargaining position and, therefore, house prices. Given that there is free entry of buyers and sellers, the equilibrium price determines market tightness and liquidity in the housing market, where housing market tightness is defined as the ratio of buyers to vacancies—a higher market tightness lowers time-to-sell, i.e. corresponds to a more liquid market. Likewise, due to free entry of financiers, outcomes in the housing market affect the equilibrium in the financial market, in particular debt and interest payments.

We show that including credit frictions in an otherwise stylized search model of the housing market leads to multiple equilibria. Intuitively, the equilibrium house price and the housing market tightness are determined by free entry into housing and Nash Bargaining over the joint surplus of the seller and the buyer. Multiple equilibria arise because both these conditions define a negative relationship between prices and housing market tightness. The reason free entry leads to a negative relationship is standard in search models of housing, and akin to the job cre-

processing costs the results are very similar. Section 2.1 discusses this assumption in more detail. Loutskina and Strahan (2009) find strong empirical evidence that liquidity matters for banks' ability to supply loans, and that banks with more liquid assets originate more mortgages, even after controlling for a large set of bank characteristics—see also Boeckx, de Sola Perea and Peersman (2020), Kashyap *et al.* (2002) and Gambacorta (2008) for similar findings that balance sheet liquidity affects banks' ability to supply loans. Broadly speaking, banks (financiers) take funds from depositors to provide loans to borrowers or to invest, i.e. they fund illiquid loans with liquid deposits. If the financier wants to allocate funds towards a mortgage loan, this lowers its ability to undertake investments and foregoes some returns. These costs arise even if banks have access to external short term funding, as long as banks' external funding is costly, see Kashyap *et al.* (2002). See also Donaldson, Piacentino and Lee (2018) for an alternative micro-foundation that leads to these liquidity/opportunity costs.

ation condition in the Diamond-Mortensen-Pissarides model of labor search, Pissarides (2000). Vacancies enter the market until the house price covers expected costs. Higher prices drive more entry of vacancies, thus lowering market tightness. However, unlike most search models, bargaining in our framework leads to a negative relationship between prices and market tightness because a higher market tightness is associated with a longer time-to-buy and, therefore, higher mortgage payments. To see this, consider first the relationship between mortgage payments and market tightness. The match between a household and a financier generates a positive surplus, some of which is extracted by the financier through mortgage repayments. Upon pre-approval, households embark on a costly search for a suitable house. Given that the financier incurs costs while the household is searching for a suitable home, and that the buyer does not begin repaying the mortgage until after she has purchased a house, a lower home-finding rate increases the expected costs for the financier and reduces the present value of future repayments. Therefore, the financier negotiates higher mortgage repayments if buyers take longer to find a house—i.e. housing market tightness is high. Turning to bargaining in the housing market, a higher market tightness raises mortgage payments and, therefore, reduces the joint surplus of the buyer and the seller (it reduces the buyer's continuation value). Given the smaller surplus, the buyer and seller negotiate a lower price. As a result, bargaining between the seller and the buyer defines a downward sloping relationship between price and tightness due to the mortgage contract. In sum, bargaining and free entry imply two downward sloping relationships between the price and the housing creation curves, and will in general feature two equilibrium points, except for a knife-edge case that yields a unique equilibrium. One equilibrium is characterized by a high price, a high home-finding rate and low interest payments, while the other equilibrium features a low price, a low home-finding rate, and high interest payments.

In our model, credit frictions determine the financing fee. Higher expected search costs for the financier lead to a higher equilibrium fee and, as a result, higher mortgage payments. This reduces the gains from trade in the housing market and subsequently house prices and time-to-sell. This mechanism represents a novel channel through which the financial sector can impact prices and liquidity in the housing market. In a numerical exercise, we study the relative contribution of the credit frictions channel to the build-up in housing prices and mortgage debt prior to the 2007 market crash. To this end, we decompose the empirically observed changes in housing market and financial variables during that period into five fundamental sources.[4] Two of these sources are shocks to housing market variables: (i) the utility of home-ownership (a demand shock); (ii) the cost of housing construction (a supply shock). The other sources are shocks to parameters that affect credit frictions: (i) credit market search efficiency and (ii) financiers' bargaining strength. In an extension, we also consider an additional shock to (iii) liquidity costs for financiers to capture the declining liquidity constraints on lenders during the period. We then conduct a series of counter-factual exercises where we shut down credit market shocks and compare the model-implied changes in prices, time-to-sell, and mortgage debt-to-price ratio to the observed changes in the data. Our counter-factual analysis shows that mortgage debt and time-to-sell are more responsive than prices to shocks associated with this channel. Quantitatively, credit frictions did not play a substantial role in the increase of housing prices. However, they were important to keep the housing market liquid—time-to-sell in the data decreased by around 10%, whereas absent any credit shocks it would have increased by around 84%. In addition, credit shocks had a large contribution to the observed increase in the mortgage debt-to-price ratio. In the data the ratio increased by 9.28%, whereas absent any credit shocks it would have decreased by 1.86%. These results are consistent with Gelain, Lansing and Natvik (2018), who also find that credit shocks did not impact housing prices as much, even though their paper features no search and a completely different source of credit frictions.

Related literature. Following the seminal work in Arnott (1989) and Wheaton (1990), a large number of papers have used search models à la Diamond-Mortensen-Pissarides to study the housing market. One strand of the literature models the housing market using a matching function as in Pissarides (2000).[5] Papers in this strand include Arefeva (2020), Burnside, Eichenbaum and Rebelo (2016), Diaz and Jerez (2013), Gabrovski and Ortego-Marti (2019), (2020a) and (2020b), Garriga and Hedlund (2020), Genesove and Han (2012), Guren (2018), Head, Lloyd-Ellis and Sun (2014) and (2016), Kotova and Zhang (2020), Novy-Marx (2009),

[4]Our analysis is similar in spirit to Gelain, Lansing and Natvik (2018) and Lansing (2019), who also decompose empirically observed changes in the data into five fundamental shocks and then examine the model-implied impact of these shocks in a series of counter-factual exercises.

[5]Our paper is, to a lesser extent, related to a big literature on housing and macroeconomics without search and matching frictions. Papers in this literature include Davis and Heathcote (2005) Gelain, Lansing and Natvik (2018) and Kydland, Rupert and Sustek (2016), among others. For a recent survey, see Piazzesi and Schneider (2016).

Piazzesi and Schneider (2009), Piazzesi, Schneider and Stroebel (2020) and Smith (2020). Another strand features changes in the reservation value of houses, rather than changes in the market tightness, to generate changes in the time-to-sell. Krainer (2001), Ngai and Tenreyro (2014), and Ngai and Sheedy (in press) provide examples of such papers. Additionally, a number of papers employ a search framework to study the housing market in the context of financially constraint households. For example, Guren and McQuade (2018) and Hedlund (2016) study the linkages between housing prices, sales, and foreclosures, whereas Head *et al.* (2016) study the link between the size of the seller's outstanding mortgage, housing prices and time-to-sell on the other.

Our work complements these previous studies by focusing on an environment in which there are search frictions in both the housing and credit markets. We show that the interaction between the two sources of friction leads to multiple equilibria, each with qualitatively different comparative statics. This is in contrast to the previous literature on search frictions in the housing market, which has not examined these frictions associated with obtaining a mortgage. Furthermore, our framework allows us to study the quantitative importance of credit frictions in determining housing prices, time-to-sell and mortgage debt. With the exception of Garriga and Hedlund (2020), none of the above papers study the effect of credit frictions on both housing liquidity (as captured by time-to-sell) and house prices. Credit frictions in our paper are different than in Garriga and Hedlund (2020), so our work is complementary to theirs. Credit frictions in Garriga and Hedlund (2020) take the form of borrowing limits determined by competitive banks in the presence of default risk. By contrast, in our paper credit frictions take the form of search frictions. It takes time for banks and buyers to form a match, and there is entry of both financiers and buyers. In addition, our framework focuses on delivering an upward sloping Beveridge Curve, consistent with the facts in the housing market, Gabrovski and Ortego-Marti (2019). One can view the difference in credit frictions as similar to the differences in credit frictions between Wasmer and Weil (2004) and models in the spirit of Kiyotaki and Moore (1997).

Our paper proceeds by introducing the environment. Next, we characterize the steady state equilibria, expand on the intuition behind the multiplicity in our model, and discuss existence and properties of the equilibria. Lastly, using a numerical exercise, we study the relative contribution of the credit frictions channel to the build-up in housing prices and mortgage debt prior to the 2007 market crash.

2. The Economy

This section describes the environment. As an overview, the main ingredients of the model are the following: (1) there are search and matching frictions in both the credit and housing markets, (2) there is free entry of buyers, sellers and financiers, and (3) house prices and mortgage repayments are determined by bargaining. Combined, these assumptions provide a tractable environment through which we can analyze how financial markets affect the equilibrium in the housing market. This framework further allows us to understand the interaction and the relative importance of housing and credit shocks for the behavior of house prices, time-to-sell and mortgage-debt.

Time is continuous. Agents are infinitely lived, risk-neutral, and discount the future at a rate r. The economy consists of households, a real estate sector, and financiers. Households are either homeowners, buyers, mortgage applicants, or they can choose not to participate in the market. They are liquidity constrained, so if they wish to purchase a home they must first be pre-approved for a mortgage by a financier. We assume that households must first search for a mortgage before searching for a house, as it seems a more realistic representation of the housing market, especially given the prevalence of lock-in rates. However, this timing is not crucial for our results. We show in the appendix that the results barely change if one assumes search in the housing market first, or if one assumes simultaneous search. There is free entry into the credit market on both sides of the market, but participation is costly and time consuming, i.e. there are search costs. Upon meeting a financier, households bargain over the mortgage repayments according to Nash Bargaining. Once households are matched with a financier they become "pre-approved" for a mortgage and can begin searching for houses, i.e. they become buyers.

The housing market is also subject to search and matching frictions. The agents in the market searching for each other are pre-approved buyers and sellers. Buyers search for houses using a realtor, who charges a fee for her services. However, this assumption is not crucial. Allowing buyers to conduct the search themselves yields the same outcome. Sellers consist either of homeowners who were separated from their house at an exogenous rate, or new construction. The measure of sellers is determined by free entry. Having entry of both buyers (through the pre-approval process above) and sellers is essential to account for housing market dynamics, in particular the observed positive correlation between buyers and vacancies, see Gabrovski and Ortego-Marti (2019). When a buyer and a seller meet, they bargain over the price, taking the mortgage agreement between the buyer and the financier as given.

2.1. The credit market

The process of obtaining a pre-approval for a mortgage is costly and time consuming. We capture this search process by assuming that there are search and matching frictions in the credit market. There is abundant empirical evidence of consumer search in the mortgage market. For example, in 2016 the National Survey of Mortgage Origination (NSMO), developed by the US Consumer Financial Protection Bureau and the Federal Housing Finance Agency (FHFA), reported that 51% of borrowers contacted more than one lender, see Alexandrov and Koulayev (2018) and Bhutta, Fuster and Hizmo (2019).[6] Among those who contacted more than one lender, 81.4% listed searching for better terms as their main reason. Only 4.6% contacted more than one lender because their application was turned down. The NSMO also includes other measures that suggest active consumer search. Around 41.9% of borrowers gathered information from brokers and lenders, 54.3% from websites and 47.1% from friends, relatives or coworkers.[7] Allen, Clark and Houde (2014a), (2014b) and (2019) also find evidence of significant consumer search in the Canadian mortgage market. Data from the Canadian Association of Accredited Mortgage Professionals shows that 52% of borrowers visit more than one lender. The Canada Mortgages and Housing Corporation reports that 60% of consumers search for additional quotes. In addition, the authors find that mortgage brokers contact on average 5.9 lenders on their clients' behalf. Further evidence of search in mortgage markets is found in different data sources from online comparison websites—LendingTree reports that only 39% of new home buyers get only one quote, see Allen *et al.* (2014a)—and from Equifax credit enquiry

[6]It is worth noting that even when buyers get only one quote, this does not mean that there is no search. This is consistent with receiving a rate above their reservation value. In fact, when borrowers were asked in the NSMO why they did not shop more, the main reason reported is that they are satisfied with the current offer—96% believed they received the lowest offer.

