Bidding Wars in the Housing Market: When Directed Search Becomes Stock-Flow Matching

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Bidding Wars in the Housing Market: When Directed Search Becomes Stock-Flow Matching*

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Abstract

This paper considers equilibrium trade in a real estate market. When search is directed, buyers have private independent values, and sellers compete on asking prices, stock-flow matching characterises equilibrium outcomes. Consistent with the data, equilibrium not only generates large and variable price spikes for new listing sales; unsuccessful sellers lower their asking prices over time; and there is equilibrium asking price dispersion. Bidding war data demonstrate that the match surplus is substantial: a lower bound equals 3.3% of house price, whereas ballpark examples suggest match surplus is around 10%.

Keywords: Housing, bidding wars, stock-flow matching, price dispersion

JEL classifications: C78, D44, D82, D83

Running head: Bidding Wars in Housing

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1 Introduction

Over the last 30 years, an important development in the real estate market has been the switch to online property websites. With just a simple click, interested buyers can quickly survey current properties for sale, observe price histories, register for new listing alerts and so on. An increasing prevalence of bidding wars has accompanied the rise in property websites. Merlo et al. (2015) report that for 1990s, only 3.8% of properties in the U.S. received multiple offers. Han and Strange (2016) report that for the 2000s, 15% of new listings enjoyed a bidding war. Arefeva (2025) reports that, according to Redfin, bidding war probabilities in the early 2020s exceeded 50%.

This paper shows how a centralized website can mediate bidding wars and asking prices. Suppose all houses are ex ante the same and consider a lone new house seller who enters a directed search market by advertising his house for sale on an readily available online website.[1] A stock of buyers who have been unable to trade to date are waiting for a desirable house to enter the market and list on the website. If several of these waiting buyers "like" the new seller's property – these preferences are idiosyncratic – then Bertrand-type competition generates a bidding war with trade then occurring straightaway. In this instance, new listings fortunate enough to attract multiple interested buyers receive a price premium.

On the other hand, the new seller may be unfortunate and receive no likes and hence no offers. In this case, the seller infers there are no currently interested buyers on the market. He subsequently competes with the stock of unmatched sellers who try to attract a buyer from the inflow of new buyers. A positive fraction of new listings fail to find a buyer and compete on their asking price. These sellers gradually reduce their asking price with time on the market thereby generating equilibrium asking price dispersion.

Now consider a lone new buyer entering the market. She first checks out all the properties currently listed online and their associated asking prices. Her idiosyncratic valuation of any property for sale is private information. If the new buyer likes one such property and chooses to make an offer, her optimal offer is the seller's reserve (asking) price because she believes no other buyer is currently interested in this property. (Otherwise why have they not yet sold?) Hence for this part of the market, the auction mechanism associated with a bidding war plays no material role: the asking price acts as a posted take-

[1] Throughout the analysis, female pronouns are used for buyers and male pronouns for sellers.

it-or-leave-it price.[2] With finite "likes," however, there is a positive probability that the buyer does not like the current listings sufficiently to make an offer and so she must wait for a desired property to come onto the market.

Individual entry of buyers and sellers (Poisson arrivals set in continuous time) transforms directed search into stock-flow matching, making the contribution in this paper relevant for related markets such as employment, used cars, and other similar durable goods. The buyer's private information – the finite number of independent "like" valuations – then drives the pricing outcomes by generating a potential competing auction for new listings with small numbers of potential buyers during bidding wars. In contrast, for houses that did not sell as new listings, the asking price of waiting sellers acts as a reservation price.

In this economy, house trading exhibits two types of competition. First there is **instantaneous competition** across "waiting" sellers who compete to trade with the inflow of new buyers. An increase in the stock of houses for sale implies each new buyer has more choice: she is not only more likely to match with a house and so can trade immediately, she is also more likely to like several properties. This makes it harder for competing sellers to extract match rents and trading prices fall with time on the market.

There is also **intertemporal competition.** When a "waiting" buyer makes an offer to a new listing, she takes into account that if the property is bought by someone else, she will then have to wait for her next desired listing. If α describes the entry rate of new listings, then r/α is the relevant market friction, where a smaller interest rate r (greater patience) or larger α (high turnover) implies lower waiting costs. In the frictionless limit where $r/\alpha \to 0$, the equilibrium match surplus becomes zero, the Law of One Price holds (there is no price dispersion), and the stock-flow equilibrium implements the competitive outcome. With positive frictions, the market is not competitive and there is a turnover externality: by reducing the expected waiting time to trade, greater α (higher turnover) raises the values of both waiting buyers and waiting sellers. In this way the well known thick market externality found in the random matching literature translates into a turnover externality: markets with greater turnover are more efficient.

In the Bayesian equilibrium shaped by these two types of competition, all new listings post the

[2]Being a competing auctions framework, the main section formally assumes buyers cannot submit offers below the reserve price. The Conclusion, however, describes equivalent equilibria where buyers are allowed to make lowball offers.

same reserve price. A fraction enjoy a bidding war with multiple interested buyers that generates price dispersion above the posted price among immediate sales and hence the variable price spikes for new listings. But a positive fraction of new listings also fail to find a buyer. These sellers gradually reduce their asking price with time on the market that generates equilibrium asking price dispersion. This pricing structure captures many natural features of trade in the real estate market. More specifically, given her (private) tastes, each buyer's optimal offer reflects (i) her preferences over the current stock of houses for sale (and associated seller asking prices), (ii) her beliefs on how many other buyers might be interested (and so the likelihood of a bidding war), (iii) her expectations on how quickly the seller's asking price is likely to fall, (iv) the rate at which other desirable properties enter the market (and their expected asking prices), while taking into account (v) the risk that by not making an offer the desired property is potentially snapped up by someone else and the opportunity lost.

The associated impact of bidding wars on prices is non-trivial and empirically supported by real estate sales data. Gilbukh (2023) and Smith et al. (2022) literally estimate a spike in prices paid for new listing sales. Noting most bidding wars are for newly listed properties, Gilbukh (2023) finds, on average, that houses which sell within days of being first listed (that is when the sale contract is agreed), enjoy an average price premium of around 2.8% of house price. Moreover, the frequency of bidding wars depends only on market tightness, the ratio of buyers to sellers in the market, where a tighter housing market generates more bidding war events. Along with a steady state "Beveridge curve," the equilibrium characterised here has many of the aspects associated with the random matching approach (e.g. Pissarides (2000)) yet here there is no random matching function.[3]

The observed price spikes provide direct information on match surplus. Bidding war information identifies a new, lower bound estimate for US housing markets, equal to 3.3% of house price, whereas ballpark calculations suggest surpluses of around 10%. Such large match surpluses not only reflect the large price premia generated by bidding wars, they explain (high?) real estate commission fees. This issue of small or large match surplus in the labour macro literature is important, yet the issue there is not settled as there is no direct measure of match surplus. The proposed measure from this paper offers a potential resolution of this issue.

