Efficiency in the Housing Market with Search Frictions*

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Abstract

This paper studies efficiency in the housing market in the presence of search frictions and endogenous entry of buyers and sellers. These two features are essential to explain the housing market stylized facts, in particular to generate an upward-sloping Beveridge Curve in the housing market. Search frictions and endogenous entry create two externalities in the market. First, there is a congestion externality common to markets with search frictions. Sellers do not internalize the effect of listing a house for sale on other sellers' probability of finding a buyer, and on buyers' home finding rate. Second, the endogenous entry of buyers leads to a composition externality, as new entrants in the markets value housing less and worsen the distribution of buyers' valuations and surplus. The equilibrium is inefficient even when the Hosios-Pissarides-Mortensen condition holds. We quantify the size of these externalities and how far the observed housing market is from the optimal allocation. The optimal vacancy rate, time-to-sell, and vacancies are about half their equilibrium counterparts, whereas the optimal number of buyers and homeowners are slightly above their decentralized equilibrium values. Finally, we investigate the effect of housing market policies on the equilibrium and how they can restore efficiency in the housing market.

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1 Introduction

Any model attempting to describe the housing market must include two essential features: search and matching frictions and entry of both buyers and sellers. Search frictions are necessary to capture that it takes time for buyers to find a suitable house and for sellers to find a buyer, i.e. that search is a costly and time-consuming process. The large fluctuations in time to sell and the co-movement between houses for sale and time-to-sell, and the large dispersion in prices even after controlling for housing observables, are clear indications of the presence of search frictions in the housing market. Entry of both buyers and sellers is essential to account for the key stylized facts in the housing market: prices are positively correlated with sales and vacancies (i.e. houses for sale), but negatively correlated with time-to-sell. In other words, when house prices are high many houses are listed for sale, there is a high volume of sale transactions, and houses sell fast. These stylized facts imply that the Beveridge Curve (i.e. the correlation between buyers and vacancies) in the housing market is upward sloping, as Gabrovski and Ortego-Marti (2019) show. Search models of the housing market without an endogenous entry of both buyers and sellers generate a counterfactual downward sloping Beveridge Curve.

These two essential characteristics of the housing market, search and matching frictions and the endogenous entry of buyers, lead to two externalities. The first externality includes both congestion and market thickness externalities that arise in markets with search frictions (Hosios (1990), Pissarides (2000)). When a seller posts a vacancy, she does not internalize that by doing so she makes it harder for other sellers to find a buyer (congestion externality), and that she makes it easier for buyers to find a home (thick market externalities). Absent the endogenous entry of buyers, the efficient allocation is restored if the Hosios-Mortensen-Pissarides condition holds, i.e. if the bargaining power of buyers equals the elasticity of the matching rate. Under this condition, the congestion and thick market externalities fully offset each other. However, the equilibrium is not efficient even under Hosios-Mortensen-Pissarides condition because the endogenous entry of buyers leads to an additional composition externality. As more buyers enter the market, the average the composition of buyers worsens, as buyers with lower valuation of being a homeowner enter the market. Although this composition externality is also present in models of the labor market with heterogenous workers and labor force participation, our framework delivers an upward sloping Beveridge Curve, consistent with the stylized facts in the housing market.

This paper studies efficiency in the housing market in the presence of both congestion and composition externalities. In addition, using empirical evidence on housing market flows and dispersion on prices, we ask the following questions: how far is the housing market from the optimal allocation? Can housing market policies restore efficiency?

To answer these questions, we develop a search and matching model of the housing market with an endogenous entry of both buyers and sellers. To model the endogenous entry of buyers, we assume that workers are heterogenous in their valuation of owning a house. Entry in this environment is determined by the marginal household who is indifferent between participating in the market and remaining idle. However, the precise entry mechanism is not essential. We show that a model similar to Gabrovski and Ortego-Marti (2019), in which entry is driven by rising search costs as more buyers enter the market, gives very similar efficiency results. The advantage with using a model with heterogeneity is that it allows us to quantify the entry mechanism more precisely using data on house price dispersion, and provides a significantly tighter quantitative calibration of entry.

We begin by characterizing the decentralized equilibrium. The equilibrium is determined by an entry condition for sellers, an entry condition for buyers and by equilibrium prices from bargaining. In addition, we show that the entry mechanism leads to an upward sloping Beveridge Curve, consistent with the stylized facts in the housing market. We then study the social planner's problem and find the optimal allocation. The equilibrium is inefficient even if the Hosios-Mortensen-Pissarides condition holds, because the planner lacks a tool with which to regulate the entry of buyers. Intuitively, in the decentralized economy households only evaluate if, given their utility of owning a home, it is worthwhile to enter the market. They do not, however, internalize their effect on the composition of buyers and, therefore, on the average surplus in the economy. By contrast, the planner internalizes the effect on the distribution of buyers' valuation and surplus.[1] A natural question, given that the housing market is inefficient, is what is the effect of housing market policies on the equilibrium and whether they restore efficiency.

To answer these questions we calibrate the model to the U.S. economy and study four policies: i) taxes on new construction; ii) taxes on profits from housing sales; iii) transfer fees to the buyer; iv) property taxes. We study these policies because they affect the incentives to enter for both buyers and sellers and how the trade surplus is split. We find that the optimal number of vacancies, vacancy rate and time-to-sell are about half their values in the decentralized economy, whereas the optimal number of buyers and number of homeowners are slightly above their decentralized equilibrium counterparts. Intuitively, the planner finds it optimal to increase home-ownership. However, she chooses to not achieve this through the means of faster matching rates for buyers because new home construction is costly. Instead

[1] Although studying directed search is challenging in the environment with heterogeneity, we show that when entry is instead determined by buyers' increasing search costs the equilibrium is inefficient even when search is directed. As with the environment with random search, the planner needs an additional tool to regulate the optimal entry of buyers.

she decreases the number of available housing units for sale and instructs more buyers to enter the market. This insures that home-ownership rates will be high and, at the same time, few houses will be idle.

Because we calibrate our economy to the U.S., our benchmark equilibrium features positive tax rates. We compare this equilibrium to the one absent any government intervention. We find that if there were no taxes, the vacancy rates and time-to-sell would be closer to their efficient level, but the number of homeowners would overshoot its optimal level by a significant amount. In addition, we study potential policies that can implement the planner's allocation in the decentralized economy. Since the model features two externalities: the congestion and composition ones, the planner will in general need at least two policy tools. We show that a combination of either taxes on profits from housing sales and property/transfer taxes or taxes on profits from housing sales and a subsidy to housing construction can implement the constrained-efficient allocation.