[7]In the US, the Fannie Mae Housing Survey and the Survey of Consumer Finances provide very similar evidence. Lee and Hogarth (2000) reports information from the University of Michigan Survey of Consumers on the number of lenders contacted, source of information, terms compared and extent of search. The authors find an extensive amount of search by borrowers—for example, 23% of borrowers contacted only one lender, with a mean and median of 4 and 3 lenders.

data, see Ambokar and Samaee (2020).[8]

To capture the above features of the mortgage market, we model credit frictions in the spirit of Petrosky-Nadeau and Wasmer (2017) and Wasmer and Weil (2004). There is free entry of both households looking for a mortgage (applicants) and financiers. Each financier finances a single home purchase. Matches between applicants $\mathfrak{a}$ and financiers $\mathfrak{f}$ are formed at a rate $\mathcal{F}(\mathfrak{a}, \mathfrak{f})$. We assume that $\mathcal{F}(\cdot, \cdot)$ is concave, increasing in both arguments, and exhibits constant returns to scale. Applicants meet a financier at a rate $f(\phi) \equiv \mathcal{F}(\mathfrak{a}, \mathfrak{f})/\mathfrak{a} = \mathcal{F}(1, \phi^{-1})$ and financiers meet applicants at a rate $\phi f(\phi) = \mathcal{F}(\mathfrak{a}, \mathfrak{f})/\mathfrak{f} = \mathcal{F}(\phi, 1)$, where $\phi \equiv \mathfrak{a}/\mathfrak{f}$ is the market tightness in the credit market. For simplicity, the matching technology is assumed Cobb-Douglas, so that $f(\phi) = \mu_f \phi^{-\alpha_f}$. Once an applicant and a financier match, they bargain over the mortgage contract. If an agreement is reached, the financier commits to pay a portion $p(1 - d)$, where p is the price of the house and d is the downpayment made by the buyer. In exchange, the buyer promises to make repayments ρ after she finds a house. The applicant then becomes pre-approved for a mortgage and can begin searching for a home.

The search process is costly for both parties. The applicant and financier suffer flow search costs c_0 and c^F respectively. The cost to applicants c_0 captures the cost associated with gathering and comparing quotes, and other costs due to submitting information and preparing forms. The financier incurs costs c^F associated with marketing, screening and servicing mortgage applicants. These cost may also include liquidity costs associated with holding relatively liquid assets. Intuitively, there are some opportunity costs when banks supply mortgages (or loans in general) associated with keeping funds relatively liquid, as the financier may forego some investment opportunities. In Kashyap, Rajan and Stein (2002), banks incur a similar cost be-

[8] More generally, the above papers are part of a larger IO literature that studies price dispersion in product markets using consumer search models in the spirit of Stigler (1961). They find large price dispersion in mortgage rates, even after controlling for lender, borrower and loan characteristics, and among loans with homogenous terms and loans that are considered fully insured by a government insurance program—in some studies the authors can control for day of the contract, branch and even officer fixed effects. Although online platforms have certainly reduced search costs for applicants, a common misperception is that they have made mortgage search unnecessary and non-existent. If anything, according to the NSMO data, borrowers who search online contact more lenders on average. There are many explanations for why borrowers search even in the presence of online comparison websites. Most major lenders do not participate in mortgages comparison websites, Bhutta *et al.* (2019). Even when borrowers receive an offer from a comparison website, they still need to send forms or make a phone call to provide sensitive information to the lender in order to get a final quote—the lender is not even obligated to lend until the information is provided. Finally, online platforms report posted prices, but there is large evidence of negotiation and bargaining. Because banks can (and do) negotiate rates, borrowers have strong incentives to search for lower rates.

cause their loan commitments require some liquid-asset holdings.[9] There is empirical evidence that liquidity matters for banks' ability to supply mortgages (and more broadly loans), and that banks with more liquid assets originate more mortgages, even after controlling for a large set of bank characteristics—see Boeckx *et al.* (2020), Kashyap *et al.* (2002), Loutskina and Strahan (2009) and Gambacorta (2008). In the quantitative exercise we first interpret c^F as costs of screening, servicing and marketing alone. We then add the interpretation that they also include liquidity costs to capture the declining liquidity constraints that banks faced during the period 1999-2006. The quantitative results are very similar in both exercises, so it is worth stressing that the results in the paper do not rely on the interpretation of c^F as liquidity costs. Intuitively, the reason is that these costs are quantitatively small compared to the surplus, similar to why vacancy costs in DMP models of the labor market do not significantly affect the quantitative response of the model to shocks.[10]

Let B_0 and F_0 denote the value functions of being an applicant and a financier *without* a pre-approved buyer, and let B_1 and F_1 denote be the value functions of a pre-approved buyer and a financier *with* a pre-approved buyer. The Bellman equations for applicants and financiers are given by

$$rB_0 = -c_0 + f(\phi)(B_1 - B_0), \tag{1}$$

$$rF_0 = -c^F + \phi f(\phi)(F_1 - F_0). \tag{2}$$

At a rate $f(\phi)$ the applicant meets a financier. She then negotiates a mortgage contract and enters the housing market, which implies a net gain of $B_1 - B_0$. Similarly, at a rate $\phi f(\phi)$ the financier finds an applicant, which implies a net gain of $F_1 - F_0$.

[9]Kashyap *et al.* (2002) show that even when banks have access to external short term funding, such as inter-bank lending, these overhead costs arise as long as banks' external funding is costly. As Kashyap *et al.* (2002) mention, page 35: " *"[A]n institution that offers liquidity on demand must invest in certain costly "overhead" in order to carry out its job effectively. In particular, the overhead in our model consists of the large volume of cash and securities that a bank holds as a buffer stock on the asset side of its balance sheet. Such a buffer stock is required to the extent that capital markets are imperfect, so that a bank cannot accommodate liquidity shocks simply by raising new external finance on a moment's notice. Moreover, this form of overhead is burdensome for a number of reasons. First, on the cash component, there is obviously the foregone interest."* Donaldson, Piacentino and Lee (2018) provide an alternative micro-foundation for these opportunity costs. These costs arise when banks cannot transform other loans and investments frictionlessly into cash to fund a loan (such as a mortgage), and investments arrive with a lower probability when banks commit to making a loan, such as mortgages.

[10]We thank an anonymous referee for helpful comments on both search in the mortgage market and on the liquidity costs for financiers.

2.2. The housing market

Buyers must secure the services of a realtor who searches for a suitable home on their behalf. Finding a home for the buyer is a costly action, for which the realtor charges a fee. On the seller side of the housing market, house vacancies come from two sources. First, homeowners are hit with a separation shock at an exogenous rate s, at which point they are mismatched with their house.[11] Upon separation, households post their existing home for sale in the housing market and search for buyers. In addition, developers can build new homes at a fixed cost k. As homeowners, developers must post a vacancy on the market in order to sell a newly built house. Houses are identical, so there is no distinction between new and existing homes.

We model search frictions in the housing market using the matching function approach in Pissarides (2000). This allows us to capture two key features observed in the data: the simultaneous existence of both buyers looking for homes and vacant houses, and the fact that it takes time for a buyer to find a suitable home and for a seller to find a buyer. Matches form at a rate $M(b, v)$, where b is the measure of buyers and v the measure of vacancies. We impose the standard properties on the matching function—it is concave, increasing in both its arguments, and exhibits constant returns to scale. Thus, the home-finding rate for buyers is given by $m(\theta) \equiv M(b, v)/b = M(1, \theta^{-1})$, and the vacancy-filling rate is $\theta m(\theta) = M(b, v)/v = M(\theta, 1)$, where $\theta \equiv b/v$ is the housing market tightness. For ease of exposition, the matching function takes the usual Cobb-Doublas form, i.e. $m(\theta) = \mu\theta^{-\alpha}$.

We assume free entry of vacancies. Given that houses are identical, free entry drives the value of existing home vacancies to k in equilibrium. When a buyer and a seller form a match, the buyer pays the price p to the seller and becomes a homeowner.[12] As Gabrovski and Ortego-Marti (2019) show, entry on both sides of the housing market is necessary to match the cyclical behavior of prices, sales, vacancies and time-to-sell. To capture depreciation, all houses (including vacancies) are destroyed at a rate δ.

Following Gabrovski and Ortego-Marti (2019), a buyer must hire the services of a realtor

[11]For example, they may need to move due to a new job or may need a larger home. For search models of the housing market with an endogenous separation or moving rate, see Gabrovski and Ortego-Marti (2020b) and Ngai and Sheedy (in press).

[12]We follow Diaz and Jerez (2013) and Ngai and Tenreyro (2014), among many others, and do not model the rental market. The treatment of the housing and rental markets as separate is supported by the empirical findings in Glaeser and Gyourko (2007) and Bachmann and Cooper (2014).

in order to buy a house. Since this is a costly action, the representative realtor charges a flow fee of $c^B(b)$, which she takes as given. Hence, the total revenue for the realtor from providing her services is $bc^B(b)$. We assume that there are no frictions associated with hiring the realtor and that her cost of servicing a mass b of buyers is $\bar{c}b^{\gamma+1}/(\gamma+1)$. Thus, profit maximization implies $c^B(b) = \bar{c}b^{\gamma}$. In particular, the equilibrium cost of searching is increasing in the number of buyers.[13] Alternatively, one can assume that buyers search themselves and that search costs rise with buyers due to congestion externalities, see Gabrovski and Ortego-Marti (2019).

The Bellman equation for a pre-approved household is given by

$$rB_1 = -c^B(b) + m(\theta)\left(H - B_1 - dp - \frac{\rho}{r+\delta}\right). \tag{3}$$

When a buyer is matched with a suitable house, she loses the value of being a buyer B_1, but gains the value of being a homeowner H. In addition she transfers the downpayment dp to the seller and begins repaying the financier the flow repayment ρ until the house is destroyed. Given risk-neutrality and a discount rate of r, this is equivalent to transferring the present value $\rho/(r+\delta)$ to the financier at the time of purchase. This alternative (but equivalent) Bellman equation (3) simplifies the exposition and solution.

The financier suffers flow costs c^F while the buyer is searching for a home. Once the buyer finds a home, the financier finances the purchase by paying $p(1-d)$ to the seller but receives repayments with a present value of $\rho/(r+\delta)$. Thus, the Bellman equation for F_1 is given by

$$rF_1 = -c^F + m(\theta)\left(\frac{\rho}{r+\delta} - F_1 - p(1-d)\right). \tag{4}$$

As we discuss later on and in the appendix, our quantitative results do not depend on c^F. In particular, one can assume that c^F equals 0 or is a constant number in (4). The qualitative results remain the same and the quantitative results barely change.[14]

Upon finding a home, the buyer enjoys a utility flow ε from being a homeowner. The

[13] As in any model of entry, some cost or price has to increase as more agents enter the market, so that there is an equilibrium entry of buyers. Otherwise the model does not feature entry. If $c^B(b)$ is constant or decreasing, either all agents enter the market or no one does. This result is consistent with the real estate empirical literature, see Gabrovski and Ortego-Marti (2019) for a more detailed description of this literature.