Finally this framework considers an important equilibrium issue: how do buyers respond if, say, a new listing deviates with an asking price that is "too high?" It is precisely this subgame issue, where

[3]See also Lagos (2000) in a taxi market context.

buyer preferences are private information, which makes equilibrium so complex. To cut a long story short, noting a house is a durable good and the seller cannot precommit to future asking prices, if the new listing posts a too high asking price (above some value R) then Coase conjecture issues kick in; e.g. Coase (1972), Gul et al. (1986). Specifically equilibrium in this subgame finds interested buyers expect the seller's asking price to fall to R "in the twinkling of an eye." But that does not describe a competitive outcome – it describes a Dutch (descending price) auction. Because this Dutch auction is payoff equivalent to a first price auction with reserve R, privately optimal bids do not change in response to this price deviation. Positive discounting then implies that to trade sooner, the seller does indeed implement the Dutch auction. It is this subgame structure off the equilibrium path which explains why this continuous time trading framework is tractable.

The paper is structured as follows. Following the literature survey in Section 2, Section 3 describes the trading environment. Section 4 identifies a candidate equilibrium consistent with stock-flow matching. Section 5 details its key empirical insights for housing market observations. Section 6 then formally identifies directed search equilibria with competing auctions where the candidate equilibrium describes its equilibrium path. Reflecting the stochastic overlapping generations structure, Theorem 2 shows there is equilibrium price indeterminacy. Section 7 summarises and explores potential extensions.

2 Related Literature and Contributions

Following Wheaton (1990), a large search and matching literature considers equilibrium trade and price formation in the housing market.[4] The search and matching approach has the basic market friction considered here. Not all traders are in the market at the same time so markets are incomplete due to a stochastic overlapping generations structure. Adopting a random matching approach where buyer-seller contacts only occur pairwise and assuming that idiosyncratic match payoffs are common knowledge, prices are then determined by Nash bargaining. This search and matching framework thereby abstracts from durable good pricing issues raised by Coase (1972) and discussed below. As in the labour market literature, the random matching approach in the housing market is readily tractable so it can introduce hetereogenous agents and both idiosyncratic and aggregate shocks.[5]

[4] Han and Strange (2015) survey early contributions.

[5] See Albrecht et al. (2007), Genesove and Han (2012), Ngai and Tenreyro (2014), Ngai and Sheedy (2020) and Arefeva (2025) for various applications in the housing context.

This paper instead uses the directed search framework where sellers compete using optimal mechanisms.[6] The link identified here between directed search and stock-flow matching is, however, new. The stock-flow matching approach has previously assumed buyer values are public information and prices determined by Bertrand competition if several buyers wish to purchase the same property; otherwise by bilateral bargaining.[7] These stock-flow matching papers, however, do not incorporate private information and hence do not derive the correspondence with directed search nor do they derive the frictionless outcomes presented here.

Coles and Smith (1998) demonstrate the empirical importance of stock-flow matching. In the labour market, aggregate match flows are a noisy high frequency time series, yet the matching function approach assumes this high frequency time series is driven by the stock of vacancies and stock of unemployed workers which are instead slow changing input variables; see Table 1 in Shimer (2007) and the discussion in Sniekers (2018). How can this be? Coles and Smith (1998) demonstrate that the longer term unemployed wait for suitable new vacancies to come onto the market. Specifically the re-employment hazard rates of workers who have been unemployed for more than one month is uncorrelated with the stock of vacancies, but highly correlated with new vacancy inflows.[8] Gilbukh (2023) and Smith et al. (2022) show this insight also applies to housing data. Aggregate sales flows are volatile and directly correlated with new listing inflows and much less correlated with the current stock of houses for sale. This should not be surprising: many new listings sell within a week of being posted and this inflow is relatively volatile, while older listings have much lower hazard rates and this stock is slow changing.

Following seminal work by McAfee (1993), the competing auctions literature considers directed search when buyers have independent private values and sellers compete in optimal mechanisms.[9] Adopting a large economy assumption with an infinity of buyers and sellers, McAfee finds all sellers post the same reserve price equal to their continuation value of remaining unsold. Albrecht et al. (2014) further show equilibrium then implies efficient investment (entry) incentives, i.e. the competitive outcome obtains for the case that buyers have independent private values. Much of the directed search

[6]Directed search applications to the housing market include Díaz and Jerez (2013), Head et al. (2014), Han and Strange (2016), Hedlund (2016b), Piazzesi et al. (2020), Rekkas et al. (2025), Kaas et al. (2026).

[7]Smith (2020b) provides an overview of the stock-flow matching literature. Prominent contributions include Taylor (1995), Coles and Smith (1998), Coles and Muthoo (1998), Lagos (2000), Ebrahimy and Shimer (2010).

[8]Econometric methods which correct for time aggregation issues confirm that high frequency variations in match flows are being driven by high frequency variations in new vacancy and new unemployed worker inflows; e.g. Gregg and Petrongolo (2005), Coles and Petrongolo (2008), Kuo and Smith (2009), Andrews et al. (2013).

[9]See also Milgrom and Weber (1982), Peters (1991), Peters and Severinov (1997).

literature makes the same simplification of a double infinity of buyers and sellers and demonstrates that trade is constrained efficient. Wright et al. (2021) provides for a recent survey.

When a finite number of traders post competing auctions, McAfee (1993) points out there must be dispersion in seller asking prices but then rules out this case by assumption. This paper speaks to this case and allows buyers to only "like" a finite (integer) number of houses currently on the market. With an integer number of options, each buyer fears the loss that a desired property could be bought by someone else, whereas in the large economy case there is always another desirable property to offset a missed opportunity. This difference endows each (integer numbered) seller with some market power which makes the trading framework more intriguing - the market outcome is no longer competitive - but also much more complex.[10]

Two simplifying assumptions contain the challenges posed from an integer number of matches and radically change the structure of equilibrium. First, time is continuous. Second, preferences are binary. In particular, the standard directed search approach focuses on a buyer search co-ordination problem and the equilibrium co-ordinates buyer search to yield a (constrained) efficient allocation.[11] In this paper, continuous time coupled with efficient trade delivers stock-flow matching which automatically resolves the buyer co-ordination problem. At any point in time each new agent might trade with several agents on the other side of the market, but none of those agents can match with anyone else; i.e. equilibrium matching is one to many.[12] Without the co-ordination problem, the nature of equilibrium trade is completely different. Sellers here obtain market power because with a positive probability the interested buyer does not like any other current properties on the market. However, although sellers are price setters and have market power, the Diamond (1971) paradox does not apply. Nor is the market outcome is competitive. There are instead two sources of equilibrium sale price dispersion – decreasing asking prices among old listings and the potential of a bidding war for new listings.

In this setting, the Coase Conjecture, Coase (1972), becomes relevant because houses are a durable good, buyer preferences are private information, and sellers post asking prices with no commitment on future prices. The Coase conjecture argues that as the period interval $\Delta \to 0^+$, the durable good monopolist sells at a price which is arbitrarily close to the competitive price. Specifying binary prefer-

[10] To appreciate the importance of this distinction in directed search, see Moen (1997) with a continuum of traders and, in contrast, Burdett et al. (2001) with finite traders in a one period context.

[11] See for example Shimer (1996), Moen (1997), Guerrieri et al. (2010) with adverse selection, Eeckhout and Kircher (2011) with two sided ex–ante heterogeneity.

[12] Caplin and Leahy (2011) analyze an application of house pricing with potential many-to-many matching.

ences – a buyer either "likes" or "does not like" each seller's property – avoids the Coase issue. For this preference structure, the durable good monopolist would set the monopoly price $p = 1$ in perpetuity (see Gul et al., 1986). Nevertheless even with binary preferences, the analysis must take into account that should a durable good seller reduce his asking price too quickly over time, buyers have an incentive to wait for lower prices. The Conclusion discusses how binary preferences might be generalised.