Related literature. Since the seminal work in Arnott (1989) and Wheaton (1990), the literature has extensively used search and matching models à la Diamond-Mortensen-Pissarides to study the housing market. This large literature includes Anenberg (2016), Arefeva (2020), Burnside *et al.* (2016), Diaz and Jerez (2013), Gabrovski and Ortego-Marti (2019, 2021a,b,c), Garriga and Hedlund (2020), Genesove and Han (2012), Guren (2018); Guren and McQuade (2018), Head *et al.* (2014, 2016), Head *et al.* (2016), Hedlund (2016) Kotova and Zhang (2020), Krainer (2001), Ngai and Tenreyro (2014),Ngai and Sheedy (2020), Novy-Marx (2009), Piazzesi and Schneider (2009), Piazzesi *et al.* (2020) and Smith (2020). Compared to these papers, we study efficiency in the housing market in a framework with search frictions and and an endogenous entry of buyers and sellers mechanism that delivers the observed positive correlation between buyers and vacancies, i.e. an upward-sloping Beveridge Curve. In addition, we characterize the congestion and composition externalities in the housing market and quantify how far the observed equilibrium is from the optimal allocation. Further, we study how labor market policies affect the equilibrium and can restore efficiency.

Our paper is also closely related to papers that study efficiency in labor markets with search frictions and compositional effects that arise from labor force participation. Papers in this literature include Albrecht *et al.* (2010), Griffy and Masters (2021), Julien and Mangin (2017) and Masters (2015). Aside from the fact that we study the housing market instead of the labor market, quantitatively we derive a mapping between the two externalities in our model, in particular the composition externality, and data on both housing market flows and the distribution of house prices. This allow us to quantify in a reliable way how far the housing market in the US is from the efficient allocation. In addition, relative to models of the labor market we show that entry of both buyers and sellers leads to an upward sloping Beveridge Curve in the housing market, and characterize the conditions under which this positive correlation between buyers and vacancies holds, a crucial property to match the housing market facts. In search models with labor market participation the Beveridge Curve is downward-sloping, consistent with the labor market stylized facts.

2 The decentralized economy with entry of buyers

We begin with a description of the decentralized economy. The main ingredients of the model are the following. First, there are search and matching frictions, which capture that it takes time for buyers to find a house and for sellers to find a buyer for their listed property. Second, there is free entry of both buyers and sellers. As Gabrovski and Ortego-Marti (2019) show, the double entry of buyers and sellers is crucial to match the stylized facts in the housing market, namely that prices are positively correlated with sales and vacancies (i.e. houses for sale) and negatively correlated with time-to-sell (TTS). Combined, these stylized facts imply that buyers and vacancies are positively correlated, i.e. the Beveridge Curve in the housing market is upward sloping. We model the endogenous entry of buyers by assuming that workers are heterogenous in in how much they value owning a house. In section 6 we show that the same inefficiency arises if buyers are homogenous, but instead the entry of buyers is driven by search costs that are increasing in the number of buyers. As Gabrovski and Ortego-Marti (2019) point out, both ways of modeling entry account for the housing market stylized facts and deliver an upward sloping Beveridge Curve. However, while the model with congestion externalities is more tractable for business cycle simulations, the version with heterogeneity provides a better mapping between the model and the data when calibrating the optimal allocation. Finally, a key feature of the model is that prices are determined by bargaining.

2.1 Environment

Time is continuous. Agents are risk-neutral, infinitely lived and discount the future at a rate r. There are two types of agents: households and developers. Households either own a home, search for a house (i.e. they are buyers), or choose not to participate in the market. Developers may enter the housing market and build a new home at a cost k if not enough existing houses are listed for sale by households through separations. Upon building a house, developers post a vacancy and search for buyers. Houses are identical, regardless of whether they are old or newly built. To capture depreciation in a tractable way, houses are destroyed at an exogenous rate δ.

It takes time for buyers to find a house and for sellers to sell their home. We capture these search frictions in the housing market by assuming a matching function $M(b, v)$, where b is the measure of buyers and v the measure of vacancies or houses for sale—we use both terms interchangeably. The matching function satisfies the usual properties: it is increasing in each of its terms, concave and displays constant returns to scale. Let $\theta \equiv b/v$ denote the housing market tightness. The matching function implies that buyers find homes at a rate $m(\theta) \equiv M(b, v)/b = M(1, \theta^{-1})$ and that sellers find buyers at a rate $\theta m(\theta) = M(b, v)/v = M(\theta, 1)$. As market tightness increases, the finding rate for buyers $m(\theta)$ decreases and the finding rate for sellers $\theta m(\theta)$ increases. Intuitively, an increase in market tightness implies that vacancies are relatively more scarce, so it becomes harder for buyers to find a house, but easier for a seller to find a buyer. In addition to these flows, some homeowners become separated from their house at an exogenous rate s, capturing that the household may need to relocate because of their job, may need to move to a different type of home, and so on. Once a separation shock occurs, households put their house for sale. Buyers incur flow costs c^B while searching for a house, and sellers incur flow posting costs c^S.

Households are heterogenous in the utility they derive from owning a home. Let ε denote the household's individual utility from owning a home, and let x denote the utility from homeownership that is common to all household. Overall, households derive a utility εx from owning a home. The parameter x allows us to capture demand shocks and provides an easy way to analyze the model's comparative statics, but it is not essential for the study of efficiency. The utility ε is a permanent household characteristic and captures households' heterogeneity in how they value owning a home, i.e. a household with individual utility ε derives a utility εx from all houses. Assume that ε follows a known distribution $F(\varepsilon)$, and that the distribution of $F(\varepsilon)$ is such that the surplus from matching is always positive. This assumption is implicit in all models without endogenous separation or formation of matches. See Gabrovski and Ortego-Marti (2021c) for a housing model with endogenous separations, in which the buyer and the house have a match-specific utility, so some matches are not formed or maintained.