[14] As in most search models with entry, we still need that either c^F in (2) is different from 0, or that there is a fixed cost of entry. For completeness, we consider shocks to c^F as one of the credit shocks in the economy in our quantitative exercise. The results barely change compared to a constant c^F in both (2) and (4).

Bellman equation for the homeowner is given by

$$rH = \varepsilon - s(H - V) - \delta H. \tag{5}$$

At a rate of s the homeowner suffers a separation shock, loses the value of being a homeowner H, but gains a vacancy which has a value V. At a rate δ the house is destroyed and the household loses H.

Lastly, the Bellman equation for a seller is given by

$$rV = -c^S + \theta m(\theta)(p - V) - \delta V. \tag{6}$$

The seller incurs a flow cost of c^S while searching for a buyer. At a rate $\theta m(\theta)$ she finds a buyer and receives the house price p. In addition, she may also lose the value of the vacancy due to depreciation at a rate δ.

2.3. Bargaining

Forming a match in both the housing and credit market generates a positive surplus that must be split between the negotiating parties. As is standard in the search literature, we assume that the surplus is split according to a generalized Nash Bargaining solution as in Nash (1950) and Rubinstein (1982). We follow Wasmer and Weil (2004) and assume sequential bargaining. The buyer and the seller take the mortgage contract as given, but they recognize that the price would affect the size of the loan, and subsequently the repayment made by the buyer. In addition, when the applicant and the financier negotiate their contract, they do not know the exact size of the loan, since they do not know the price of the house. Thus, they bargain over a repayment schedule $\rho(p)$ for any given price.

In the credit market, the surpluses of the applicant and the financier are given by

$$S^A = B_1 - B_0, \tag{7}$$

$$S^F = F_1 - F_0. \tag{8}$$

In the housing market, the surpluses of the buyer and the seller are given by

$$S^B = \left(H - B_1 - dp - \frac{\rho}{r+\delta} \right), \tag{9}$$

$$S^S = (p - V). \tag{10}$$

The repayment, ρ, is the solution to the Nash Bargaining problem

$$\rho = \arg\max_{\rho} (S^F)^{\beta} (S^A)^{1-\beta}, \tag{11}$$

and the house price p is the solution to

$$p = \arg\max_{p} (S^S)^{\eta} (S^B)^{1-\eta}, \tag{12}$$

where β is the bargaining strength of the financier and η is the bargaining strength of the seller. The solution ρ satisfies the first order condition

$$\beta S^A = (1-\beta) S^F. \tag{13}$$

Intuitively, with Nash Bargaining both negotiating parties receive their outside option. In addition, the financier receives a share β of the total surplus, whereas the applicant receives a share $1-\beta$. As we will show later, a similar condition holds in the housing market as well.

3. Equilibrium

This section studies the equilibrium in the steady-state. A central feature of our model is the existence of multiple equilibria. In general, there are two equilibria with a positive mass of buyers.[15] Multiple equilibria in our model arise due to frictions in the credit market and the fact that buyers must compensate financiers for their expected costs. An equilibrium is a tuple $\{\theta, \phi, p, \rho, b, \mathfrak{a}, v\}$ that satisfies the conditions that we characterize below.

Free entry into the credit market requires that $B_0 = F_0 = 0$. Hence, the surpluses of the applicant and financier are given by $S^A = B_1 = c_0/f(\phi)$ and $S_I = F_1 = c^F/(\phi f(\phi))$. Nash

[15] As we show in proposition 2, depending on parameter values the equilibrium may be trivial with no entry of buyers, sellers and financiers. For a knife-edge case of parameter values the equilibrium may be unique.

Bargaining implies that the equilibrium credit market tightness is given by the following credit entry equation (CE)

$$\text{(CE)}: \qquad \phi = \frac{1-\beta}{\beta}\frac{c^F}{c_0}. \tag{14}$$

This condition is analogous to the equilibrium credit market tightness in Wasmer and Weil (2004). The tightness is the ratio of the bargaining powers of the applicant and the financier and their search costs. Combining $F_1 = c^F/(\phi f(\phi))$ with the Bellman equation for a matched financier (4) yields the repayment equation (RE)

$$\text{(RE)}: \qquad \frac{\rho}{r+\delta} = p(1-d) + \frac{r+m(\theta)+\phi f(\phi)}{m(\theta)\phi f(\phi)}c^F. \tag{15}$$

The left hand size of (RE) is the size of the mortgage, $\rho/(r+\delta)$. In equilibrium it is equal to the sum of the principal $p(1-d)$ and the financing fee. Given free entry, the fee is set such that the financier recovers her expected costs of financing the loan. These expected costs, and in turn the fee, are increasing in the market tightness θ for two reasons. First, a tighter market implies a lower house finding rate and, therefore, that the financier incurs the costs c^F for a longer period. Second, a lower matching rate for buyers pushes the repayment period further into the future. Due to discounting, this implies a lower present value of the future repayments.[16] It is worth noting that there are still two equilibria even if c^F is set to 0 in (4), and c^F in (2) is interpreted as costs associated with finding applicants, advertising and processing applications. The reason is that financiers still receive the mortgage repayments at a later point in time when households take longer to find a home. As a result, the fee is still increasing in market tightness θ in this alternative environment.[17]

The (RE) condition implies that the buyer's surplus S^B is linear in the price. Thus, the Nash Bargaining solution for the price satisfies

$$\eta S^B = (1-\eta)S^S. \tag{16}$$

[16]This effect is similar in spirit to the capitalization effect in the standard search models of the labor market with disembodied technological growth, see for example Pissarides (2000), Chapter 3.

[17]The quantitative results are also very similar in these two versions of the model, as we discuss later on in section 4.

Combining (16) with (3) yields the following buyer entry condition

$$\text{(BE)}: \qquad \frac{c^B(b)}{m(\theta)} + \frac{rc_0}{m(\theta)f(\phi)} = \frac{1-\eta}{\eta}(p-k). \tag{17}$$

The right-hand-side of (BE) corresponds to the buyer's surplus. The left hand side consists of the cost of searching for a house $c^B(b)$, plus the flow value of being a buyer $rc_0/f(\phi)$ times the average time it takes to find a suitable home $1/m(\theta)$. Intuitively, agents enter the market until the realtor fees $c^B(b)$ are large enough so that all expected gains are dissipated.

The (BE) imposes a condition on the equilibrium mass of buyers. It follows that the (BE) imposes a condition on the mass of applicants: at the steady state $\mathfrak{a}$ must be such that b satisfies (BE). The flow into the pool of buyers is given by the mass of applicants times their mortgage-finding rate $\mathfrak{a}f(\phi)$ and the flow out by the mass of buyers times the house-finding rate $bm(\theta)$. In the steady state, these two are equal, so $\mathfrak{a} = bm(\theta)/f(\phi)$.

The Bellman equation for a vacancy (6), combined with the free entry condition for housing construction, yields the following housing entry condition (HE)

$$\text{(HE)}: \qquad p = k + \frac{(r+\delta)k + c^S}{\theta m(\theta)}. \tag{18}$$

Due to free entry, houses are constructed until all profits dissipate. At that point, the price is just enough to cover the costs of constructing and servicing a vacancy: the construction cost k, the seller's expected search cost $c^S/(\theta m(\theta))$, and the user costs while the vacancy is unfilled $(r+\delta)k/(\theta m(\theta))$.

Combining the Nash Bargaining solution for the price, the free entry condition for applicants (RE) and the Bellman equation for a homeowner (5) yields the price equation (PP)

$$\text{(PP)}: \qquad p = k + \eta\left[\frac{\varepsilon + sk}{r+s+\delta} - \frac{c_0}{f(\phi)} - \frac{r + m(\theta) + \phi f(\phi)}{m(\theta)\phi f(\phi)}c^F - k\right]. \tag{19}$$

Intuitively, the price is such that the seller receives her outside option and a fraction η of the surplus. The surplus in turn is the buyer's gain in value from being a homeowner net of the cost of financing and the construction cost. The financing cost consists of the average search cost incurred as an applicant and the financing fee charged by the financier. The presence of the fee in the price equation is the reason the model exhibits multiple equilibria.

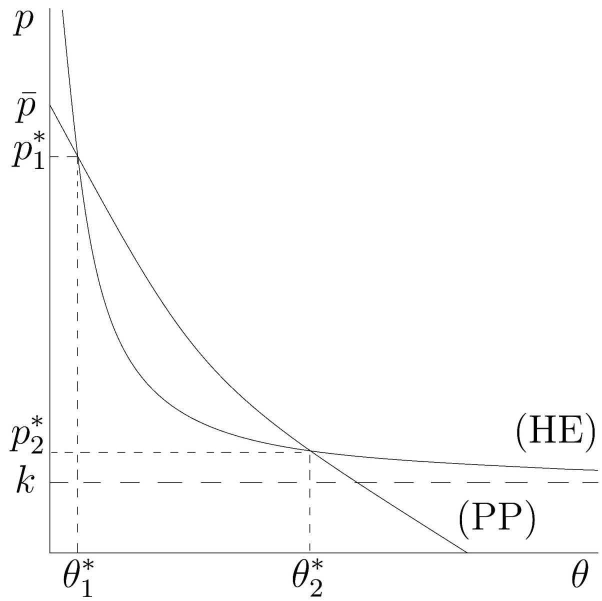


Figure 1: Equilibrium price and housing market tightness

Note: *Figure 1 depicts the house entry condition (HE) from (18) and the price relationship (PP) from (19), which determine the equilibrium price p^* and market tightness $\theta^* = b^*/v^*$. The (HE) condition captures that an increase in house prices makes posting a vacancy more profitable, which leads to a larger entry of sellers and a lower tightness. The (PP) condition is determined by Nash Bargaining between the buyer and the seller.*

Definition 1. *The equilibrium consists of a tuple $\{\theta, \phi, p, \rho, b, \mathfrak{a}, v\}$ that satisfy: (i) the (CE) condition (14); (ii) the (HE) condition (18); (iii) the (RE) condition (15); (iv) the (PP) condition (19); (v) the (BE) condition (17); (vi) $\mathfrak{a} = bm(\theta)/f(\phi)$; and (vii) $v = b/\theta$.*

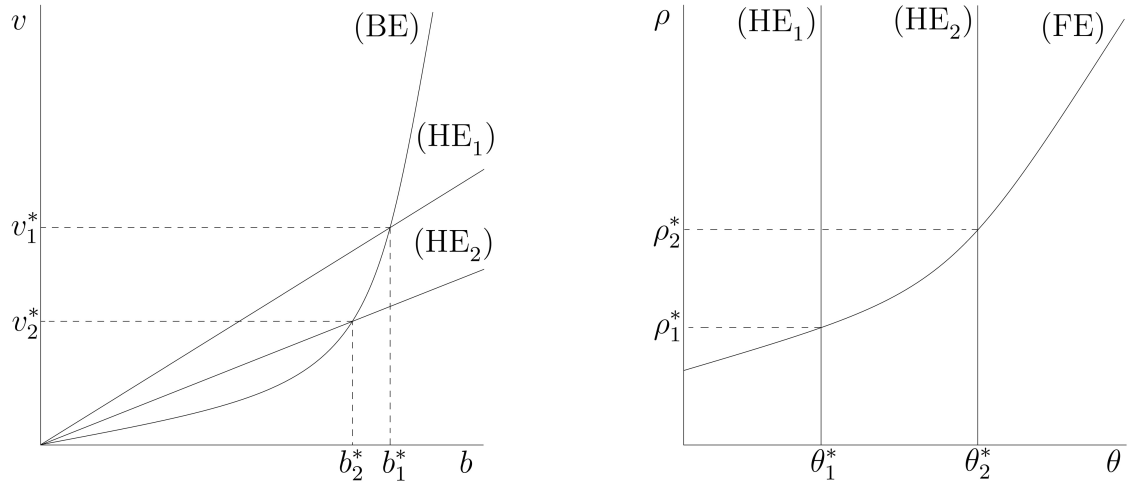
Figure 1 illustrates graphically the equilibrium housing market tightness θ and house prices p. As is standard in search models, the (HE) curve is downward sloping in (θ, p) space. Intuitively, a higher market tightness increases the seller's matching rate, which decreases the housing price needed to recover her investment and search costs. As θ tends to infinity, the price converges to k, and as θ tends to 0 it diverges to infinity. In our model, the price curve is downward sloping as well, in contrast to search models in the labor market (see Pissarides (2000)), where the wage curve is upward sloping in the labor market tightness. The reason behind this is the following. When the applicant and the financier bargain over a contract, they take into account the average time it takes for a buyer to find a suitable home. In a tight housing market it takes longer for buyers to find a suitable home, so the financier both receives the value of the mortgage at a later point in time and incurs higher search costs. As a result, when she negotiates the contract with the applicant, she demands to be compensated with a higher fee. This increases the cost of financing and subsequently reduces the surplus of the match between a buyer and the seller in the housing market, which leads to a lower price p. Overall, when the buyer bargains with the seller, the buyer's agreement point $H - dp - \rho/(r+\delta)$ depends negatively on the market tightness θ, which leads to the downward sloping price curve (PP). When the tightness is zero, buyers match instantaneously and there is no financing fee. As θ increases, the fee eventually becomes so large that the (PP) curve crosses the zero line.