3 Economic Framework

Time is continuous and has an infinite horizon. To focus exclusively on steady state outcomes, there is a continuum of buyers and sellers, where the measure of buyers is N_B and the measure of sellers is N_S.[13] All traders discount the future at rate $r > 0$.

Each seller holds one unit of an indivisible, durable good (a house) and each buyer wishes to buy one house. A seller's valuation of his house is zero. Buyer preferences over the stock of houses currently for sale are idiosyncratic and unobserved by others; i.e. buyers have independent private values. To avoid Coase conjecture issues, assume binary valuations: each buyer either "likes" any given house, in which case her payoff to owning it is one, otherwise she "does not like" the house in which case her payoff to owning it is zero. Obviously gains to trade only exist between each seller and the number of buyers who like his house.

To obtain an integer number of likes from a continuum of traders, assume idiosyncratic buyer preferences over houses described by the Poisson distribution. Specifically, given a random sample of measure N houses for sale, the probability a given buyer likes $k = 0, 1, 2, ...$ of these potential purchases is

$$P(k) = \frac{e^{-x}x^k}{k!} \tag{1}$$

where $x = \lambda N$ is the expected number of houses liked and λ is an exogenous preference parameter. Once preferences are determined, a buyer's valuations do not change over time: she will always like those k houses she currently likes, will never like those she doesn't currently like and her preferences remain private information. Of course, if one of those $k > 0$ houses is sold to someone else, that house

[13]With finite traders, the integer number of traders evolves stochastically over time. See the Markov equilibrium defined in Coles and Muthoo (1998).

is withdrawn from the market and she is left with $k-1$ properties that she likes.

Turnover occurs as new buyers and new sellers flow into the market at an equal and constant exogenous rate $\alpha > 0$. Over any (small) period of time $\Delta > 0$, $\alpha\Delta$ denotes the measure of new sellers (and also new buyers) who enter the market. The probability a representative buyer likes k of these new listings is given by (1) with $x = \lambda\alpha\Delta$. Putting $k = 1$, the probability this buyer likes exactly one new listing is $\alpha\lambda\Delta + 0(\Delta^2)$. Hence in continuous time, the process by which each buyer likes a new listing is Poisson with arrival rate $\alpha\lambda$ (and the number of properties she currently likes increases by one). However, other buyers might also like the new listing. The probability that k other buyers like the new listing is given by (1) with $x = \lambda N_B$. Symmetry implies a current seller also finds a new buyer who likes his property enters the market at rate $\alpha\lambda$. Each new buyer likes k other properties currently for sale, with probability given by (1) with $x = \lambda N_S$.

A competing auctions structure determines equilibrium prices. Given buyers have independent private values, the seller's optimal mechanism is a first price auction with an optimally chosen reserve price p_s.[14] Each seller simultaneously advertises his house on a property website and posts the asking (reserve) price p_s and a first price auction. All potential buyers costlessly check out all advertised postings and each buyer decides to make an offer, or not, to just one seller. As such, this trading environment conforms with the basic directed search formulation of Burdett et al. (2001) in which all buyers observe all asking prices and there are no external impediments stopping a given buyer from trading with a given seller. On the other hand, there are not gains to trade if a buyer does not like a seller's house.

At first sight an auction structure within directed search might seem inconsistent with observed trade in real estate markets;[15] however, an important feature of trade in this framework is that in the equilibria derived in this paper only new listings attract multiple interested buyers. It is therefore only for new listings that a bidding war (i.e the auction mechanism) occurs and plays a meaningful role.

Given the asking prices and the (integer) set of houses liked by the potential buyer, the buyer either **(I. offer)** contacts one seller and, given their asking price p_s, makes an offer $p \geq p_s$. If the seller receives several offers, he accepts the highest and, if hers is the best offer, she purchases the house at

[14] Second price auctions are payoff equivalent. The issue is to determine each seller's optimal reserve price and how it changes with seller time on the market.

[15] See Barkley et al. (2025) on the Melbourne market and Anundsen et al. (2023) on the Norwegian market when houses are often sold at formal auctions.

the tendered price. If trade occurs, the buyer and seller then exit the market with payoff p to the seller and $1 - p$ to the buyer;

or

(II. silence) she can choose not to make any offers and time proceeds.

This competing auctions framework rules out lowball offers $p < p_s$. The Conclusion discusses how results extend when such offers $p < p_s$ are allowed. Although in this economy the seller can commit to his current reserve price p_s, he cannot commit to future asking prices. Once all offers are made, trades are realised and after an instant ($\Delta > 0$ but arbitrarily small), all remaining sellers update their beliefs on how many potentially interested buyers he has and, along with new entrant sellers, each posts a privately optimal asking price. Interested buyers again decide whether to make an offer (or not) to one seller and so on. An important feature of the private values assumption is that a seller does not know how many buyers (if any) are interested in buying his property - all he observes are offers which are privately made and not verifiable to outside parties. Silence essentially waits for the seller to reduce his asking price (c.f. the Coase conjecture).

4 Immediate Trade Equilibria

Despite the deceptively simple trading environment adopted here, a Markov Bayesian equilibrium in discrete time is not tractable except with a large economy assumption (McAfee, 1993).[16] In continuous time with finite likes the approach here is to first construct a candidate solution using standard insights from search theory and stock-flow matching. There is no claim this is the unique equilibrium. There is no argument that inefficient equilibria do not exist. See McAfee (1993) for a discussion of such issues. But given this candidate, the second step is to consider a Bayesian equilibrium where all agents use optimal strategies, where beliefs are consistent with agent strategies and Bayes Rule, and where the

[16]When new buyers only like an integer k properties in discrete time, a buyer co-ordination problem remains. Suppose time is discrete and a new buyer has finite k opportunities to secure a desired property. Because sellers post first price auctions then, in each attempt to purchase a good, she either successfully wins the auction or, if she is outbid, next period, after period delay $\Delta > 0$, she contacts her next choice seller and so on. Continuation buyers are thus described by a pair (k, k') where k is the number of original goods liked (on first entry), k' is the remaining goods liked following unsuccessful purchasing efforts. This process generates history dependence. Because asking prices are disperse, her chosen sequence of contacts depends on the seller asking prices across her k desired properties. If she fails to win her first auction, in the subgame she now likes k-1 goods, but selection implies their asking prices no longer correspond to the market distribution and those prices also evolve over time. The relevant state space is infinitely dimensional (the distribution of prices across a continuing buyer's remaining k' desired properties) and equilibrium is not tractable.

candidate equlibrium describes the equilibrium outcome; i.e. its equilibrium path.

The crucial simplification in this approach is to restrict attention to only efficient equilibria. Efficiency implies all gains to trade are immediately realised – delay is costly – thereby restricting the analysis to considering only a Candidate Immediate Trade Equilibrium (Candidate ITE). Efficiency coupled with the directed search protocol imply that an ITE will exhibit market segmentation. In the continuous time limit, the time interval $\Delta \to 0^+$, hence $k\Delta \to 0$. Given finite k purchasing options (driven by the Poisson likes) and $\Delta > 0$ but vanishingly small, efficient trade implies a new buyer either likes at least one existing property for sale and successfully trades almost immediately, or does not like any existing house for sale and fails to secure a property. A similar logic applies to any new seller.