There is free entry of both buyers and sellers. Given free entry of buyers, households keep entering the market until the value of becoming a buyer equals zero, the value of their outside option. Intuitively, this entry condition for buyers pins down the utility of the marginal buyer, and determines the endogenous measure of buyers. Similarly, free entry of sellers implies that sellers enter the market until the value of a vacancy equals the construction cost k, regardless of whether the house is newly built or existing (all houses are identical). As is common in markets with search frictions, there are rents from matching. We assume that prices are determined by Nash Bargaining (Nash (1950), Rubinstein (1982)), where β denotes the buyer's bargaining strength. Once a buyer and a seller are matched, the buyer pays the price $p(\varepsilon)$ to the seller. As section 2.2 below shows, the price depends on the size of the surplus and, therefore, the household's utility from owning a home ε.

Similar to many papers in the literature, we do not model the rental market and treat it as a separate market (see, for example, Diaz and Jerez (2013) and Ngai and Tenreyro (2014), among others). This assumption is well supported empirically by Glaeser and Gyourko (2007), who find that rental and owner occupied homes have very different characteristics, and that there is no arbitrage between both types of homes. In addition, Bachmann and Cooper (2014) find that most flows are within each rental/owner category. In addition, flows from the owner to rental segment are acyclical, and turnover is unrelated to vacancies in the rental market. Overall, the empirical evidence supports the view that the rental market can be treated as a separate market.

2.2 Equilibrium

Let $B(\varepsilon)$ and $H(\varepsilon)$ denote the value functions of a buyer and homeowner with utility ε, and V denote the value function of a vacancy. The values functions satisfy the following Bellman equations

$$rB(\varepsilon) = \max\{0, -c^B + m(\theta)[H(\varepsilon) - B(\varepsilon) - p(\varepsilon)]\}, \tag{1}$$

$$rH(\varepsilon) = \varepsilon x - s[H(\varepsilon) - V - B(\varepsilon)] - \delta[H(\varepsilon) - B(\varepsilon)]. \tag{2}$$

Intuitively, (1) captures that buyers can choose whether to enter the housing market. When they search for a house, they incur flow costs c^B. At a rate $m(\theta)$, buyers find a house, pay the house price $p(\varepsilon)$ and become a homeowner, which carries a net gain $H(\varepsilon) - B(\varepsilon) - p(\varepsilon)$. Equation (2) captures that a homeowner derives a utility εx from owning a house, which depends on her individual utility ε of owning a house. At a rate s a separation shock occurs, and the household lists her house for sale, which has a value V, and decides whether to become a buyer. At a rate δ the house is destroyed, which implies a net loss of $H(\varepsilon) - B(\varepsilon)$.

The Bellman equation for a seller listing a house is

$$rV = -c^s + \theta m(\theta) \int_{\varepsilon_R}^{\infty} (p(\varepsilon) - V) \frac{dF(\varepsilon)}{1 - F(\varepsilon_R)} - \delta V. \tag{3}$$

Sellers incur flow costs c^S while they search for buyers. At a rate $\theta m(\theta)$, they meet a buyer from the distribution $F(\varepsilon)/(1 - F(\varepsilon_R))$. The vacancy is also subject to a destruction shock, which happens at a rate δ.

The buyer and the seller split the surplus from matching according to Nash Bargaining. Let $S^B(\varepsilon)$ and $S^S(\varepsilon)$ denote the surplus of the buyer and seller when the buyer's valuation of homeownership is ε, and let $S(\varepsilon) \equiv S^B(\varepsilon) + S^S(\varepsilon)$ denote the total surplus from matching. Prices solve the following Nash Bargaining problem

$$p(\varepsilon) = \arg\max_{p(\varepsilon)} \left(S^B(\varepsilon)\right)^{\beta} \left(S^S(\varepsilon)\right)^{1-\beta}, \text{ for all } \varepsilon \geq \varepsilon_R. \tag{4}$$

The first order condition to the above problem gives the Nash sharing rule

$$\beta S^S(\varepsilon) = (1-\beta) S^B(\varepsilon), \text{ for all } \varepsilon \geq \varepsilon_R. \tag{5}$$

In particular, the above sharing rule implies that the buyer extracts a fraction β of the surplus and the seller a fraction $1-\beta$, i.e. $S^B(\varepsilon) = \beta S(\varepsilon)$ and $S^S(\varepsilon) = (1-\beta)S(\varepsilon)$.

Free entry of sellers implies that sellers enter the market until the value of a vacancy covers the construction costs k. On the buyer's side, households participate in the market as long as the value of being a buyer $B(\varepsilon)$ is greater than zero. Given that $B(\varepsilon)$ is strictly increasing in the utility ε, free entry of buyers implies that there exists a unique reservation utility ε_R that satisfies $B(\varepsilon_R) = 0$. Buyers with a utility $\varepsilon \geq \varepsilon_R$ participate in the market. In sum, free entry of buyers and sellers imply

$$V = k, \tag{6}$$

$$B(\varepsilon_R) = 0. \tag{7}$$

Intuitively, given a utility of the marginal buyer ε_R, free entry of sellers pins down the market tightness. Given the equilibrium market tightness, free entry of buyers pins down the marginal buyer ε_R and, therefore, the measure of buyers.

Combining the Bellman equations for the buyer and seller (1) and (2) with free entry for sellers $V = k$ implies, for all $\varepsilon \geq \varepsilon_R$

$$S^B(\varepsilon) = \frac{\varepsilon x + c^B + sk + \beta m(\theta) k}{r + s + \delta + \beta m(\theta)} - p(\varepsilon), \tag{8}$$

$$S^S(\varepsilon) = p(\varepsilon) - k. \tag{9}$$

Combining the above surpluses with the Nash bargaining rule (5) gives the equilibrium price (PP) condition

$$\text{(PP):} \qquad p(\varepsilon) = k + (1-\beta)\left(\frac{\varepsilon x + c^B + sk + \beta m(\theta) k}{r + s + \delta + \beta m(\theta)} - k\right). \tag{10}$$

Intuitively, due to Nash Bargaining sellers are compensated for their outside option, which equals the value of a house for sale k, and receive a share $1-\beta$ of the surplus.