Since both curves are downward sloping there will be, in general, two equilibrium points (θ_1^*, p_1^*) and (θ_2^*, p_2^*). Intuitively, all parties are indifferent between these two points. In the first equilibrium, the seller finds it harder to fill her vacancy, but is compensated with a higher price. The buyer is matched quicker with a suitable home and is charged a lower fee, but has to pay a higher price. The financier charges a low fee, but does not have to incur large costs and repayment begins relatively sooner. In the second equilibrium the opposite is true. The seller fills her vacancies quickly, but charges a low price. The buyer pays a high fee and incurs higher search costs but pays a low price. The financier incurs high costs and waits longer for repayments from the buyer to begin, but charges a higher fee.[18]

Figure 2 represents graphically the determination of equilibrium buyers, vacancies, and repayment. The equilibrium size of the housing market is governed by the (BE) and (HE) conditions. The two curves intersect twice. One intersection is at $b = v = 0$. This trivial equilibrium exists for each θ. Since there are two equilibrium market tightnesses, there are two curves (HE_1) and (HE_2) each corresponding to θ_1^* and θ_2^*. At the low market tightness the housing creation condition is steeper which implies a larger market size, i.e. b_1^* and v_1^* are larger than b_2^* and v_2^* respectively. Intuitively, when housing market tightness is low, the house finding rate is higher. This means that the buyer expects lower search costs, which induces more entry of buyers into the market.

From the (RE) condition, a lower market tightness implies a lower equilibrium repayment ρ. A low tightness leads to a high matching rate for buyers, so the financier faces lower costs and expects to begin receiving the repayments sooner. Thus, she is willing to negotiate a lower

[18]Empirically, we observe the equilibrium conditions and not directly the (PP) and (HE) curves. Testing empirically whether the (PP) curve is downward sloping is similar to a demand curve estimation exercise. One would need to find shocks to the (PP) curve that leave the (HE) curve unchanged. Such an exercise is not straightforward to implement empirically, as most shocks considered in the housing literature affect both curves. Nevertheless, the framework is consistent with the housing market dynamics, in particular the upward sloping Beveridge Curve and the positive correlation of buyers and vacancies in the housing market, see Gabrovski and Ortego-Marti (2019).



(a) Equilibrium buyers and vacancies

(b) Equilibrium repayment

Figure 2: Equilibrium

Note: *In figure 2a, the (HE) condition is obtained from the equilibrium market tightness in Figure 1, which describes a straight line with a slope proportional to the equilibrium market tightness. The (BE) curve in figure 2a depicts the buyers entry (BE) condition (17). The (BE) condition captures that an increase in the ratio of vacancies to buyers makes it easier for buyers to find a house and leads to an increase in the entry of buyers. The (BE) curve is the equivalent of the Beveridge Curve in DMP models of the labor market and is upwards sloping due to buyers entry. In figure 2a, the (RE) condition (15) is obtained by Nash Bargaining over the mortgage repayments and the two equilibrium market tightnesses θ_1^* and θ_2^* correspond to the two equilibria in Figure 1.*

repayment. However, it is worth noting that the size of the mortgage at the first equilibrium is smaller even though this equilibrium features a higher price. This implies that the increase in the financing fee from switching to the high tightness equilibrium is large enough to compensate for the drop in the price.

Proposition 1. *The equilibrium with a lower price p features a larger mortgage size, $\rho/(r+\delta)$.*

A proof of proposition 1 is included in the appendix. Our economy does not always feature two equilibria. The following proposition states that if the seller's cost of creating and maintaining a vacancy are too high there will not exist any non-trivial equilibria. For a knife-edge case the equilibrium is unique. A proof is included in the appendix.

Proposition 2. *There exist two distinct equilibria if and only if*

$$\left(\frac{\alpha}{1-\alpha}\right)\left(1+\frac{r}{\phi^* f(\phi^*)}\right)\eta c^F m^{-1}\left(\frac{\left(1+\frac{r}{\phi^* f(\phi^*)}\right)c^F}{(1-\alpha)\left[\frac{\varepsilon+sk}{r+s+\delta}-\frac{c_0}{f(\phi^*)}-\frac{c^F}{\phi^* f(\phi^*)}-k\right]}\right) > (r+\delta)k + c^S \tag{20}$$

There is a unique equilibrium if the above holds with equality, and if the inequality is reversed *there exist no equilibria.*

4. Numerical Exercise

Due to the credit frictions in our model, the financial sector affects prices and time-to-sell on the housing market through a mechanism not previously explored in the literature. In this section, we study the quantitative importance of this channel. To this end, we decompose the relative contribution of credit and housing market shocks to the observed build-up in housing prices and mortgage debt and to the lack of trend in the time-to-sell prior to the 2007 market crash. We conduct two exercises. First, we begin with the interpretation of financiers costs c^F as simply screening costs. In particular, we hold the cost c^F constant and show that the results are robust for a wide range of values. In the second exercise, we interpret c^F as also including liquidity costs in the line of Kashyap *et al.* (2002). This allows the model to capture the decline in liquidity constraints during the 2000s prior to the Great Recession. We show that the results are very similar under the two interpretations and that the main result holds in both exercises: credit shocks were important for the behavior of time-to-sell and mortgage debt, but did not affect prices as much. Intuitively, costs are quantitatively small relative to the match surplus, so they have a small impact on the quantitative results. A similar result occurs in DMP search and matching models of the labor market. For standard calibrations, vacancy costs do not have a significant impact on a DMP model's amplification.

As is common in the housing search literature, for example Diaz and Jerez (2013), Head *et al.* (2014), Ngai and Sheedy (in press), and Novy-Marx (2009), we use both demand and supply shocks to generate movements in prices and time-to-sell. The two housing market shocks correspond to changes in (*i*) the utility from housing ε; (*ii*) construction costs k. Regarding credit shocks, in section 4.2 we first consider shocks to: (*i*) the matching efficiency in the credit market μ_f; and (*ii*) the bargaining power of the financier β. In section 4.3, we also include (*iii*) a shock to the liquidity costs of the financier c^F to capture the observed decline in liquidity constraints. We focus on these credit shocks because they define the relative size of the financing fee in the model and entry in the credit market, which is the channel through which the financial sector affects housing prices and the time-to-sell.

In order to back out the implied sizes of these shocks we first calibrate our model to the U.S. economy for the years $1999 - 2000$. We then pick the changes in ε, k, μ_f, β and (in our second exercise) c^F that match the observed changes in (i) prices, (ii) time-to-sell, (iii) mortgage debt-to-price ratio, (iv) mortgage loan originations to applications ratio, and (v) liquidity costs (in our second exercise) from their initial values to their average in $2005-2006$.[19] The focus of this paper is on the trend behavior of the housing market and mortgage debt, not on business cycle fluctuations. Therefore, we look at the steady state elasticities of the key variables, similar to Ngai and Sheedy (in press). In search models, these elasticities give locally a good sense of the model response to an innovation, see Shimer (2005). In the appendix we show that these targets uniquely determine each of the parameter values for $\{\varepsilon, k, c^F, \mu_f, \beta\}$.

The main part of our numerical analysis is a series of counter-factual exercises. We first shut down all credit shocks. In that case the resulting model-implied changes in housing prices, time-to-sell, and mortgage debt-to-price ratio are only driven by housing market shocks. We then compare these changes to those observed in the data. A larger discrepancy between the model-implied changes and the ones observed empirically means a relatively larger quantitative importance of credit frictions. We then repeat this exercise, shutting down credit shocks one at a time, to gauge their relative quantitative importance.

4.1. Calibration

The model is calibrated at a quarterly frequency. The discount rate r is 0.012 in order to match an annual discount factor of 0.953. The utility of home-ownership ε is normalized to 1. The destruction rate δ equals 0.004 to match an annual housing depreciation rate of 1.6% (Van Nieuwerburgh and Weill (2010)). As in Diaz and Jerez (2013), we target an average tenure in a home of 9 years, which gives an s equal to 0.024. We set the elasticity of the house finding rate with respect to the tightness α, as well as the elasticity α_f to 0.5. The elasticity of $c^B(b)$ with respect to the measure of buyers γ is 2 and we normalize $\bar{c} = 0.1$. We set the downpayment d equal to 20%.

To calibrate the rest of the parameters we use eight targets. The U.S. Bureau of the Census reports that the average Median Number of Months on Sales Market for $1999-2000$ was 4.39 months. Thus, we set the time-to-sell to 1.4625. As in Gabrovski and Ortego-Marti (2019), the average time to buy is set to the average time to sell. We follow Ghent (2012) and set the

[19] The results are very similar if we choose the years 2006-2007, see Gabrovski and Ortego-Marti (2018), a previous working paper version of this paper. Using the predicted changes from an estimated time trend yields almost the same results, which are available upon request.

seller's expected search cost to 5.1% of the price and the buyer's expected search cost to 8% of the housing price. We decompose the buyer's cost into costs associated with search on the credit market (2.5pp) and on the housing market (5.5pp).[20] Bernanke (1983) uses the spread between Bba corporate bonds and Treasury Bills as a proxy for what he defines as the Cost of Credit Intermediation (CCI), which includes the cost of advertising, screening and servicing loans. The CCI in his paper has a very close interpretation to our cost c^F. In the same spirit, we choose a c^F that matches the average of the spread between the yield on Moody's Seasoned Aaa Corporate Bond and the yield on 10-year constant maturity Treasury bonds for the period of 1999-2000. To check the robustness of the results to alternative values of c^F, we also conduct the same numerical exercise for a wide range of values, as we describe in section 4.2. This gives a c^F equal to 0.3727% of the principal $(1-d)p$. Next, we set the average time to find a mortgage to 0.4898 in order to match an average closing time of 44.57 days in the data.[21] Lastly, we assume that the household has the same bargaining power in both the credit and housing markets, i.e. $\beta = \eta$. This yields $c^S = 1.5548$, $c_0 = 2.2757$, $k = 41.3445$, $\beta = \eta = 0.5673$, $\mu = 0.6838$, $c^F = 0.1329$ and $\mu_f = 0.4309$.