Efficiency implies that in equilibrium old buyers do not like old houses. And so when time is continuous and trade is efficient, stock-flow matching emerges and implies the market segments into two distinct sectors: "new" buyers with duration on the market $\tau = 0$ who like finite $k \geq 0$ properties and try to secure one of them, and "old" buyers with $\tau > 0$ who previously failed to secure a trade and now have $k' = 0$: they do not like the remaining properties. Because there are no gains to trade between the continuing stocks of buyers and sellers, steady state finds the measure N_B of continuing buyers do not like any house in the current listings and wait for desired new listings to come onto the market. Similarly measure N_S of continuing sellers wait for interested new buyers. Because there are no gains to trade across the two sectors, these segmented markets do not interact even though search is directed.

This segmentation structure is crucial for tractability. Specifically, an ITE with stock-flow matching decomposes into two submarkets:

(i) a **waiting buyers market:** the measure N_B stock of currently unmatched buyers match with the inflow of new listings. The Poisson arrival structure implies the probability a waiting buyer likes two new listings at the same point in time is zero. Hence when a new seller enters the market, he rationally believes that any waiting buyer who is interested in his property does not like any other properties currently listed on the market;

(ii) a **waiting sellers market:** the measure N_S stock of currently unmatched sellers match with the inflow of new buyers. The Poisson arrival structure again implies the probability that a waiting seller attracts two new buyers at the same point in time is zero. Thus when a new buyer enters the market she rationally believes the waiting seller does not currently have any other interested buyers. And so if she decides to make an offer, she simply offers his asking price $p = p_s$ and trade occurs at this price.

Furthermore, it is possible to identify twin roles – one in each segmented market – for the asking price. In particular, there is

(iii) a **central trading price** R where trades always occur at higher prices $p \geq R$ in the waiting buyers market – there is "excess demand" – and at lower prices $p \leq R$ in the waiting sellers market.

With private tastes, directed search implies seller competition determines equilibrium R. Sellers here enjoy market power and match surplus is strictly positive which reflect the stochastic overlapping generation structure from Poisson entry. More fundamentally, Theorem 2 later reveals that a continuum of directed search equilibria exist; i.e. there is equilibrium price indeterminacy for R.

4.1 The Candidate ITE

The Candidate ITE has the following two proposed properties (P1) and (P2) associated with market segmentation which will subsequently be verified to hold.

(**P1**) In the waiting buyers market, each new seller posts a first price auction with reserve price $p_s(0) = R$. In equilibrium all interested waiting buyers submit price offers $p \geq R$ and the property is sold to the highest bidder. If the seller receives no offers, he infers there are no interested buyers and enters the waiting sellers market with duration on the market $\tau = 0$.

(**P2**) In the waiting sellers market, the stock of waiting sellers trade with the inflow of new buyers. The first price auction remains an optimal mechanism because buyers have independent private values. Search is also directed in the sense that a new buyer makes an offer to the "liked" property with the lowest asking price $p_s < R$. Nevertheless the auction mechanism itself does not play an important role: because there is no buyer competition in the waiting sellers market, the optimal bid equals the asking price $p = p_s$.

In order to further characterise the Candidate ITE, let V_S and V_B denote the expected lifetime payoffs of a representative waiting seller and representative waiting buyer respectively. $1 - V_B - V_S$ describes match surplus. Equilibrium R – the waiting buyer's reservation price which equals the reserve asking price posted by a new listing – is taken as given at this stage. Anticipating results it is useful to describe R using a standard surplus sharing formulation

$$R = V_S + \theta[1 - V_B - V_S], \tag{2}$$

where $\theta \in [0, 1]$ is, for the moment, treated as given. The subsequent determination of equilibrium θ – derived from the outcome from seller posted asking prices and buyer bidding and hence distinct from bargaining – is new.

Theorem 1 now describes the buyer and seller waiting payoffs V_S and V_B and the reservation price R in the Candidate ITE.

Theorem 1. In the Candidate ITE, consistency with $P(1)$ and $P(2)$ implies that for any surplus sharing value of $\theta \in [0, 1]$

$$R = \frac{\theta[r + \alpha\lambda e^{-\lambda N_S}]}{\theta[r + \alpha\lambda e^{-\lambda N_S}] + (1-\theta)[r + \alpha\lambda e^{-\lambda N_B}]} \tag{3}$$

$$V_S = \frac{\theta\alpha\lambda e^{-\lambda N_S}}{\theta[r + \alpha\lambda e^{-\lambda N_S}] + (1-\theta)[r + \alpha\lambda e^{-\lambda N_B}]} \tag{4}$$

$$V_B = \frac{(1-\theta)\alpha\lambda e^{-\lambda N_B}}{\theta[r + \alpha\lambda e^{-\lambda N_S}] + (1-\theta)[r + \alpha\lambda e^{-\lambda N_B}]}. \tag{5}$$

Theorem 1 implies $1 - V_B - V_S > 0$ – there is positive match surplus. $\theta > 0$ then implies $R > V_S$ – sellers post asking prices greater than their continuation value of holding the good. Section 6, will later show how this Candidate ITE is consistent with equilibrium pricing strategies in a directed search equilibrium. Before doing so, Section 5 discusses empirical insights and theoretical intuitions revealed by (3)-(5). The reminder this section, however, establishes Theorem 1.

4.2 The Waiting Buyers Market with (P1)

Because buyer values are private information, when a new seller enters the market, the number of waiting buyers k who like his property is an unobserved random variable distributed according to (1) with $x = \lambda N_B$. Assume that in the Candidate ITE, each new seller posts the same reserve price R, and let F_B denote the distribution of price offers made by a representative waiting buyer who likes a new seller's property. Because λN_B is the expected number of likes, $\lambda N_B[1 - F_B(p)]$ is then the expected number of waiting buyers who like the house and offer a price above p. Hence a waiting buyer who bids price $p \geq R$ has expected payoff

$$W_B(p) = e^{-\lambda N_B[1-F_B(p)]}[1-p] + [1 - e^{-\lambda N_B[1-F_B(p)]}]V_B.$$

From the Poisson arrival of buyers in (1), $e^{-\lambda N_B[1-F_B(p)]}$ is the probability our buyer with price p is not outbid by another waiting buyer, and in that event she wins the auction with payoff $1-p$. Otherwise she loses the auction to a higher bidder and continues as a waiting buyer with value V_B.

The waiting buyer must be indifferent between any two potential and viable bids, hence the equilibrium offer distribution $F_B(.)$ is given by

$$e^{-\lambda N_B[1-F_B(p)]}[1-p] + [1 - e^{-\lambda N_B[1-F_B(p)]}]V_B = e^{-\lambda N_B}[1-R] + [1 - e^{-\lambda N_B}]V_B, \tag{6}$$

where the right hand side describes the expected value of bidding the reserve price R which wins only when nobody else likes the property. Most importantly, because interesting new properties arrive according to a Poisson process with parameter $\alpha\lambda$, the value of being a waiting buyer satisfies

$$rV_B = \alpha\lambda \left[\left\{ e^{-\lambda N_B}[1-R] + [1 - e^{-\lambda N_B}]V_B \right\} - V_B \right]$$

hence

$$V_B = \frac{\alpha\lambda e^{-\lambda N_B}}{r + \alpha\lambda e^{-\lambda N_B}}(1-R). \tag{7}$$

Equation (7) has a simple interpretation: $\alpha\lambda e^{-\lambda N_B}$ is the rate at which a new listing comes onto the market which the waiting buyer likes and nobody else is interested. In that case bidding the reserve price R wins the auction and the buyer reaps payoff $1-R$.