Free entry of sellers $V = k$, together with the Bellman equation for a vacancy (3) gives the Housing Entry (HE) condition

$$\text{(HE):} \qquad \frac{(r+\delta)k + c^S}{\theta m(\theta)} = \bar{p} - k, \tag{11}$$

where $\bar{p} \equiv \int_{\varepsilon_R}^{\infty} p(\varepsilon)dF(\varepsilon)/(1-F(\varepsilon_R))$ is the observed average price. Intuitively, the left hand-side captures the expected costs from finding a buyer, which include the search costs c^S and the user cost $(r+\delta)k$ for the expected duration of the vacancy $1/(\theta m(\theta))$. The right-hand side corresponds to the expected seller's surplus, after taking into account the distribution of buyers' valuation in the market. The Housing Entry (HE) condition captures that developers keep entering the market until the expected cost of finding a buyer equals the expected surplus from selling the house. Integrating prices in (10) and substituting into (11) gives

$$\text{(HE):} \qquad \frac{(r+\delta)k + c^S}{\theta m(\theta)} = (1-\beta)\left[\frac{\bar{\varepsilon}x + c^B - (r+\delta)k}{r+s+\delta+\beta m(\theta)}\right] \tag{12}$$

where $\bar{\varepsilon} \equiv E(\varepsilon|\varepsilon \geq \varepsilon_R) = \int_{\varepsilon_R}^{\infty} \varepsilon dF(\varepsilon)/(1-F(\varepsilon_R))$.

Free entry $B(\varepsilon_R) = 0$ gives the Buyer's Entry (BE) condition

$$\text{(BE):} \qquad \frac{c^B}{m(\theta)} = \beta\left[\frac{\varepsilon_R x - (r+\delta)k}{r+s+\delta}\right]. \tag{13}$$

Intuitively, the above equation captures that buyers keep entering the market until the marginal buyer's expected cost of finding a home (the left-hand side of (13)) equals the buyer's surplus of being a homeowner, which equals the present discounted value of the return ε_R net of the user cost $(r+\delta)k$, using the effective discount is $r+s+\delta$. The BE condition corresponds to the Beveridge Curve in the housing market. It plays a similar role to the BE condition in Gabrovski and Ortego-Marti (2019) and determines the measure of buyers, given the equilibrium market tightness that satisfies the HE condition (12).

2.3 Entry of buyers and the Beveridge Curve

The BE curve defines a relationship between the measure of buyers and vacancies, and corresponds to the Beveridge Curve in the housing market. Although the BE curve may be downward sloping for some combination of parameters, it is clearly upward sloping for any standard calibration. As in Gabrovski and Ortego-Marti (2019), the double (endogenous) entry of buyers and vacancies is what allows the model to match the stylized facts of the housing market, in particular the positive correlation between buyers and vacancies, eventhough the entry mechanism in this paper is driven by heterogeneity, whereas it is driven by congestion in the cost of searching in Gabrovski and Ortego-Marti (2019).

The slope of the BE curve depends on two opposite effects. On the one hand, more vacancies lowers market tightness, which makes it easier for buyers to find a house and induces entry of buyers. On the other hand, as buyers find homes more quickly the stock of buyers depletes, which is the usual mechanism in search models of housing without buyer entry—and which delivers a counterfactual downward sloping Beveridge Curve in the absence of endogenous buyers' entry. Whether the BE Curve is upward sloping depends on which effect dominates. Given housing market flows and for a standard calibration, the first effect dominates and the BE curve is upward sloping, consistent with the housing market stylized facts. By contrast, the Beveridge Curve in labor markets is downward sloping. Relative to the housing market, entry into the labor market is not as sensitive as in the housing market, which is likely a reflection of how essential labor income is for households' wealth accumulation—for the vast majority of households, most of their wealth comes from labor income.

To see this more clearly, let h denote the homeownership rate, i.e. the fraction of households participating in the market who own a home. The number of buyers is then given by

$$b = N(1 - F(\varepsilon_R))(1 - h). \tag{14}$$

where N is the large measure of potential buyers and is constant. Increasing vacancies lowers market tightness θ, which lowers the utility of the marginal buyer ε_R, i.e. there is more entry of buyers. This effect leads to a positive correlation between buyers b and vacancies v. However, a lower θ lowers the fraction of market participants who are buyers $1-h$, since they find homes more quickly. Whether the BE curve describes a positive of negative relationship between buyers and vacancies depends on which effect dominates.

Using that in the steady state the flows into homeownership equal the flows out of it gives that

$$h = \frac{m(\theta)}{m(\theta) + s + \delta}. \tag{15}$$

Let $\alpha \equiv -m'(\theta) \cdot \theta / m(\theta) > 0$ denote the elasticity of the matching rate $m(\theta)$ and $f(\varepsilon)$ the pdf of the distribution $F(\varepsilon)$. Log-differentiating the above expressions and totally differentiating the (BE) curve gives the following elasticity $\epsilon_{b,v} \equiv (db/dv) \cdot (v/b)$ of buyers with respect to vacancies

$$\epsilon_{b,v} = -\frac{\Delta(\theta, \varepsilon_R)}{1 - \Delta(\theta, \varepsilon_R)}, \tag{16}$$

where $\Delta(\theta, \varepsilon_R)$ is given by

$$\Delta(\theta, \varepsilon_R) = \alpha \left[-\frac{f(\varepsilon_R)\varepsilon_R}{1 - F(\varepsilon_R)} \frac{\frac{c^B}{m(\theta)}}{\frac{c^B}{m(\theta)} + \frac{(r+\delta)k}{r+s+\delta}} + \frac{m(\theta)}{m(\theta) + s + \delta} \right]. \tag{17}$$

Using the (BE) condition (13) to substitute $\varepsilon_R \equiv \varepsilon_R(\theta)$ gives an expression that depends only on θ and parameters. Given any standard calibration $\Delta(\theta, \varepsilon_R(\theta)) < 0$, for all $\theta > 0$, which implies an upward-sloping BE curve. In addition, in the quantitative section 5 we show that in response to demand and supply shocks, buyers and vacancies move in the same direction, which is what allows the model to match the stylized facts of the housing markets.

3 The social planner's allocation

The social planner faces two externalities. First, there are the usual congestion and thick market externalities in markets with search frictions. When sellers list a house for sale, they do not internalize that this makes it harder for other sellers to find a buyer (congestion externality) and easier for buyers to find a house (thick market externality). Second, the planner faces is a composition externality. When buyers decide whether to participate in the market, they do not internalize that they worsen the distribution of utilities. As more households participate in the market, they value housing less. The average utility, and therefore surplus, in the economy declines as more households participate in the market. When the planner internalizes both externalities, the Hosios-Mortensen-Pissarides condition is not sufficient to restore the efficient allocation. Intuitively, this condition controls for the congestion externality, but an additional policy is required to restore entry of buyers to the efficient level.