Even though our model features two equilibria, only one is consistent with the data targets in our calibration strategy. Hence, we use that equilibrium to study the quantitative importance of the credit frictions channel for the housing price and time-to-sell.

4.2. Baseline results

We calibrate the relative size of our four shocks so that the model matches four stylized facts about the changes that occurred in the U.S. housing and credit markets between 1999 and 2006.[22] First, housing prices increased by 52.31%.[23] Second, the time-to-sell decreased by 10.07%. Third, the ratio of mortgage originations to loan applications decreased by 3.02%.[24]

[20]Woodward (2003) reports average closing costs for mortgage origination of $4,050$ dollars and an average loan amount of $130,000$. Assuming a down payment of 20%, the average cost for the buyer is 2.5% of the price.

[21]The data is taken from the Ellie Mae Originations Insight Report for the years of 2012 through 2019.

[22]More specifically, we calculate the changes between average values for $1999-2000$ and $2005-2006$.

[23]We follow Diaz and Jerez (2013) and calculate the real house price by deflating the Case-Shiller U.S. National Home Price Index by the Consumer Price Index (less shelter).

[24]In our model the mass of mortgage originations is $bm(\theta) = \mathfrak{a} f(\phi)$. Dividing this by the mass of applicants, $\mathfrak{a}$, implies the ratio of originations to applications is given by $f(\phi)$. The data is taken from the Home Mortgage Disclosure Act National Aggregate Report. We use data on both conventional, government insured (FHA) and government guaranteed (FSA, RHS, and VA) loans.

Fourth, the mortgage debt-to-price ratio increased by 9.28%.[25] The calibrated values of the shocks along with their data targets are summarized in Table 1. The appendix shows that these targets uniquely pin down the values for $\{\varepsilon, k, \mu_f, \beta\}$. Table 2 reports the calibrated values for the shocks. All credit shocks are moderately large and of similar magnitude to shocks in the housing market.

The data targets imply that both the ratio of mortgage originations to loan applications and the matching efficiency on the credit market decreased prior to the 2007 market crash. It should be noted that this is not necessarily at odds with the common view that mortgage lending standards in the U.S. decreased during that period. In particular, if the lower standards incentivized entry by applicants with sub-prime credit ratings this could translate to a lower mortgage originations to loan applications ratio in the data. Through the lens of our model, the increase in sub-prime borrowers would map into lower credit market efficiency. Intuitively, an increase in the pool of applicants with poor credit ratings decreases the credit score of the average applicant. As the average applicant now has a lower score, she must submit more credit applications before she finds a financier willing to pre-approve her. This translates into a drop in the mortgage finding rate and ultimately a lower credit market matching efficiency.

We gauge the quantitative impact of the credit frictions channel through a series of counterfactual exercises reported in Table 3. First, we ask the question: What would have been the changes in prices, time-to-sell, and debt-to-price in the absence of credit shocks? We then repeat the same question for each of the credit shocks. Overall, the credit frictions channel had a relatively small impact on the price. Without credit shocks, the price would have increased an additional 8pp. By contrast, in the absence of credit shocks, the time-to-sell would have increased by 84% and the debt-to-price ratio would have decreased by 1.86%.

If the efficiency of the credit market matching technology had not decreased, then the time-to-sell would have increased by 66%, but the debt-to-price ratio would have increased by 1.24%. Intuitively, when the matching technology is more efficient, then both the mortgage-finding and applicant-finding rates are higher. This reduces the financing fee and consequently the debt-to-price ratio. Furthermore, it would have increased the gains from trade in the housing market.

[25]We calculate the debt-to-price ratio by dividing the Mortgage Debt Outstanding for One to Four Family Residences reported by the Federal Reserve Board by the Estimates of the Total Housing Inventory (All Housing Units) reported by the U.S. Bureau of the Census. We then divide the resulting ratio by the Case-Shiller National Home Price Index.

As a result, both the housing price and time-to-sell would have increased.

From our counter-factual exercise, had the bargaining strength β remained constant, then time-to-sell would have increased by about a third and the debt-to-price ratio would have increased by only 1.59%. Intuitively, β influences the entry of financiers. When β is lower, financiers receive a lower fraction of the surplus, so they have less of an incentive to enter the market. Hence, the tightness ϕ increases. This leads to lower congestion and as a result lower search costs for the financier, which reduces the financing fee and ultimately the debt-to-price ratio. At the same time, the lower financing fee increases the surplus of the match between the buyer and the seller, so the seller charges a higher price. As a result, construction of new houses becomes more profitable, which incentivizes entry into the housing market and increases the time-to-sell.

To assess the robustness of the results to alternative values of c^F, we conduct the same numerical exercise for a wide range of values. Figure 3 shows the results. For each value of c^F we follow the same calibration as in the baseline. Overall, it is clear that results barely change if we assume lower values of c^F. Intuitively, the reason is similar to why vacancy costs do not affect significantly the performance of a DMP model, these costs are small relative to the surplus from matching.

4.3. Declining liquidity constraints

The period 1999 to 2006 was characterized by decreasing liquidity constraints on banks due to both monetary policy and, especially, the rapid growth of securitization, see Loutskina and Strahan (2009) and the references therein. In our model, such a decline in liquidity costs is captured by a decline in the cost c^F. To quantitatively assess the importance of this decline in liquidity constraints, we perform the same exercise as in section 4.2 with an additional target for the shock to the cost c^F. More specifically, in addition to the four targets in section 4.2, the shock to c^F is calibrated to match a 41.96% decline in the spread between the yield on Moody's Aaa Corporate Bonds and the yield on 10-year constant maturity bonds.[26] The calibrated values of the shocks along with their data targets are summarized in Table 4. As in the baseline exercise, the targets uniquely determine the values for the shocks to $\{\varepsilon, k, \mu_f, \beta, c^F\}$, see the appendix for a proof.

[26] Targeting alternative spreads yields similar results (available upon request).

If the liquidity cost c^F had remained constant, time-to-sell would have decreased by about 20%. Intuitively, with a constant c^F the price would have been relatively lower. Given free entry, the lower price leads to a lower time-to-sell. The implication for financiers is that they now face higher search costs. This leads to a higher fee and debt-to-price ratio relative to an environment with credit shocks.

5. The role of downpayment and savings

A salient feature of the housing market in the US is that the vast majority of homeowners require a mortgage to finance their home purchase. The National Association of Realtors reports that, during 2016, 88% of all buyers financed their homes. Not only that, in the 2001 US Census nearly all home-occupied houses without a mortgage are the results of homeowners paying off a mortgage loan, see Alexandrov and Koulayev (2018). Most search models of the housing market assume that buyers are able to finance the full value of the house. In contrast to these papers, with the exception of Garriga and Hedlund (2020), we capture credit constraints in the housing market and assume that homebuyers are only able to gather the funds to make a downpayment on the house—or how they finance the downpayment, most likely through savings, is determined outside the model. Our stance relative to the literature is that our model captures that buyers are limited in how much self-financing they can use to purchase a home, the remaining balance must be funded by financiers. Still, the bargaining stage shows that buyers are better off if they are able to bring more funds as a downpayment, as this reduces their repayments to financiers. This section studies how sensitive the results are to the size of the downpayment and, therefore, to allowing buyers some additional self-financing.

We run the numerical exercise in section 4 for different values of the downpayment d ranging from 10% to 30%—the baseline calibration assumes a 20% downpayment. For each value of d we follow the same calibration strategy and conduct the same counterfactual exercise, i.e. we shut down the credit shocks and look at the effect on time-to-sell, prices and mortgage debt. Figure 4 shows the results when we allow for a shock to c^F, but the results with a constant cost c^F are almost identical and available upon request. With a 30% downpayment instead of 20% and absent credit shocks, prices would have increased by 59.47%, time-to-sell by around 74.34%, and loan to value would have decreased by 2.04%. With a 20% downpayment those numbers are 60.31%, 84.29% and 1.86% respectively. Figure 4 also shows the counterfactual when each credit shock is shut down one by one, which gives a similar picture. Overall, the main result of the paper holds: credit shocks have a larger impact on liquidity in the housing market and mortgage debt than on prices. If anything, a higher downpayment suggests a weaker effect of credit shocks on liquidity in the housing market, i.e. credit shocks play a bigger role in keeping time-to-sell low during the pre-bust period when the downpayment is lower.[27]

6. Conclusion

This paper develops a tractable dynamic model of the housing market with search and credit frictions. Buyers are liquidity constrained and must be pre-approved for a mortgage by a financier before they can buy a home. Both the credit market and the housing market are subject to search and matching frictions. To account for housing market dynamics, the model's key features include free entry of buyers, sellers and financiers, and bargaining over prices. Credit frictions generate a novel channel through which the financial sector affects prices and time-to-sell in the housing market. We show that the interaction between credit and search frictions may lead to multiple equilibria. One equilibrium features a high price, a high home-finding rate and low interest payments, while the other is characterized by a low price, a low home-finding rate and high interest payments. We use our framework to quantify the importance of the credit channel for the observed trend in housing prices, time-to-sell and mortgage debt in the housing market during prior to the 2007 crash. A counter-factual analysis suggests that credit shocks contributed relatively less to the build-up in prices, consistent with some previous studies that focus on different sources of credit frictions. However, credit shocks were quantitatively important to account for the observed build-up of mortgage debt and behavior of liquidity in the housing market.

Our framework assumes random search à la Pissarides (2000). Diaz and Jerez (2013) consider directed search instead and show that it is equivalent to a model with random matching with the bargaining strength equal to the matching elasticity, a result that also arises in Moen (1997). Directed search adds a significant complication in our framework due to the fact that we have search in two markets, the credit and housing markets. A study of competitive search in such a framework is, therefore, left for future research. We envision two possible extensions

[27] We thank an anonymous referee for helpful suggestions and discussions on how credit constraints affect the equilibrium.

of our work. First, housing construction is a costly endeavor and developers are often liquidity constrained. Hence, it may be worthwhile to examine a model in which there are credit frictions on the seller's side of the market as well. Second, our model features risk-neutral agents and no risk of mortgage default. A fruitful future research avenue might be to analyze an extension of our work with risk-averse agents and endogenous mortgage defaults. This extension seems particularly interesting in light of recent findings by Hurst, Keys, Seru and Vavra (2016) that GSE mortgages rate loans do not vary spatially, despite large variation in predictable default risk across regions.

Technical Appendix

Proof of Proposition 1

Proof. From (15) and (19) it follows that

$$\frac{\rho}{r+\delta} = (1-d)\eta\left[\frac{\varepsilon+sk}{r+s+\delta} - \frac{c_0}{f(\phi)}\right] + (1-d)(1-\eta)k + [1-(1-d)\eta]\frac{r+m(\theta)+\phi f(\phi)}{m(\theta)\phi f(\phi)}c^F. \tag{A1}$$

Thus, the loan size is increasing in the market tightness, θ. Since the price is decreasing in the tightness, the claim in the proof follows.

□

Proof of Proposition 2

Proof. From equations (18) and (19) it follows that in equilibrium

$$\theta m(\theta)\eta\left[\frac{\varepsilon+sk}{r+s+\delta} - \frac{c_0}{f(\phi^*)} - \frac{c^F}{\phi^* f(\phi^*)} - k\right] - \theta\eta\left(1+\frac{r}{\phi^* f(\phi^*)}\right)c^F - (r+\delta)k + c^S = 0. \tag{A2}$$

The left hand side of (A2) is a concave function with a unique maximum. Its maximum is attained at

$$\theta = m^{-1}\left(\frac{\left(1+\frac{r}{\phi^* f(\phi^*)}\right)c^F}{(1-\alpha)\left[\frac{\varepsilon+sk}{r+s+\delta} - \frac{c_0}{f(\phi^*)} - \frac{c^F}{\phi^* f(\phi^*)} - k\right]}\right).$$

If at that point the left hand side of (A2) is positive, then the curve intersects the zero line at two distinct points. If it is zero, then this is the unique equilibrium, and if it is negative then there exist no equilibria.