4.3 The Waiting Sellers Market with (P2)

Along the equilibrium path, a new seller with duration on the market $\tau = 0$ sets asking price $p_s(0) = R$ and all interested waiting buyers bid a price $p \geq R$ according to distribution F_B described by (6). The crucial implication, however, is that if no offers are received, the seller infers there is no buyer currently on the market who likes his property: he becomes a waiting seller with duration $\tau > 0$. This seller now waits for interested new buyers to enter the market which occurs at rate $\alpha\lambda$.

Because buyers have private independent values, the waiting seller continues to post a first price auction but potentially lowers his asking price $p_s < R$ if doing so increases his hazard rate of sale. In an

ITE, new buyers will have a threshold price consistent with the payoff to continued search, i.e. to waiting in silence. In a Candidate ITE waiting sellers will not post an asking price above this reservation value. On the other hand, some measure of waiting sellers must post asking prices arbitrarily close to this buyer threshold price. To ease the notation burden and to anticipate equilibrium outcomes in Section 6 (asking prices cannot jump up or down), further suppose that for the moment that this reservation price coincides with R from the waiting buyer market. Each waiting seller then trades off choosing a higher asking price but no greater than R against a lower hazard rate of sale.

As the construction of equilibrium price dispersion is standard, see Burdett and Mortensen (1998) for example, the essential details are presented quickly. All waiting sellers post an asking price $p \in [0, R]$ to maximise expected discounted profit. Let F_S denote the steady state distribution of asking prices across waiting sellers. For future reference let $p_s(\tau)$ denote how a seller changes his asking price by duration τ. Symmetry implies all waiting sellers must obtain the same expected discounted value V_S. Because equilibrium requires the actual distribution of announced prices F_S to be consistent with optimal price setting, this analysis follows the equilibrium price dispersion literature and defines a replication:

Definition 1. Given F_S and buyer reservation price R, suppose each waiting seller posts an asking price $p \in [0, R]$ to maximise expected discounted utility. A seller's replication is a set of optimal price strategies that generate F_S.

A seller's replication is a fixed point problem for F_S. Lemma 1 is a well known standard result stated here without formal proof - see for example Wilde (1977).[17]

Lemma 1. A seller's replication implies F_S is continuous (no mass points), has a connected support with supremum $\overline{p} = R$.

Consider now a waiting seller who sets asking price $p \leq R$. Conditional on a new buyer liking his property, Lemma 1 implies the seller's expected payoff is

$$W_S(p) = pe^{-\lambda N_S F_S(p)} + V_S(1 - e^{-\lambda N_S F_S(p)}),$$

[17] A formal proof uses standard contradiction arguments. F_S cannot have mass points, say at p, otherwise a seller would deviate to a marginally lower price p^- which yields a discrete increase in the probability of a sale and so strictly greater payoff. The support must be connected otherwise the price offered at the infimum of the hole is strictly dominated by the price offered at its supremum (for both have the same probability of sale). And if $\overline{p} < R$, then announcing p=R strictly dominates $p= \overline{p}$ for both prices have the same positive probability of trade.

$N_S F_S(p)$ is the measure of properties whose asking price is below p, so $e^{-\lambda N_S F_S(p)}$ is the probability this interested new buyer does not like any other properties which are cheaper. In that case (P2) implies the seller successfully trades at price p. The seller otherwise continues as a waiting seller. Because all optimal price offers must yield the same payoff, F_S is given by

$$pe^{-\lambda N_S F_S(p)} + V_S(1 - e^{-\lambda N_S F_S(p)}) = e^{-\lambda N_S} R + (1 - e^{-\lambda N_S})V_S \tag{8}$$

where the right hand side describes the expected value of posting asking price p=R. Interesting new properties arrive on the market according to a Poisson process with parameter $\alpha\lambda$, hence

$$rV_S = \alpha\lambda \left\{ e^{-\lambda N_S} R + [1 - e^{-\lambda N_S}]V_S - V_S \right\}$$

$$\Rightarrow V_S = \frac{\alpha\lambda e^{-\lambda N_S}}{r + \alpha\lambda e^{-\lambda N_S}} R \tag{9}$$

It is important to note for the subsequent discussion of lowball offers in the Conclusion that the equilibrium conditions for the waiting sellers market are symmetric to those in the waiting buyers market. Although sellers here are posting asking prices, the market outcome is equivalent to a first price procurement auction by new buyers with unobserved private values.

4.4 The Beveridge Curve

The surplus sharing rule (2) together with (7) and (9) yield a closed form solution for R, V_S, V_B. That solution simplifies to the one stated in Theorem 1 using the following steady state condition.

Lemma 2. Steady state with stock flow matching implies (N$_B, N_S$) satisfy

$$e^{-\lambda N_B} + e^{-\lambda N_S} = 1 \tag{BC}$$

Proof. See Appendix. □

Equation (BC) implicitly defines a steady state relationship between the inventory of houses N_S and the number of households looking to purchase, akin to the familiar Beveridge Curve in the labour market and hence the (BC) label.[18] Using (2),(7),(9) and simplifying using (BC), standard algebra yields the

[18]Like the aggregate Phillips Curve, the Beveridge Curve is intuitive but identifying and measuring its properties is problematic for labour as well as housing markets. As Piazzesi et al. (2020) advises, caution is needed in interpreting this relationship. The Beveridge Curve here is a steady state relationship derived from constant and equal inflows of buyers and

reduced form solutions for R, V_S, V_B as stated in Theorem 1.

5 Key Insights of Stock-Flow Matching

This section reviews the key insights and intuition associated with Theorem 1. To understand this trading structure, note that each new listing trades immediately with probability $1 - e^{-\lambda N_B}$; i.e. when at least one waiting buyer likes the property. Equation (BC) then implies that this probability equals $e^{-\lambda N_S}$. Hence steady state (N_B, N_S) implies a composition effect: fraction $e^{-\lambda N_S}$ of trades occur in the waiting buyers market, where trades occur at prices $p \geq R$, while fraction $e^{-\lambda N_B}$ of trades instead occur in the waiting sellers market at prices $p \leq R$, where (BC) notes these two fractions add up to one.

Instantaneous competition occurs across waiting sellers who compete to trade with the inflow of new buyers. Consider an increase in N_S where (BC) implies a corresponding fall in N_B. As N_S increases, the composition effect implies proportionally more trades occur in the waiting sellers market at inferior prices $p \leq R$. Furthermore, an increase in N_S implies it is more likely that the interested new buyer likes several properties which makes it harder for each waiting seller to extract match rents. Taking the limit as $N_S \to \infty$, $N_B \to 0$ by (BC). Theorem 1 then implies $V_S \to 0$ whereas (8) implies the distribution of seller asking prices F_S converges to a mass point at $p = 0$. Hence, as the stock of sellers becomes large, (almost) all trades occur in the waiting sellers market (a new buyer will almost certainly like at least one property) at a price arbitrarily close to zero (new buyers will almost certainly like more than one property). In this case, seller competition finds new buyers extract all rents. By symmetry, as N_S instead becomes small so that $N_B \to \infty$, most trades in this case occur in the waiting buyers market. In the limit as $N_B \to \infty$, all trades occur at a price arbitrarily close to one; i.e. new sellers extract all rents.