Let c denote new construction and $\tilde{h}$ denote the number of homeowners. As before, N is a constant large measure of potential buyers. We express buyers as a function of the total measure of homeowners $\tilde{h}$ instead of using the fraction of market participants who are homeowners h, as it simplifies the derivations. The planner maximizes

$$\max_{h,v,\theta,\varepsilon_R,c} \int_0^\infty e^{-rt} \left\{ \left(\int_{\varepsilon_R}^\infty \varepsilon x \frac{dF(\varepsilon)}{1-F(\varepsilon_R)} \right) \tilde{h} - [N(1-F(\varepsilon_R)) - \tilde{h}]c^B - vc^S - ck \right\} dt \qquad (18)$$

subject to

$$\dot{\tilde{h}} = v\theta m(\theta) - (s+\delta)\tilde{h}, \qquad (19)$$

$$\dot{v} = e + sh - \delta v - v\theta m(\theta), \qquad (20)$$

$$N(1-F(\varepsilon_R)) - \tilde{h} = \theta v. \qquad (21)$$

The social planner maximizes the present discounted value of the overall utility from homeownership, taking into account households heterogenous valuations and the amount of entry, net of buyers' search cost, vacancy cost and construction costs. The constraints on the planner's problem include the law of motions for homeownership and vacancies, and the relationship between buyers, vacancies and market tightness.[2]

In the steady state, the first order conditions of the planners give the optimal allocation $\{\theta, \varepsilon\}$, which is determined by

$$\frac{(r+\delta)k + c^S}{\theta m(\theta)} = \alpha \left\{ \frac{[(1-h)\bar{\varepsilon} + h\varepsilon_R]x - (r+\delta)k}{r+s+\delta} \right\}, \qquad (22)$$

$$\frac{c^B}{m(\theta)} = \left(\frac{1-\alpha}{\alpha}\right) \frac{(r+\delta)k + c^S}{\theta m(\theta)} - \frac{xh(\bar{\varepsilon} - \varepsilon_R)}{m(\theta)}. \qquad (23)$$

The appendix includes the derivation. Comparing the planner's first-order conditions with the corresponding HE and BE conditions in the decentralized economy (12) and (13) shows that the Hosios condition does not restore efficiency. The optimal allocation reflects that the planner does not only care about the marginal buyer, she is also concerned about the average composition of buyers. By contrast, in the decentralized equilibrium only the marginal buyer matters for entry. When making their decision on whether to enter the housing market, households simply evaluate whether their utility of owning a home yields a positive value of becoming a buyer, i.e. they compare their ε to the marginal value ε_R. If their utility ε is greater than the marginal value ε_R they enter the market. They do not internalize the effect of their entry on the composition of buyers, which affects the overall surplus in matches. Therefore, the decentralized equilibrium is inefficient even when the Hosios-Mortensen-Pissarides condition is satisfied, because of the additional composition externality.

[2] Obviously, using the last constraint to replace θ and then solving the planner's problem gives the same solution, but the above problem makes the exposition more intuitive.

4 Decentralized economy with housing policies

In this section we derive the equilibrium in the decentralized economy with housing market policies. We consider four housing policies. First, homeowners pay property taxes τ_p on their home. Second, buyers pay taxes τ_b when they purchase a house. On the seller side, sellers pay a tax τ_s upon selling the house, which we assume applies to the net price $p(\varepsilon)-V$. Finally, construction may be taxed or subsidized at a rate τ_k, where $\tau_k > 0$ corresponds to a tax on construction and $\tau_k < 0$ to a subsidy. The rest of the environment is the same as in section 2. The Bellman equations are given by

$$rB(\varepsilon) = -c^B + m(\theta)[H(\varepsilon) - B(\varepsilon) - (1+\tau_b)p(\varepsilon)], \tag{24}$$

$$rH(\varepsilon) = \varepsilon x - \tau_p p(\varepsilon) - s(H(\varepsilon) - V - B(\varepsilon)) - \delta(H(\varepsilon) - B(\varepsilon)), \tag{25}$$

$$rV = -c^S + \theta m(\theta)(1-\tau_s) \int_{\varepsilon_R}^{\infty} (p(\varepsilon) - V) \frac{dF(\varepsilon)}{1 - F(\varepsilon_R)} - \delta V. \tag{26}$$

The equilibrium is derived following the same procedure as in section 2. Free entry of buyers and sellers implies that

$$B(\varepsilon_R) = 0, \tag{27}$$

$$V = (1+\tau_k)k. \tag{28}$$

The surplus of buyers and sellers are given by

$$S^B(\varepsilon) = H(\varepsilon) - B(\varepsilon) - (1+\tau_b)p(\varepsilon), \tag{29}$$

$$S^S(\varepsilon) = (1-\tau_S)(p(\varepsilon) - V). \tag{30}$$

Let $\tilde{\tau} \equiv \tau_b + \tau_p/(r+s+\delta)$ denote the effective tax rate for buyers, which captures that the buyer pays a fraction τ_b of the price when she buys the house and a fraction τ_p while she owns a house, with a present discounting value of $\tau_p/(r+s+\delta)$. Given that $\partial S^B(\varepsilon)/\partial p(\varepsilon) = -(1+\tilde{\tau})$ and $\partial S^S(\varepsilon)/\partial p(\varepsilon) = (1+\tau_s)$, the Nash Bargaining first order conditions imply

$$S^B(\varepsilon) = (1-\tilde{\beta})S(\varepsilon), \tag{31}$$

$$S^S(\varepsilon) = \tilde{\beta}S(\varepsilon), \tag{32}$$

where $S(\varepsilon) \equiv S^B(\varepsilon) + S^S(\varepsilon)$ and $\tilde{\beta} \equiv \beta(1-\tau_S)/[(1-\beta)(1+\tilde{\tau}) + \beta(1-\tau_S)]$ is the effective bargaining weight. This is a notable difference compared to the equilibrium without policies. The housing market policies τ_b, τ_p and τ_s now affect the size of the surplus. Consider for example property taxes. Intuitively, if the buyer pays a higher price, part of the surplus is lost because the homeowner pays higher property taxes, which reduces the size of the surplus. The Nash Bargaining solution takes into account the effect of a change in the price on the surplus, given the housing market policies. The effective weights in the Nash Bargaining solution capture the effect of the tax rates on the surplus. A similar result emerges with labor market policies (Lagos (2006), Pissarides (2000) and Ortego-Marti (2020)).