$\square$

Calibration identification

In this section we prove that the calibration strategy uniquely identifies the model parameters and that the numerical exercise uniquely identifies the shocks.

The parameters $\{r, \varepsilon, \delta, s, \alpha, \alpha_f, \gamma, \bar{c}, d\}$ are set directly. We calibrate the rest of parameters using eight moments: (i) time-to-sell is 1.4625 quarters; (ii) time-to-buy equals time-to-sell; (iii) the average cost for the seller is 5.1% of the price; (iv) the buyer's expected cost on the credit market is 2.5% of the price; (v) her cost on the housing market is 5.5% of the price; (vi) Moody's Aaa spread is 1.499%; (vii) the average time to approve a mortgage is 0.4898; (viii) the buyer's bargaining strengths in the credit and housing market are equal.

Using (ii), the market tightness in the housing market is $\theta = 1$. Then, (i) implies that $\mu = 0.6838$. Furthermore, (vii) yields $f(\phi) = 2.0416$. Next, (iii) yields $c^S/p = 0.0349$; (v) yields $c^B(b)/p = 0.0376$; (vi) yields $c^F/p = 0.003$; and (iv) and (vii) together imply $c_0/p = 0.051$. The (HE) then implies that

$$\frac{k}{p} = \frac{\theta m(\theta) - \frac{c^S}{p}}{\theta m(\theta) + r + \delta} = 0.9273. \tag{A3}$$

Rearranging the (BE) condition yields

$$\eta = \frac{1 - \frac{k}{p}}{\frac{c^B(b)/p}{m(\theta)} + \frac{rc_0/p}{m(\theta)f(\theta)} + 1 - \frac{k}{p}} = 0.5673. \tag{A4}$$

Thus, (viii) implies that $\beta = 0.5673$ as well. Next, the (CE) condition implies that $\phi = 0.0445$. It follows that $\mu_f = 0.4309$. Rearranging the (PP) equation,

$$p = \frac{\frac{\eta\varepsilon}{r+s+\delta}}{1 - \frac{k}{p} - \eta\left[\frac{sk/p}{r+s+\delta} - \frac{c_0/p}{f(\phi)} - \frac{r+m(\theta)+\phi f(\phi)}{m(\theta)f(\phi)}\frac{c^F}{p} - \frac{k}{p}\right]} = 44.5858. \tag{A5}$$

Combining the above yields that $c^S = 1.5548$, $c^F = 0.1329$, $c_0 = 2.2757$ and $k = 41.3445$.

Next, we establish that the targets in the numerical exercise uniquely identify the shocks. The four targets we have are: (i) the price increased by 52.31%; (ii) the time-to-sell decreased by 10.07%; (iii) the debt-to-price ratio increased by 9.28%; and (iv) the mortgage-finding rate decreased by 3.02%. Using primes to denote values in the new steady state, after the shocks have taken place, (i), (ii), (iv) yield that the price satisfies $p' = 67.9075$, time-to-sell $TTS' = 1.3153$, and the mortgage-finding rate $f(\phi')' = 1.98$. Therefore, market tightness is given by $\theta' = 1.2364$. The (HE) condition then implies that $k' = 64.5051$.

Observe that at the original steady state, the (RE) equation implies that $\rho = 0.5976$. Hence, the mortgage size is $\rho/(r+\delta) = 37.3504$, and the debt-to-price ratio is given by $\rho/[p(r+\delta)] = 0.8377$. Thus, target (iii) implies that the new mortgage size is $\rho'/(r+\delta) = 62.1643$. Rearranging the (RE) condition yields the new market tightness in the credit market:

$$\phi' = \frac{[r + m(\theta')]c^F}{f(\phi')' m(\theta') \left[\frac{\rho'}{r+\delta} - p'(1-d) - \frac{c^F}{m(\theta')}\right]} = 0.0079. \tag{A6}$$

As a result, $\mu_f' = 0.1763$. Using the (CE) equation,

$$\beta' = \frac{1}{1 + \phi' \frac{c_0}{c^F}} = 0.8671. \tag{A7}$$

Lastly, the (PP) equation implies that

$$\varepsilon' = (r + s + \delta) \left[\frac{p' - k'}{\eta} + k' + \frac{c_0}{f(\phi')'} + c^F \frac{r + m(\theta') + \phi' f(\phi')'}{m(\theta')\phi' f(\phi')'}\right] - sk' = 1.6281. \tag{A8}$$

Hence, k', μ_f', β', ε' are all uniquely identified.

With 5 shocks, the new value of liquidity costs $c^{F'}$ is identified using the observed 41.96% decline in the spread between the yield on Moody's Aaa Corporate Bonds and the 10-year constant maturity Treasury bonds. Thus, we set $c^{F'}$ to 0.2168% of the principle $(1-d)p'$. Since the downpayment is set to 20% and housing prices increased by 52.31%, the resulting value for $c^{F'}$ is 0.1178. The rest of shocks are then identified using the same steps described in the baseline model with 4 shocks.

Appendix: Alternative Timings

This section explores the robustness of our results to changes in the assumption on the timing of search. First, we build the model under the alternative timing assumption that buyers must first search for a home, and only once they are matched with a house can they begin searching for a mortgage. We show that the main theoretical insights carry over and that the quantitative results are qualitatively unchanged. Second, we introduce a version of the model where agents can search simultaneously for a mortgage and a home. We show that the quantitative results are robust to this specification as well.

Alternative timing: sequential search

The economy is analogous to the one in the main text. The only point of departure is on the assumption of the sequence of search home buyers take: they must first search for a home, and only once they are matched with a house can they begin searching for mortgages.

Economy and Steady State Equilibria

In the housing market, the Bellman equations for a buyer and a vacancy are given by

$$rB_0 = -c^B(b) + m(\theta)\left[B_1 - B_0\right], \tag{A9}$$

$$rV_0 = -c^S + \theta m(\theta)\left[V_1 - V_0\right] - \delta V_0. \tag{A10}$$

The flow value of a buyer searching for a home is given by the matching rate, $m(\theta)$, times the capital gain if matched, $B_1 - B_0$ less the search cost $-c^B(b)$. Similarly, a seller must incur the flow cost c^S but matches with a buyer at the rate $\theta m(\theta)$. Once the two match, the seller transitions to having a vacancy matched with a buyer who is searching for a mortgage, which yields the capital gain of $V_1 - V_0$. Finally, the seller's home is subject to depreciation, so at a rate δ she looses her vacancy.

Buyers who search for financing must pay the flow cost c_1. At a rate $f(\phi)$ they find a financier willing to extend them a line of credit. Once she is approved for a mortgage, the buyer purchases the home and becomes an owner, transfers the down payment to the seller and the net present value of the mortgage loan to the financier. At the same time, the seller receives the price for the home and parts with her vacancy. She incurs no costs while waiting for the buyer to find a mortgage lender, so the two Bellman equations are given by

$$rB_1 = -c_1 + f(\phi)\left[H - B_1 - dp - \frac{\rho}{r+\delta}\right], \tag{A11}$$

$$rV_1 = f(\phi)\left[p - V_1\right]. \tag{A12}$$

On the other side of the mortgage market financiers search for buyers who are matched with a home. This is a costly activity, so a financier incurs the flow cost of c^F. She is matched with a buyer at a rate $\phi f(\phi)$. Upon matching she finances the purchase of the home by transferring $(1-d)p$ to the seller. She receives the net present value of the mortgage $\rho/(r+\delta)$, but loses her option value of search F. Hence, the Bellman equation for a financier is given by

$$rF = -c^F + \phi f(\phi)\left[\frac{\rho}{r+\delta} - F - p(1-d)\right]. \tag{A13}$$

Lastly, a homeowner enjoys her utility flow of having a house. At the rate s she suffers a moving shock and posts her house for sale on the market. At a rate δ her house suffers a destruction shock. Hence,

$$rH = \varepsilon + s\left[H - V_0\right] - \delta H. \tag{A14}$$

We maintain the assumption that the home price and the repayment are determined by sequential Nash bargaining: the applicant and the financier take prices as given, but the buyer and the seller anticipate the second stage bargaining outcome. More explicitly,

$$p = \arg\max_{p'} \left[V_1 - V_0\right]^{\eta}\left[B_1 - B_0\right]^{1-\eta}, \tag{A15}$$

$$\rho = \arg\max_{\rho'} \left[\frac{\rho'}{r+\delta} - (1-d)p - F\right]^{\beta}\left[H - B_1 - dp - \frac{\rho'}{r+\delta}\right]^{1-\beta}. \tag{A16}$$

We also maintain the assumption of free entry, so in equilibrium $B_0 = F = 0$ and $V_0 = k$.

Hence, (A13) implies the repayment equation below

$$\frac{\rho}{r+\delta} = p(1-d) + \frac{c^F}{\phi f(\phi)}. \tag{A17}$$

The free entry conditions also imply that the surpluses for the financier, the buyer on the housing market, and the seller are given by $c^F/[\phi f(\phi)]$, $B_1 = c^B(b)/m(\theta)$, and $[(r+\delta)k + c^S]/[\theta m(\theta)]$ respectively. Using (A16) and (A11) gives the credit entry equation

$$\phi = \frac{(1-\beta)c^F}{\beta\left[\frac{rc^B(b)}{m(\theta)} + c_1\right]}. \tag{A18}$$

Next, plugging in (A14) and (A17) into (A11) implies that the surplus for the buyer is given by

$$S^B = \frac{f(\phi)}{r+f(\phi)}\left[\frac{\varepsilon + sk}{r+s+\delta} - \frac{c_1}{f(\phi)} - \frac{c^F}{\phi f(\phi)} - p\right]. \tag{A19}$$

From (A12) the surplus of the seller is given by

$$S^S = \frac{f(\phi)}{r+f(\phi)}p - k. \tag{A20}$$

Thus, Nash bargaining implies that $\eta S^B = (1-\eta)S^S$ and the buyer entry condition below

$$c^B(b) = \frac{1-\eta}{\eta}\frac{(r+\delta)k + c^S}{\theta}. \tag{A21}$$

The expression of the seller's surplus, (A20) and (A10) yield the housing entry condition

$$p = \frac{r+f(\phi)}{f(\phi)}\left[k + \frac{(r+\delta)k + c^S}{\theta m(\theta)}\right]. \tag{A22}$$

Lastly, Nash bargaining together with (A19) and (A20) yield the price equation below

$$p = \eta\left[\frac{\varepsilon + sk}{r+s+\delta} - \frac{c_1}{f(\phi)} - \frac{c^F}{\phi f(\phi)}\right] + (1-\eta)\frac{r+f(\phi)}{f(\phi)}k. \tag{A23}$$

Equations (A17), (A18), (A21), (A22), (A23) together with the steady state condition $\mathfrak{a} = bm(\theta)/f(\phi)$ characterize the steady state equilibrium in the economy.