Intertemporal competition also occurs. When a waiting buyer makes an offer $p \geq R$, she takes into account that if she loses the auction she will then wait for her next desired listing. Equations (3)-(5) reveal that r/α is the relevant market friction. This ratio describes total discounting over the

sellers. In practice, aggregate fluctuations and endogenous entry will most likely affect observed patterns. For example, if growth is balanced from equal inflows, relative numbers of buyers and sellers are unlikely to vary much around their trend. Buyers and sellers will then appear positively correlated even though the Beveridge has validity. The joint buyer-seller decision compounds this issue given the stock-flow turnover externality. Moreover, buyer data are typically scare. Despite these qualifications, Redfin monthly aggregate US data in the post-pandemic period from 2021 onward reveal a strong negative correlation between buyers and sellers -0.46468 across all residences and -0.54935 for single family homes.

expected waiting time where r smaller (greater patience) or α larger (high turnover) implies a lower waiting cost. By reducing the expected waiting time to trade, Theorem 1 implies greater α (higher turnover) raises both V_S and V_B. By reducing the time spent waiting for a match to enter the market, higher turnover improves aggregate efficiency.

Equation (BC) describes a negative steady state relationship between the measures of buyers and sellers on the market. To understand this relationship, consider a simpler one-dimensional partnership framework – a tennis club where new members seek partners. Suppose there are P unmatched partners and new members arrive at a constant rate over time. Regardless of that arrival rate, a steady state has to have the property that one half of new members immediately find a match (and take an unmatched partner out of the stock P) and one half fail to find a match and so enter the unpartnered stock P. In other words P must satisfy $e^{-\lambda P} = 1/2$. Importantly changing the inflow rate α – it could even be time varying – does not affect this steady state argument. Indeed it reveals why higher turnover rates, which reduce waiting times to trade, are equivalent to a fall in the discount rate and why r/α is the relevant friction. (BC) is the two dimensional analogue of this tennis club example, which can be written as $1 - e^{-\lambda N_S} = e^{-\lambda N_B}$. The left hand side is the probability that a new buyer matches immediately and so a waiting seller exits the market, while the right hand side is the probability a new seller fails to match immediately and so enters the waiting sellers market.

5.1 The Limiting Frictionless Equilibrium

Consider the frictionless limit $r/\alpha \to 0$. Taking this limit, Theorem 1 implies $R \to R^C$ where

$$R^C = \frac{\theta e^{-\lambda N_S}}{\theta e^{-\lambda N_S} + (1-\theta)e^{-\lambda N_B}},$$

$V_S \to R^C$ and $\mathrm{V}_B \to 1 - R^C$. The limiting frictionless equilibrium finds that the match surplus disappears, i.e. $1 - V_B - V_S \to 0$, as does price dispersion: all trades occur at the same limiting price $p = R^C$. Moreover, because $V_S = R^C$ in this limit (sellers post a reserve price equal to their continuation value), the insights of Albrecht et al. (2014) go through: an extended framework with endogenous entry finds entry is efficient.

The frictionless limit also reveals the way in which market clearing works with stock-flow matching when extended to endogenous entry.[19] Consider this frictionless case where the "Law of One Price"

[19] Smith (2020a) and Smith et al. (2022) characterise housing market volatility in a stock-flow economy with endogenous

holds; i.e. where all trades occur at the same price p. Suppose that in steady state, entry is endogenous where $\alpha_B(p)$ describes the inflow of new buyers which is decreasing in the market price p and $\alpha_S(p)$ describes the inflow of new sellers which is increasing in p. Because steady state requires these inflows must be equal, let $p^c \in [0,1]$ denote the clearing price where $\alpha_B(p^c) = \alpha_S(p^c) \equiv \alpha$. Steady state in the frictionless limit now requires the limiting price

$$R^C = \frac{\theta e^{-\lambda N_S}}{\theta e^{-\lambda N_S} + (1-\theta)e^{-\lambda N_B}} = p^c. \tag{10}$$

For any $\theta \in (0,1)$, equations (BC) and (10) now uniquely determine the steady state composition of the market (N_S, N_B). It is easy to show a solution (N_S, N_B) always exists. Similar to a standard competitive supply and demand analysis, the underlying tattonement is that if the frictionless price $p = R^C$ exceeds the clearing price p^c, the inflow of sellers then exceeds the inflow of new buyers and the Beveridge curve implies the stock of buyers N_B falls as the stock of sellers N_S increases. An increase in sellers implies increased competition across those sellers and (10) shows the frictionless price R^C is then driven down to p^c.

In essence, for any $\theta \in (0,1)$ the equilibrium composition of the market (N_S, N_B) ensures market clearing, where a higher θ (sellers extract a larger share of match surplus) results in higher N_S (greater seller price competition) to hold R^C at the clearing price p^c. Because the frictionless limit guarantees efficient entry (because sellers post reserve price R^C equal to their continuation value $R^C = V_S$) and because market composition (N_S, N_B) implements the clearing price, the limiting frictionless equilibrium implements the competitive outcome. But differently from standard arguments, this competitive solution does not imply zero trader stocks $N_B = N_S = 0$. Rather (N_S, N_B) must lie on the Beveridge curve and the market clearing condition (10) then determines equilibrium market composition.

The rest of the paper returns to the case of strictly positive frictions, $r/\alpha > 0$, and exogenous inflows $\alpha_B = \alpha_S \equiv \alpha$. With $r/\alpha > 0$, Theorem 1 and (8) imply sellers extract market rents by posting asking prices $p_s > V_S$ and the market is not competitive.

5.2 Market Tightness, Bidding Wars and the Composition of Trade

In the frictionless limit there are no bidding wars because match surplus is zero and the Law of One Price applies. But the data reveal that bidding wars are commonplace and, based on their estimated

seller entry but without private valuations.

size and frequency, calculations below find match surplus $1 - V_B - V_S$ is substantial. Assuming strictly positive frictions $r/\alpha > 0$, let $\phi = N_B/N_S$ denote market tightness. Given (BC), market tightness then uniquely determines the composition of the market (N_B, N_S) where $N_B = N_B(\phi)$ increases and $N_S = N_S(\phi)$ falls with market tightness. Market tightness thus determines the composition of trade, where fraction $e^{-\lambda N_S(\phi)}$ of trades occur in the waiting buyers market.

With positive frictions, market tightness determines the frequency of bidding wars. Define y as the bidding war statistic of the fraction of trades where the seller receives multiple offers. Steady state implies

$$y(\phi) = 1 - e^{-\lambda N_B} - \lambda N_B e^{-\lambda N_B} \tag{11}$$

with $N_B = N_B(\phi)$. To derive this relationship, consider a new seller. The second term $e^{-\lambda N_B}$ describes the probability this seller will ultimately trade in the waiting sellers market with only a single offer, while $\lambda N_B e^{-\lambda N_B}$ is the probability he sells immediately in the waiting buyers market but only gets one offer. Because all remaining trades receive multiple offers, (11) identifies steady state $y(\phi)$. Inspection reveals that $y(\phi) \in [0, 1]$ is a continuous increasing function of market tightness ϕ.