Following the same steps as in section 2 gives the following equilibrium conditions

$$p(\varepsilon) = \frac{\tilde{\beta}[\varepsilon + c^B + s(1+\tau_k)k] + (1-\tilde{\beta})(r+s+\delta+m(\theta))(1-\tau_s)(1+\tau_k)k}{r+s+\delta+(1-\tilde{\beta})m(\theta) - \tau_s(1-\tilde{\beta})(r+s+\delta+m(\theta)) + \tilde{\tau} + \tilde{\beta}(r+s+\delta)}, \tag{33}$$

$$\frac{(r+\delta)(1+\tau_k)k + c^S}{\theta m(\theta)(1-\tau_s)} = \bar{p} - (1+\tau_k)k, \tag{34}$$

$$\frac{c^B}{m(\theta)} = (1-\tau_s)(1-\tilde{\beta})\left[\frac{\varepsilon_R x + s(1+\tau_k)k - (1+\tilde{\tau})(1+\tau_k)k}{(r+s+\delta)[(1-\tilde{\beta})(1-\tau_s) + \tilde{\beta}(1+\tilde{\tau})]}\right]. \tag{35}$$

Setting $\tau_b = \tau_p = \tau_s = \tau_k = 0$ gives the equilibrium conditions in the decentralized economy without policies in section 2.

5 Quantifying inefficiency in the housing market

We explore the quantitative implications of the model in a numerical exercise. To begin our exercise, we introduce the calibration strategy and the resulting equilibrium. Next, we gauge the quantitative size of the externalities by comparing the benchmark equilibrium with the planner's socially optimal allocation. We further compare the benchmark to the equilibrium absent any government intervention. The exercise concludes with an exploration of the optimal policies that implement the planner's allocation in the decentralized economy.

Following Gabrovski and Ortego-Marti (2021a) we set $r = 0.012$ so as to match an annual discount factor of 0.953. We further set $\delta = 0.004$ to match an annual housing depreciation rate of 1.6% (Van Nieuwerburgh and Weill (2010)). The matching function is assumed to be Cobb-Douglas with $m(\theta) = \mu\theta^{-\alpha}$. We set the elasticity $\alpha = 0.16$ following the evidence in Genesove and Han (2012). The utility distribution is postulated to be Pareto with a shape parameter $\tilde{\alpha}$ and a minimum utility normalized to $\underline{\varepsilon} = 1$. We further normalize x to unity. The development tax τ_k is set to zero. We set the profit tax rate for the seller to 3.65% which is the average effective tax rate for the Real Estate Developer firms for the years 2014 — 2019 as reported by Aswath Damodaran.[3] The Tax Foundation in its "Facts and Figures

[3]The data can be found at http://people.stern.nyu.edu/adamodar/New_Home_Page/dataarchived.html. We exclude 2018 for which there is no data on taxes paid.

2018" reports an effective annual property tax rate for the United States of 1.13% so we set $\tau_p = 0.0028$. The median real estate transfer tax rate reported by the National Association of Realtors is 0.16% and so we set $\tau_b = 0.0016$. Lastly, we normalize the size of the market and set $b = 1$.

To calibrate c^B and c^S we target expected costs for the buyer and seller equal to 8% and 5.1% of the average house price, following Ghent (2012). We target a time-to-sell of 1.76 quarters which is the average of the Median Number of Months on Sales Market reported by the U.S. Bureau of Census for the period of 1987:1 — 2017:4. We also set the time-to-buy to be equal to the time to sell following Gabrovski and Ortego-Marti (2019), Gabrovski and Ortego-Marti (2021a) and the evidence in Genesove and Han (2012). These two targets yield μ and k. Ngai and Sheedy (2020) calculate a listing rate, given by the number of new listings on the market divided by the stock of owner-occupied houses not already for sale, equal to 1.667%. This target implies a separation rate of $s = 0.0126$. Kotova and Zhang (2020) report housing price dispersion of 16.84%. The authors further attribute 14.67% of that to buyer heterogeneity. Using these estimates we can back out an implied mean-min ratio for prices equal to 1.0884. This yields $\tilde{\alpha} = 1.2698$. It turns out that one can normalize ε_R as it acts as a scaling variable. Accordingly we set $\varepsilon_R = 10.1307$ so that the average equilibrium price is 491.2, the average price in thousands of dollars reported in Kotova and Zhang (2020). This normalization, together with the buyer entry condition allows us to can back out $\beta = 0.2994$. Lastly, we normalize $b = 1$ which yields the population parameter $N = 668.49$. Table 1 summarizes the calibration.

Given the model's calibration we compute the benchmark equilibrium, the planner's socially optimal allocation, and the equilibrium absent any government intervention. We summarize the results in table 2. The benchmark equilibrium features a vacancy rate of 2.83%. This is very close to the empirically observed vacancy rate for the U.S. of 1.9%.[4] Our model also matches very well the data on construction: the construction rate in our model is 0.4% whereas the one in the data is 0.27%.[5] Turning our attention to the efficient allocation, the planner finds it optimal to reduce the time-to-sell by almost half. This is achieved by increasing the number of buyers by 13.65% and reducing the number of vacancies by 41.51%. Intuitively the congestion externality induces over-creation of vacancies in equilibrium so the

[4]To obtain the vacancy rate for the U.S. we have averaged out the Homeowner Vacancy Rate reported by the United States Census Bureau for the period 1987:1 — 2017:4.

[5]We calculate the construction rate as the ratio of new construction to the total stock of houses. In the model's steady state this ratio is given by δ. To compute the empirical counterpart of this moment we take the average ratio in the data for the period 1987:1 — 2017:4. The data on new construction is taken from the New Privately-Owned Housing Units Completed series by U.S. Census Bureau and U.S. Department of Housing and Urban Development and the data on the stock of homes from the All Housing Units series reported in the Housing Vacancy Survey of the U.S. Census Bureau.

planner wants to correct for that. At the same time, the composition externality leads to a sub-optimally low home-ownership rate in equilibrium. Because of that the planner instructs a higher number of households to enter the market. The resulting optimal vacancy rate is 1.64%. Absent government policies the equilibrium features vacancy rates and time-to-sell that are closer to the efficient ones. At the same time, the number of buyers, homeowners, and vacancies overshoot their socically optimal levels. As a result, our model predicts that the effect of the calibrated market policies is unclear: they do not necessarily push the equilibrium closer or further to the socially optimal allocation.