In general the economy exhibits multiple equilibria. To see this, we can use (A18) and (A21) to arrive at an alternative housing entry equation

$$\tilde{p} = \frac{(1-\beta)c^F}{(1-\eta)r\beta\phi} - \frac{c_1}{r(1-\eta)}, \tag{A24}$$

where $\tilde{p} \equiv [pf(\phi)/[r+f(\phi)] - k]/\eta$. Similarly, we can rearrange the price equation

$$\tilde{p} = \frac{f(\phi)}{r+f(\phi)} \frac{\varepsilon + sk}{r+s+\delta} - \frac{c_1}{r+f(\phi)} - \frac{c^F}{\phi[r+f(\phi)]} - k. \tag{A25}$$

These two equations above define $(\tilde{p}, \phi)$ as a function of model parameters. Whereas (A24) defines a downward sloping curve, the curve defined by (A25) is upward sloping for small ϕ and downward sloping for large ϕ. To see this clearly, if $h(\phi)$ represents the left-hand side of (A25), then

$$h'(\phi) = \frac{(r\frac{\varepsilon+sk}{r+s+\delta} + c_1)f'(\phi)}{[r+f(\phi)]^2} + \frac{c^F[r+f(\phi)+\phi f'(\phi)]}{\phi^2[r+f(\phi)]^2}. \tag{A26}$$

The first term of the expression is negative, whereas the second is positive. For small ϕ the second term dominates and for large ϕ the first one does. Hence, in general the model exhibits multiple equilibria.

Numerical Results

First, we describe the calibrated economy. The targets are kept the same as in the main exercise, namely: (i) time-to-sell is set at 1.4625 quarters; (ii) time-to-buy equals time-to-sell; (iii) the average cost for the seller is 5.1% of the price; (iv) the buyer's expected cost in the credit market is 2.5% of the price; (v) her cost on the housing market is 5.5% of the price; (vi) Moody's Aaa spread is 1.499%; (vii) the average time to approve a mortgage is set to 0.4898; (viii) the bargaining strengths for the buyer in the credit and housing market are equal to each other. However, due to the alternative timing assumption, in this exercise the moments in the model are different. The following parameters are set exogenously, so their values are still $r = 0.012$, $\varepsilon = 1$, $\delta = 0.004$, $s = 0.0238$, $\alpha = 0.5$, $\alpha_f = 0.5$, $\gamma = 2$, $\bar{c} = 0.1$ and $d = 0.2$. The time it takes to sell a house in the model is given by the average time a seller waits to be matched with a buyer plus the expected time it takes for the buyer to secure a mortgage, i.e. time-to-sell equals

$1/[\theta m(\theta)]+1/f(\phi)$. Target (vii) yields a mortgage-finding rate $f(\phi)=2.0416$. Hence, target (i) implies that $\theta m(\theta)=1.0281$. The expected time-to-buy is similarly given by $1/m(\theta)+1/f(\phi)$. Hence, target (ii) yields $\theta=1$ and $\mu=1.0281$. Targets (iii), (iv), (v) and (iv) then imply that $c^S/p=0.0524$, $c_1/p=0.051$, $c^B(b)/p=0.0565$, $c^F/p=0.003$. Rearranging the housing construction condition (A22) yields

$$\frac{k}{p}=\left[\frac{f(\phi)}{r+f(\phi)}-\frac{1}{\theta m(\theta)}\frac{c^S}{p}\right]\left[1+\frac{r+\delta}{\theta m(\theta)}\right]^{-1}=0.9287. \tag{A27}$$

Next, rearranging the buyer entry condition (A21) yields the bargaining strength

$$\eta=\frac{\frac{r+\delta}{\theta}\frac{k}{p}+\frac{1}{\theta}\frac{c^S}{p}}{\frac{c^B(b)}{p}+\frac{r+\delta}{\theta}\frac{k}{p}+\frac{1}{\theta}\frac{c^S}{p}}=0.5434. \tag{A28}$$

Hence, $\beta=0.5434$ as well. The credit entry condition (A18) yields

$$\phi=\frac{(1-\beta)\frac{c^F}{p}}{\beta\left[\frac{rc^B(b)/p}{m(\theta)}+\frac{c_1}{p}\right]}=0.0485. \tag{A29}$$

Hence, target (vii) implies $\mu_f=0.4494$. Next, the price equation (A23) yields

$$p=\frac{\eta\varepsilon/(r+s+\delta)}{1+\frac{\eta}{f(\phi)}\frac{c_1}{p}+\frac{\eta}{\phi f(\phi)}\frac{c^F}{p}-\frac{\eta s}{r+s+\delta}\frac{k}{p}-\frac{(1-\eta)(r+f(\phi))}{f(\phi)}\frac{k}{p}}=45.2712. \tag{A30}$$

The solution for the price implies $k=42.0435$, $c^S=2.3736$, $c_1=2.3107$, $c^F=0.135$. Thus, all the parameters are uniquely identified given the targeted moments.

Next, we proceed with the numerical exercise by deriving the implied shocks in ε, k, μ_f, and β. The four targets are: (i) the price increased by 52.31%; (ii) the time-to-sell decreased by 10.07%; (iii) the debt-to-price ratio increased by 9.28%; (iv) the mortgage-finding rate decreased by 3.02%. We again use primes to denote values at the new steady state, after the shocks have taken place. Thus, $p'=68.9514$, $f(\phi')'=1.98$, and the new debt-to-price ratio is 0.9071. Target (ii) yields $\theta'=1.4413$. Hence, using equation (A27), it follows that $k'=65.7604$. The repayment equation, (A17), together with target (iii) imply

$$\phi' = \frac{c^F/p'}{f(\phi')' \left[\frac{\rho'/(r+\delta)}{p'} - (1-d)\right]} = 0.0082. \tag{A31}$$

Hence, $\mu_f' = 0.179$. The buyer entry condition, (A21), implies $c^B(b') = 1.9973$. This, combined with the credit entry equation (A18) yields

$$\beta' = \frac{c^F}{c^F + \phi' \left[\frac{rc^B(b')}{m(\theta')} + c_1\right]} = 0.8622. \tag{A32}$$

Lastly, the price equation (A23) implies that $\varepsilon' = 1.6127$. Thus, the targets uniquely identify the four shocks in the numerical exercise.

The results of the counter-factual exercise are summarized in Table 6. Comparing the results with the ones in our baseline model shows that the alternative timing leads to the same conclusions as in the baseline exercise. Absent credit shocks, prices increase by 59.56%, time-to-sell by 54.15% and debt-to-price ration drops by 1.34%, compared to 60.31%, 84.29% and 1.86% respectively in the baseline model.

Alternative timing: simultaneous search

In this section we study an economy where agents are allowed to search for credit and housing simultaneously.

Economy

Denote by b_H, b_F, b_u buyers who are matched with a house, a financier, or not matched at all respectively. Similarly, let v_b denote vacancies matched with a buyer and v_u vacancies that are unmatched. For financiers we denote those matched with a buyer who is searching for a home by $\mathfrak{f}_b$ and those who are yet unmatched by $\mathfrak{f}_u$. The simple accounting identities below hold:

$$b = b_H + b_F + b_u, \tag{A33}$$

$$v = v_b + v_u, \tag{A34}$$

$$\mathfrak{f} = \mathfrak{f}_b + \mathfrak{f}_u, \tag{A35}$$

$$b_H = v_b, \tag{A36}$$

$$b_F = \mathfrak{f}_b. \tag{A37}$$

Given our notation, the market tightness in the housing market is given by $\theta \equiv (b_u + b_F)/v_u$ and the tightness on the credit market by $\phi \equiv (b_u + b_H)/\mathfrak{f}_u$.

Since buyers can search for a home and financing simultaneously, there is a chance that a seller meets a buyer who is already matched with a financier. We denote this probability by $\pi_F = b_F/(b_F + b_u)$. Similarly, if a financier matches with a buyer there is a probability $\pi_H = b_H/(b_H + b_u)$ that the buyer is already matched with a home. The Bellman equations for a buyer who is unmatched, matched with a home, and matched with a financier are given by:

$$rB_u = -c^B(b) + m(\theta)\left[B_H - B_u\right] + f(\phi)\left[B_F - B_u\right], \tag{A38}$$

$$rB_H = -c^B(b) + f(\phi)\left[H - B_H - dp_H - \frac{\rho_H}{r+\delta}\right], \tag{A39}$$

$$rB_F = -c^B(b) + m(\theta)\left[H - B_F - dp_F - \frac{\rho_F}{r+\delta}\right], \tag{A40}$$

where p_H and ρ_H are the price and repayment that result from Nash bargaining if the buyer is first matched with a house, and p_F and ρ_F are the price and repayment if the buyer is first matched with a financier instead.

Once a buyer finds a suitable house and secures financing she becomes a homeowner and her value function is given by

$$rH = \varepsilon - s\left[H - V_u\right] - \delta H. \tag{A41}$$

The Bellman equations for a vacancy that is unmatched and matched with a buyer looking for financing are

$$rV_u = -c^S + \theta m(\theta)\left[(1-\pi_F)(V_b - V_u) + \pi_F(p_F - V_u)\right] - \delta V_u, \tag{A42}$$

$$rV_b = -c^S + f(\phi)(p_H - V_b). \tag{A43}$$

For financiers the Bellman equations are analogously given by

$$rF_u = -c^F + \phi f(\phi)\left[(1-\pi_H)\left[F_b - F_u\right] + \pi_H\left[\frac{\rho_H}{r+\delta} - F_u - (1-d)p_H\right]\right], \tag{A44}$$

$$rF_b = -c^F + m(\theta)\left[\frac{\rho_F}{r+\delta} - F_b - (1-d)p_F\right]. \tag{A45}$$

The free entry conditions are $V_u = k$ and $F_u = B_u = 0$. The price and repayment are negotiated to maximize the Nash surplus:

$$p_H = \arg\max_{p'}\left[V_b - V_u\right]^{\eta}\left[B_H - B_u\right]^{1-\eta}, \tag{A46}$$

$$p_F = \arg\max_{p'}\left[p' - V_u\right]^{\eta}\left[H - B_F - dp' - \frac{\rho_F}{r+\delta}\right]^{1-\eta}, \tag{A47}$$

$$\rho_H = \arg\max_{\rho'}\left[\frac{\rho'}{r+\delta} - (1-d)p_H - F_u\right]^{\beta}\left[H - B_H - dp_H - \frac{\rho'}{r+\delta}\right]^{1-\beta}, \tag{A48}$$

$$\rho_F = \arg\max_{\rho'}\left[F_b - F_u\right]^{\beta}\left[B_F - B_u\right]^{1-\beta}. \tag{A49}$$

Equation (A48) implies that

$$(1-\beta)\left[\frac{\rho_H}{r+\delta} - (1-d)p_H - F_u\right] = \beta\left[H - B_H - dp_H - \frac{\rho_H}{r+\delta}\right]. \tag{A50}$$

Free entry, (A39) and (A43) along with (A46) and (A50) imply

$$\eta\left[B_H - B_u\right] = (1-\eta)\left[V_b - V_u\right]. \tag{A51}$$

Free entry and (A45) along with (A47) imply that

$$(1-\eta)\left[p_F - k\right] = \eta\left[H - B_F - dp_F - \frac{\rho_F}{r+\delta}\right]. \tag{A52}$$

Combining free entry with (A49) yields

$$\beta B_F = (1-\beta)F_B. \tag{A53}$$

The steady state conditions below along with equations (A38), (A39), (A40), (A41), (A42), (A43), (A44), (A45), (A50), (A51), (A52), (A53) and the flow accounting conditions $b_u m(\theta) = b_H f(\phi)$ and $b_u f(\phi) = b_F m(\theta)$ close the model:

$$(s+\delta)h = m(\theta)b_F + f(\phi)b_H, \tag{A54}$$

$$v_b f(\phi) = v_u(1-\pi_F)\theta m(\theta), \tag{A55}$$

$$\mathfrak{f}_b m(\theta) = \mathfrak{f}_u(1-\pi_H)\phi f(\phi). \tag{A56}$$

Numerical Exercise

We calibrate the model using the same calibration strategy as in the main text. One notable difference is that in the current specification the buyer's expected cost while searching for both credit and housing is governed by the flow cost $c^B(b)$. As a result we drop the moments which target the expected search costs on each market and combine them into one moment that targets the total expected search cost. In particular, we set $r = 0.012$, $\varepsilon = 1$, $\delta = 0.004$, $s = 0.0238$, $\alpha = 0.5$, $\alpha_f = 0.5$, $\gamma = 2$, $\bar{c} = 0.1$, and $d = 0.2$. The rest of the parameters are set to match the following 7 moments: (i) time-to-sell equals 1.4625 quarters; (ii) time-to-buy equals time-to-sell; (iii) the average cost for the seller is 5.1% of the price; (iv) the buyer's expected cost is 8% of the price; (v) Moody's Aaa spread is 1.499%; (vi) the average time to approve a mortgage is 0.4898; (vii) the buyer's bargaining strengths in the credit and housing market are equal. This yields $c^S = 1.6475$, $k = 43.8340$, $\beta = \eta = 0.6028$, $\mu = 0.8898$, $c^F = 0.1408$ and $\mu_f = 0.5212$. Furthermore, the calibration implies that the average cost the buyer incurs while searching for a home is 5.32% of the price, and 2.68% while searching for financing. These are very close to the moments in the calibration of the baseline model.