To illustrate further, consider first a balanced market where $N_B = N_S$ and so $\phi = 1$. In that case trades are evenly split between the waiting buyers and waiting sellers markets and the distribution of trade prices is evenly spread across the central price R. Furthermore given $\phi = 1$, (BC) and (11) then imply $y = 15\%$ which, interestingly, is the bidding war statistic reported in Han and Strange (2016). Notice further that each buyer who is waiting for a desired new listing then faces a large 30% probability of being caught in a bidding war. Why 30%? Because $\phi = 1$ implies only half of the trades occur in the waiting buyers market, in which case this 30% risk of a bidding war translates to the average 15% bidding war statistic across all trades.

In contrast Merlo et al. (2015) report for the 1990s a very much lower bidding war statistic $y =$3.8%. Reverse engineering finds predicted market tightness $\phi = 0.24$. This much lower tightness has several interesting implications. For example $\phi = 0.24$ implies if the average completed spell for buyers is 3 weeks, then for sellers it is 3 months; i.e. it takes sellers on average 4 times longer to trade. Moreover, finding a desired house is relatively easy. With probability 73% a new buyer finds a desired house is already on the market and with a low asking price $p \leq R$. In contrast selling is hard: with symmetric probability 73% the seller will have to wait for an interested buyer and N_S large implies asking price competition is intense. Although $\phi = 0.24$ implies bidding wars are rare ($y = 3.8\%$), each waiting buyer still faces a much larger 14% probability of getting caught in a bidding war.

5.3 Calculating Match Surplus Using Bidding War Information

Gilbukh (2023) identifies a non-parametric estimate of the average price effect due to bidding wars. Specifically she first runs a standard hedonic price regression using final sales price (rather than list price) on observed housing characteristics. She orders the residuals by time on the market τ at the point of agreement (the contract date) rather than completion date, and reports the average residual for each duration τ as a fraction of the agreed house price. This procedure reveals a large 2.8% price spike for new listings that sell within a week – the data are weekly – while there are no further price spikes at all longer durations: the average residual by duration is instead negative and varies relatively smoothly between 0 and -1.1%. See Figure 4 in Gilbukh (2023).

This estimated price spike provides an opportunity to directly calculate match surplus in the housing market. For new listing sales (in the waiting buyers market), a revenue equivalent second price auction implies expected trading price

$$E\overline{p} = \frac{xe^{-x}R + [1 - e^{-x} - xe^{-x}][1 - V_B]}{1 - e^{-x}}$$

where $x = \lambda N_B(\phi)$. Rearranging suitably gives

$$1 - V_B = E\overline{p} + \frac{xe^{-x}}{1 - e^{-x}}[1 - V_B - R] \geq E\overline{p}$$

The estimated Gilbukh price spike for new listings that sell within a week identifies price premium $E\overline{p} = 0.028$.

Similarly in the waiting sellers market, the expected trading price is

$$E\underline{p} = \frac{xe^{-x}R + [1 - e^{-x} - xe^{-x}]V_S}{1 - e^{-x}}$$

where this time $x = \lambda N_S(\phi)$ and so

$$V_S = E\underline{p} + \frac{xe^{-x}}{1 - e^{-x}}[V_S - R] \leq E\underline{p}.$$

Hence market surplus $1 - V_B - V_S \geq E\overline{p} - E\underline{p}$ and so the difference in estimated price premia yields a lower bound for match surplus.

To obtain an measure for $E\underline{p}$, Figure 1 and footnote 1 in Gilbukh (2023) imply that of those houses that sold in the data around 15% sold within the first week. Because the average residual in the hedonic price regression must be zero, this implies

$$0.15E\overline{p} + 0.85E\underline{p} = 0$$

and so $E\underline{p}$ =-0.5% in the waiting sellers market. This yields the lower bound calculation

$$1 - V_B - V_S \geq E\overline{p} - E\underline{p} = 3.3\%$$

measured as a percentage of final sale price; i.e. match surplus is at least 3.3% of house price.

Of course this is only a lower bound. Simple algebra using the above finds market surplus

$$1 - V_B - V_S = \frac{E\overline{p} - E\underline{p}}{\left[1 - \theta\frac{\lambda N_S e^{-\lambda N_S}}{1-e^{-\lambda N_S}} - \frac{(1-\theta)\lambda N_B e^{-\lambda N_B}}{1-e^{-\lambda N_B}}\right]}. \tag{12}$$

It is easy to show market surplus attains its lower bound when $\theta = 1$ and $N_S \to \infty$, but becomes arbitrarily large if instead $N_S \to 0$. Although real estate data record total listings for sale, there is no direct information on θ, λ, N_B. But two ballpark calculations suggest match surplus is around the 10% mark.

In the balanced market case with $N_B = N_S = N$ suggested by the Han and Strange (2016) bidding war statistic, equation (12) implies:

$$1 - V_B - V_S = \frac{E\overline{p} - E\underline{p}}{1 - \lambda N},$$

which does not depend on θ. Because (BC) further implies $\lambda N = \ln 2$ in a balanced market, predicted match surplus is then 11%. Alternatively Gilbukh (2023) finds around 15% of new listings sell within the week, which suggests 15% of trades occur in the waiting buyer's market; i.e. $\mathrm{e}^{-\lambda N_S} = 0.15$, $\mathrm{e}^{-\lambda N_B} = 0.85$. For the symmetric $\theta = 1/2$ case, equation (12) implies match surplus is around 9%.[20]

These measures are, of course, only ballpark estimates. Nevertheless match surplus is large, at a minimum equal to 3.3% and seemingly of the order of 10%. It is particularly interesting that match

[20] Equation (12) implies the calculated match surplus is 5% if $\theta = 0$, and a much higher 36% if $\theta = 1$. Theorem 2, however, finds these values of θ are not consistent with existence of an equilibrium. For r/α very small, Theorem 2 implies equilibrium θ must take values between 0.4 and 0.5. For such θ, match surplus ranges between 7.6% and 9%.

surplus would seem large despite the assumed absence of actual search frictions. And, of course, large surplus is consistent with large price residuals in hedonic price regressions which Gilbukh (2023) shows are directly correlated with time on the market; i.e. new listing sales enjoy premium prices.[21]

6 A Directed Search Equilibrium

This section completes the analysis by determining optimal agent strategies in a directed search equilibrium. For simplicity and consistency with many websites, assume seller pricing histories – the sequence of these asking prices $p_s(\tau)$ posted by waiting sellers – are observed. An often heard argument is that because waiting sellers are indifferent between any asking price $p \sim F_S$, an equilibrium will imply sellers randomise over prices; e.g. Burdett and Mortensen (1998). However, price randomization cannot describe equilibrium in a durable goods market such as housing. If a buyer expects an imminent price cut, she has the incentive to wait for the lower asking price. Durable good pricing issues have real bite on the set of possible equilibrium outcomes.

To illustrate this point in the Candidate ITE, suppose a new seller posts equilibrium asking price $p_s = R$. An optimal bid for a waiting buyer who likes this house is $p = R$. In equilibrium the bid $p = R$ only wins if there are no other interested buyers. Suppose now that rather than submit price offer $p = R$, the interested buyer deviates and makes no offer, thereby choosing silence. In the event that no other buyer likes the property, the seller receives no offers. Believing no one likes his property, this seller enters the waiting seller market. But if he then randomises with an asking price $p_s \sim F_S$, the interested buyer strictly prefers not to offer $p = R$ in the initial auction. Why? Because in the event that no-one else likes the property, rather than bid price R today it is much better to make no offer and an instant later pay price $p < R$ with distribution F_S.