Because our model features two externalities: the congestion and composition externalities, in general the planner needs to use two or more policies to implement the socially optimal allocation. Given the taxes in our model such implementation can be achieved in infinitely many ways. For the purposes of exposition we focus on two possible implementations: i) a combination of taxes on housing development and profits; ii) a combination of taxes on profits and taxes on homeowners. If the planner is to implement the optimal allocation using taxes on only the supply side of the market, then she needs to impose about a 50% profit tax rate and needs to subsidize housing construction at a rate of 4.41%. If the planner is to implement the social optimum by a combination of τ_s and $\tilde{tau}_b$, then the optimal tax rate for sales is about 51% and the optimal tax rate for homeowners is about 7.14%.

6 Extensions: buyer entry with increasing search costs

This section studies efficiency with a mechanism of entry similar to Gabrovski and Ortego-Marti (2019) and shows that the results are similar to previous sections. This extension shows shows that the exact mechanism of entry is not essential, the composition externality is still present. Households are now homogenous in how much they value homeownership, i.e. they all derive a common utility x from owning a home. Comparing the decentralized and optimal allocation in this environment illustrates even more clearly why the Hosios condition does not restore efficiency. It also allows us to find quantitatively how efficiency depends on the elasticity of buyers' entry with respect to movements in other housing market variables. However, for quantitative purposes we prefer the environment in which entry is driven by heterogeneity, because it allows us to use data on prices dispersion to calibrate buyers' entry more precisely. Intuitively, entry with heterogeneity is determined by the distribution of households heterogeneity, which we can match using house price data—more specifically, house price dispersion.

6.1 The decentralized economy

Entry is now driven by increasing search costs for buyers. Assume that households must secure the services of a realtor to start searching for a house. Searching for houses is costly for the realtor. The realtor's cost of servicing b buyers is given by $\bar{c}b^{\gamma+1}/(\gamma+1)$, which is consistent with many findings in the real estate literature (Sirmans and Turnbull (1997)). In exchange for their realtor services, the realtor charges a fee c^B, so the realtor's revenue is bc^B. Profit maximization implies that the fee is given by $c^B(b) = \bar{c}b^{\gamma}$, which is increasing in the number of buyers. Intuitively, $c^B(b)$ captures search costs such as arranging and scheduling viewings, driving to view houses or locating properties that match buyers' preferences. In reality, buyers incur some of these costs themselves, but for simplicity of the exposition we assume that the realtor bears all the costs and then charges a fee $c^B(b)$. Assuming instead that buyers incur all costs themselves, and that costs are increasing in the number of buyers due to congestion, gives the exact same results. As Gabrovski and Ortego-Marti (2019) show, this environment delivers an endogenous entry mechanism and an upward-sloping Beveridge Curve. In addition, it accounts for the housing market stylized facts qualitatively and quantitatively.

The Bellman equations in this environment are given by

$$rH = x - s(H - V) - \delta H, \tag{36}$$

$$rB = \max\{0, -c^B(b) + m(\theta)(H - B - p))\}, \tag{37}$$

$$rV = -c^S + \theta m(\theta)(p - V) - \delta V. \tag{38}$$

The intuition for the above Bellman equations is similar to the Bellman equations in section 2. The solution is derived following similar steps. Combining the Nash bargaining rule and free entry with the above Bellman equations yields the following Housing Entry (HE), Buyer Entry (BE) and Price (PP) conditions

$$\text{(HE):} \qquad \frac{(r+\delta)k + c^S}{\theta m(\theta)} = (1-\beta)\left(\frac{\varepsilon + sk}{r+\delta+s} - k\right), \tag{39}$$

$$\text{(BE):} \qquad \frac{c^B(b)}{m(\theta)} = \beta\left(\frac{\varepsilon + sk}{r+\delta+s} - k\right), \tag{40}$$

$$\text{(PP):} \qquad p = \beta k + (1-\beta)\left[\frac{\varepsilon + sk}{r+\delta+s}\right]. \tag{41}$$

The PP and HE conditions determine the equilibrium market tightness θ. Given the equilibrium condition θ, the BE condition yields the equilibrium measure of buyers b. It is straightforward to verify that the equilibrium exists and is unique. This environment yields an upward-sloping Beveridge Curve, which corresponds to the BE curve. Intuitively, as more sellers enter the market, buyers find it more profitable to enter the market because they can find houses more quickly, so buyers and vacancies are positively correlated. Gabrovski and Ortego-Marti (2019) show that a similar environment in discrete time and with business cycle fluctuations accounts for the housing market stylized facts qualitatively and quantitatively.

6.2 The social planner's allocation

In this environment the planner continues to face a congestion and a composition externalities. The composition externality operates in a similar way as in the environment with heterogeneous buyers in section 2. As more buyers enter, they raise search costs for other buyers through congestion. Therefore, the decentralized equilibrium is inefficient because buyers do not internalize the effect their entry has on other buyers' search costs. By contrast, the social planner does take into account that an allocation with more buyers raises search costs.

Let $\tilde{h}$ and c denote, as before, the number of homeowners and construction. The planner's problem is given by

$$\max_{\theta,c} \int_0^\infty e^{-rt}\left[x\tilde{h} - v\theta c^B(v\theta) - vc^S - ck\right]dt, \tag{42}$$

subject to

$$\dot{v} = c + sh - \delta v - v\theta m(\theta), \tag{43}$$

$$\dot{\tilde{h}} = v\theta m(\theta) - (s+\delta)h. \tag{44}$$

Setting up the Hamiltonian and using the first order conditions gives the following equilibrium conditions in the steady state

$$\frac{(r+\delta)k + c^S}{\theta m(\theta)} = \alpha\left(\frac{\varepsilon + sk}{r+s+\delta} - k\right), \tag{45}$$

$$\frac{c^B(b)}{m(\theta)} = \left(\frac{1-\alpha}{1+\gamma}\right)\left(\frac{\varepsilon + sk}{r+s+\delta} - k\right), \tag{46}$$

where α continues to denote the elasticity of the matching rate $q(\theta)$. The appendix provides the derivations and shows that the above conditions are necessary and sufficient. Equations (45) and (46) are the counterpart of the equilibrium conditions in the decentralized equilibrium (39) and (41).