To identify the shocks in μ_f, β, ε, and k we use the same four moments. Namely, (i) the price increased by 52.31%; (ii) the time-to-sell decreased by 10.07%; (iii) the debt-to-price ratio increased by 9.28%; (iv) the mortgage-finding rate decreased by 3.02%. The resulting shocks are: 61.98% decrease in μ_f; 46.05% increase in β; 65.66% increase in ε; 56.02% increase in k. This results in the counter-factual exercises summarized in Table 7. The results under simultaneous search are very similar to the ones from our baseline model. Debt-to-price changes slightly more compared the the other timing assumptions due to the fact that simultaneous search requires a different calibration, given the implied search costs. However, the main result of the paper still holds: credit shocks contributed relatively less to the build-up in prices, but were quantitatively important to account for the observed build-up of mortgage debt and the behavior of liquidity in the housing market.

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Tables and Figures

Table 1: Equilibrium

Variable	Equilibrium Quantity
Price	44.59
Credit Market Tightness	0.04
Buyers	4.09
Vacancies	4.09
Sales	2.80
Mortgage Size	37.35
Financing Fee	4.71%

Note.- Table 1 reports the equilibrium quantities in the original steady state given our calibration. See section 4 for details.

Table 2: Size of Calibrated Shocks, Baseline

Shock		Data Target	
Variable	% Change	Variable	% Change
ε	62.81%	Price	52.31%
k	56.02%	Time-to-Sell	-10.07%
μ_f	-56.46%	Mortgage Originations to Applications Ratio	-3.02%
β	52.77%	Mortgage Debt to Price Ratio	9.28%

Note.- Table 2 reports the size of the shocks to $\{\varepsilon, k, \mu_f, \beta\}$ in the baseline model with a constant financier cost c^F required to match the movement in house prices, time-to-sell, the ratio of originations to loan applications and the mortgage debt to price ratio. These targets uniquely determine the values for $\{\varepsilon, k, \mu_f, \beta\}$. See section 4.2 for details.

Table 3: Impact of Credit Shocks, Baseline

No Change in Credit Market Shocks μ_f, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	60.31%	84.29%	-1.86%
No Change in Matching Efficiency, μ_f			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	58.77%	66.12%	1.24%
No Change in Bargaining Strength, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	55.97%	33.13%	1.59%

Note.- Table 3 reports the counterfactual changes in house prices, time-to-sell and the debt-to-price ratio absent credit shocks in the baseline model with constant financier cost c^F. See section 4 for details.

Table 4: Size of Calibrated Shocks, Variable Cost c^F

Shock		Data Target	
Variable	% Change	Variable	% Change
ε	62.81%	Price	52.31%
k	56.02%	Time-to-Sell	−10.07%
c^F	−11.40%	Aaa Corporate bond yield relative to 10y constant maturity Treasury bond	−41.96%
μ_f	−59.08%	Mortgage Originations to Applications Ratio	−3.02%
β	52.84%	Mortgage Debt to Price Ratio	9.28%

Note.- Table 4 reports the size of the shocks to $\{\varepsilon, k, c^F, \mu_f, \beta\}$ required to match the movement in house prices, time-to-sell, the spread between the Aaa corporate bonds yield and a 10 years constant maturity Treasury bond, the ratio of originations to loan applications and the mortgage debt to price ratio. These targets uniquely determine the values for $\{\varepsilon, k, c^F, \mu_f, \beta\}$. See section 4.3 for details.

Table 5: Impact of Credit Shocks, Variable Cost c^F

No Change in Credit Market Shocks c^F, μ_f, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	60.31%	84.29%	-1.86%
No Change in Liquidity Costs, c^F			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	51.52%	-19.30%	10.31%
No Change in Matching Efficiency, μ_f			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	59.07%	69.63%	0.89%
No Change in Bargaining Strength, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	55.98%	33.24%	1.57%

Note.- Table 5 reports the counterfactual changes in house prices, time-to-sell and the debt-to-price ratio absent credit shocks in the model with variable financier cost c^F. See section 4 for details.

Table 6: Impact of Credit Shocks, Alternative Timing

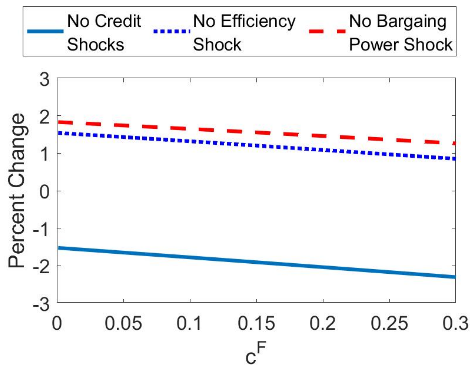
No Change in Credit Market Shocks μ_f, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	59.56%	54.15%	−1.34%
No Change in Matching Efficiency, μ_f			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	57.98%	25.83%	1.67%
No Change in Bargaining Strength, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	56.01%	56.87%	1.88%

Note.- Table 6 reports the counterfactual changes in house prices, time-to-sell and the debt-to-price ratio absent credit shocks in the alternative model in which households must first search for a house and then for financing. See the appendix for details.

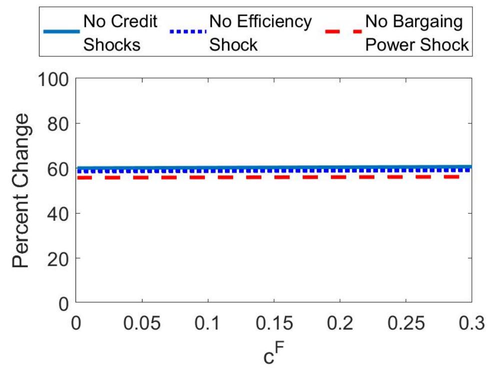
Table 7: Impact of Credit Shocks, Simultaneous Search

No Change in Credit Market Shocks μ_f, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	55.11%	49.63%	6.97%
No Change in Matching Efficiency, μ_f			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	52.18%	7.79%	11.07%
No Change in Bargaining Strength, β			
Variable	Price	Time-to-Sell	Debt-to-Price
Counter-factual Change	56.37%	66.95%	4.97%

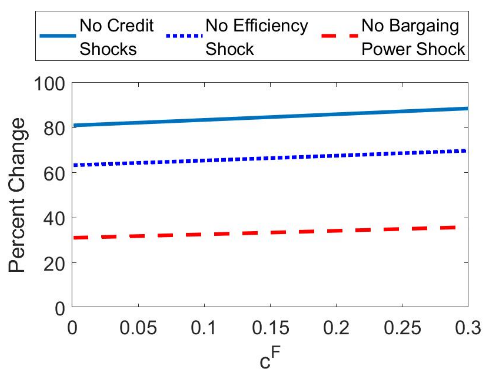
Note.- Table 7 reports the counterfactual changes in house prices, time-to-sell and the debt-to-price ratio absent credit shocks in the alternative model in which households simultaneously search for houses and mortgages. See the appendix for details.



(a) Debt-to-Price Ratio

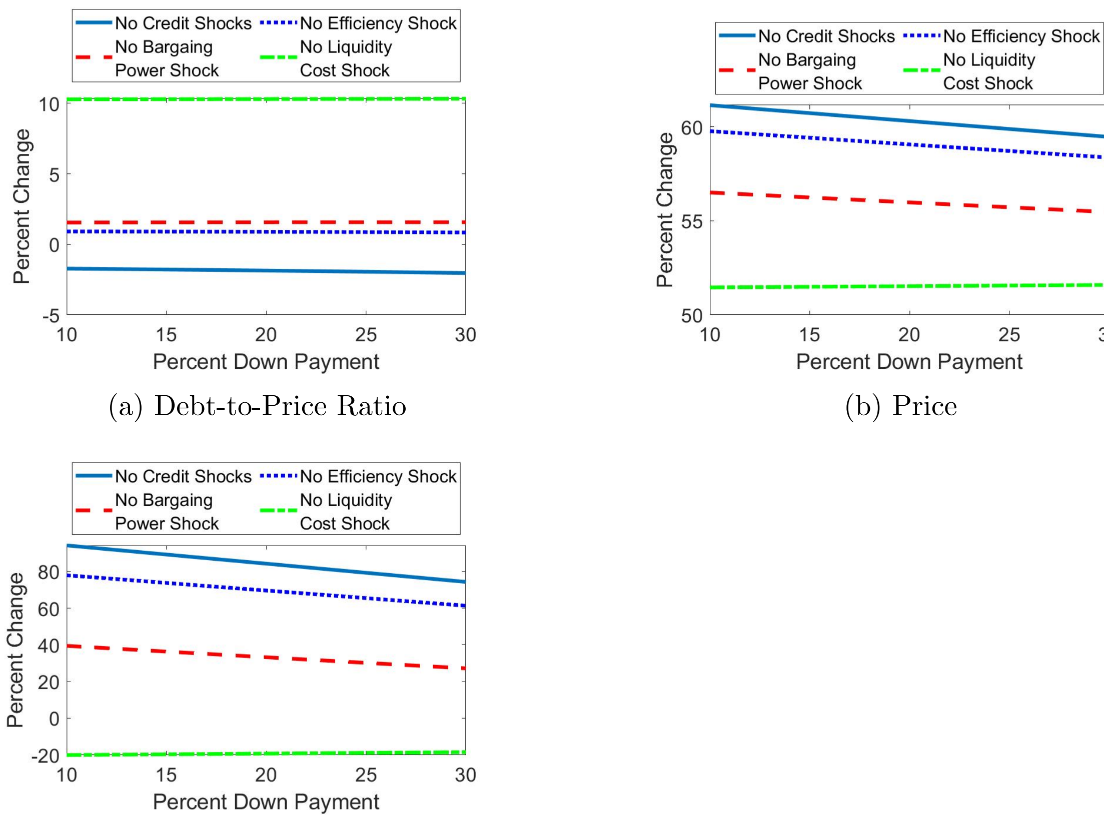


(b) Price



(c) Time-to-Sell

Figure 3: Counterfactual Changes for Different Costs c^F



(a) Debt-to-Price Ratio

(b) Price

(c) Time-to-Sell

Figure 4: Counterfactual Changes for Different Downpayments Values