Comparing the decentralized allocation given by (39) and (41) with the optimal allocation from (45) and (46) shows that the Hosios-Mortensen-Pissarides condition does not restore efficiency. More specifically, restoring efficiency in the decentralized equilibrium requires

$$\beta = \alpha \quad \text{and} \quad \beta = \frac{1-\alpha}{1+\gamma}. \tag{47}$$

The first condition $\beta = \alpha$ corresponds to the Hosios-Mortensen-Pissarides condition. Since $\alpha < 1$, the decentralized is efficient if and only if $\gamma = 0$, i.e. there is no entry of buyers. As soon as the entry of buyer becomes endogenous, the equilibrium is inefficient even when the Hosios-Mortensen-Pissarides condition holds. In the appendix we show that the same result holds when there is directed search: efficiency is only restored if there is no entry of buyers. An advantage with the environment in this section is that it very clearly illustrates the issue the planner faces. The planner must first fix the buyer's entry condition (46). Once the planner imposes the optimal level of buyers, the Hosios-Mortensen-Pissarides eliminates the congestion externality and restores efficiency. Without first fixing the optimal level of buyer, the Hosios-Mortensen-Pissarides condition cannot restore efficiency in the market. This is why in section (5) two housing market policies are required to eliminate the two externalities and restore efficiency: one policy to set the measure of buyers to the efficient level (i.e. eliminate the composition externality), and one to restore the efficient level of market tightness (i.e. eliminate the congestion externality).

7 Conclusion

This paper studies efficiency in the housing market with search frictions and endogenous entry of both buyers and sellers. These two features are fundamental to account for the stylized facts of the housing market, in particular to generate a positive correlation between buyers and vacancies, i.e. an upward sloping Beveridge Curve. We show that in this environment two externalities arise: congestion and composition externalities. We characterize the efficient allocation and show that the decentralized equilibrium is inefficient even when the Hosios-Mortensen-Pissarides condition holds. In particular, decentralized economy features inefficiently low levels of home-ownership and inefficiently high vacancy rate and time-to-sell. Finally, this paper studies housing market policies and how they can restore efficiency in the housing market.

Technical Appendix

Social planner's solution

The hamiltonian for the social planner's problem is given by

$$H = e^{-rt}\{x\bar{\varepsilon}\tilde{h} - vc^S - ck - c^B[N(1-F(\varepsilon_R)) - \tilde{h}] + \lambda_{\tilde{h}}[v\theta m(\theta) - (s+\delta)\tilde{h}] \tag{A1}$$

$$+ \lambda_v[c + s\tilde{h} - \delta v - v\theta m(\theta)] + \lambda_\theta[N(1-F(\varepsilon_R)) - \tilde{h} - \theta v]\} \tag{A2}$$

where as before $\bar{\varepsilon} \equiv E(\varepsilon|\varepsilon \geq \varepsilon_R) = \int_{\varepsilon_R}^{\infty} \varepsilon dF(\varepsilon)/(1-F(\varepsilon_R))$. The first-order conditions are given by

$$\frac{\partial H}{\partial c} = 0 \Rightarrow \lambda_v = k, \tag{A3}$$

$$\frac{\partial H}{\partial \theta} = 0 \Rightarrow \lambda_\theta = (1-\alpha)m(\theta)(\lambda_{\tilde{h}} - \lambda_v), \tag{A4}$$

$$\frac{\partial H}{\partial \varepsilon_R} = 0 \Rightarrow \lambda_\theta = c^B + xh(\bar{\varepsilon} - \varepsilon_R), \tag{A5}$$

$$\frac{\partial H}{\partial \tilde{h}} = -\dot{\lambda}_{\tilde{h}} + r\lambda_{\tilde{h}} \Rightarrow \lambda_{\tilde{h}} = \frac{x\bar{\varepsilon} + c^B + sk - \lambda_\theta}{r+s+\delta}, \tag{A6}$$

$$\frac{\partial H}{\partial v} = -\dot{\lambda}_v + r\lambda_v \Rightarrow \frac{(r+\delta)k + c^S}{\theta m(\theta)} = \alpha(\lambda_{\tilde{h}} - k). \tag{A7}$$

Combining the above first-order conditions above and considering the steady state gives the planner's allocation (22) and (23).

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Preferences/Technology	Parameter	Value	Source/Target
Discount rate	r	0.012	annual discount factor= 0.953
Utility scale	x	1	normalization
Elasticity of Matching Function	α	0.16	Genesove and Han (2012)
Destruction rate	δ	0.004	Van Nieuwerburgh and Weill (2010)
Separation Rate	s	0.0126	Listing rate = 1.67%
Efficiency of Matching Function	μ	0.5682	TTB= 1.76 quarters
Seller cost	c^S	14.233	Average seller cost= 5.1% of price
Buyer cost	c^B	22.327	Average seller cost= 8% of price
Construction cost	k	451.99	TTS= 1.76 quarters
Pareto shape	$\tilde{\alpha}$	1.2698	$\bar{p}/p^R = 1.0884$
Bargaining power	β	0.2994	$\varepsilon_R = 10.1307$, normalization
Population	N	668.49	$b = 1$, normalization

Table 1: Calibration

Moment	Calibrated Benchmark	Optimal	$\tau_s = \tau_k = \tau_b = \tau_p = 0$
Vacancy rate	2.83	1.64	2.64
Listing rate	1.67	1.66	1.67
TTS	1.76	1.01	1.64
Buyers	1	1.14	1.21
Vacancies	1	0.58	1.12
Home-owners	34.33	35.08	41.07

Table 2: Moments

Taxes	Calibrated Benchmark		Optimal	
	Percentage of price	Dollar Value	Percentage of price	Dollar Value
τ_s	3.65%	1.43	50.34%	21.6
τ_k	0%	0	-4.41%	-19.91
τ_s	3.65%	1.43	50.93%	22.44
$\tilde{\tau}_b$	10%	49.39	7.14%	35.44

Table 3: Optimal Policies