Dynamic consistency requires $p_s(0^+) = R$, otherwise a bid $p = R$ for the new seller's property is not optimal. The interested buyer simply waits an instant for that discretely lower price $p_s(0^+) < R$. Indeed at any duration τ, an ITE implies there cannot be an expected discrete price cut otherwise an interested new buyer would wait an instant for that discretely lower asking price. However, as lower

[21] Prices in auction models as well as search and matching models have a private match specific component and a common component. Search and matching models often abstract from this common component even though this component reflects, among other things, resale values. Identifying the private component linked with match surplus as computed here is a possible step toward decomposing these two components and hence their contribution to price volatility.

priced houses sell, steady state requires that the remaining sellers cut their asking prices to replace them.

The objective is therefore to construct a dynamically consistent pricing equilibrium in which the seller's asking price path $p_s(\tau)$ satisfies $p_s(0) = R$ and is a decreasing function. Proposition 1 below shows that equation (16) described in Theorem 2 is the unique decreasing optimal price path which generates F_S. Proposition 1 further establishes the condition that in an ITE $\theta < \overline{\theta}$, which ensures that asking prices never fall so quickly that buyers wait for lower asking prices and thereby contradict the ITE.

A second issue is that there is no random matching function.[22] In each trade in the waiting buyers market, there is just one new seller who in equilibrium posts asking price $p_s = R$, and an unobserved, stochastic number of interested buyers who either bid prices $p \geq R$ or make no offer (silence). To determine equilibrium R, Proposition 2 below answers the all-important question: what happens in the subgame if the new seller deviates with a higher asking price $p_s > R$?

The proof of Proposition 2 identifies a second condition on equilibrium outcomes, $\theta \geq \underline{\theta}$, which yields an ITE equilibrium property akin to the Coase conjecture: should a new seller deviate with a higher reserve price $p_s > R$, buyers believe the seller will, in the next instant, cut that reserve price to R. Equivalently, buyers expect a Dutch descending price auction where the asking price is (arbitrarily) quickly lowered to the reserve price R. Because bids do not change – the Dutch auction is payoff equivalent to a first price auction with reserve R, discounting implies the seller's optimal strategy is to implement the Dutch auction.

Using these two Propositions, Theorem 2 then establishes that a Bayesian equilibrium exists for all $\theta \in [\underline{\theta}, \overline{\theta}]$, where $\underline{\theta} < 1/2 < \overline{\theta}$. These θ are the potential equilibrium outcomes not ruled out by the Propositions 1 and 2. Although this interval excludes the Diamond paradox ($\theta = 1$) as well as the competitive outcome where $R = V_S$ (and so $\theta = 0$ by Theorem 1), the equilibrium θ (and so by extension the equilibrium R) is not unique. Stock-flow matching eliminates the buyer search co-ordination problem. The stochastic overlapping generation structure arising from Poisson entry with

[22] When preferences are public information, the standard stock-flow matching approach assumes that Nash bargaining with exogenous seller bargaining power $\theta \in [0, 1]$ determines R. With directed search, the standard approach finds equilibrium θ is uniquely determined consistent with the Hosios (1990) condition. But the Hosios condition requires a matching function which is absent here. With stock-flow in this paper, Poisson "like" preferences alongside efficiency govern aggregate matches and the associated Beveridge Curve (BC) can be considered a microfoundation of an aggregate matching function.

positive match surplus then yields equilibrium price indeterminacy. Indeed because buyers must co-ordinate expectations on future market prices, it is possible to construct sunspot equilibria.

The first step toward achieving these outcomes is to define an equilibrium.

Definition 2. A **Steady State Baysesian Immediate Trade Equilibrium** consists of (i) efficient trade with market composition (N_B, N_S) consistent with (BC), (ii) privately optimal seller pricing strategies $p_s(.)$ and privately optimal buyer offer strategies, and (iii) all beliefs consistent with agent strategies, price histories and Bayes rule.

6.1 The Equilibrium Asking Price Path $p_s(\tau)$

To construct a dynamically consistent pricing equilibrium, consider a pure strategy equilibrium where each waiting seller's asking price path $p_s(\tau)$ is a decreasing function with $p_s(0) = R$. The proof of Proposition 1 below shows (16) described in Theorem 2 is the unique decreasing path which generates the steady state distribution of asking prices F_S. The restriction $\theta < \overline{\theta}$ on the ITE equilibrium outcome further ensures asking prices never fall so quickly that buyers prefer to wait for lower asking prices.

Proposition 1. Price path $p_s(.)$ given by (16) coupled with seller turnover generates the steady state asking price distribution F_S. Furthermore given R and V_S defined in Theorem 1, this path implies $e^{-r\tau}[1 - p_s(\tau)]$ is strictly decreasing in τ if and only if

$$\theta < \overline{\theta} = \frac{r + \alpha\lambda e^{-\lambda N_B}}{r + 2\alpha\lambda e^{-\lambda N_B}} > 1/2. \tag{13}$$

Proof. See Appendix. □

Proposition 1 implies equilibrium θ cannot be too large. To understand why, suppose instead $\theta = 1$ in which case Theorem 1 implies $R = 1$. But an interested buyer will not bid price $p = 1$ because it yields no surplus. Because positive discounting $r > 0$ implies $\underline{p}_s < 1$, the buyer's dominating strategy is to choose silence and wait for the seller to post a lower asking price $p_s(\tau) < 1$. Given an equilibrium $\theta \leq \overline{\theta}$, however, the asking price $p_s(.)$ falls with time on the market but sufficiently slowly that $e^{-r\tau}[1 - p_s(\tau)]$ is also decreasing in τ. This condition ensures that delaying making an offer in the waiting sellers market is always strictly payoff decreasing so that silence is never optimal.

6.2 Taking A House Off the Market

Suppose $\theta = 0$. Theorem 1 implies $\mathrm{V}_S = R = 0$ and so waiting sellers have value equal to zero. This also cannot describe an ITE: each waiting seller is instead strictly better off by taking their house off the market and re-auctioning at some future date where there is a positive probability of multiple interested buyers and Bertrand competition.

To demonstrate this point, define $x \in [0, \lambda N_B]$ as the expected number of buyers who like the current seller's property. In the Candidate ITE, there were just two types of sellers: new sellers with $x = \lambda N_B$, and waiting sellers with $x = 0$. The option of taking the property off the market implies x is a seller state variable with initial value $x_0 = \lambda N_B$ for new sellers. Because all buyers observe the seller's price history, all have common, rational beliefs on x. Suppose then a seller takes his house off the market, say by setting an unrealistic asking price $p_s = 1$. Lemma 3 now describes how the seller's x increases over time.

Lemma 3. In a Bayesian equilibrium, if seller $x \in [0, \lambda N_B]$ takes his house off the market, then x increases over time according to

$$\dot{x}(x) = \mu \left[\lambda N_B - x\right], \tag{14}$$

where $\mu \equiv \alpha[1 - e^{-\lambda N_B}]/N_B$.

Proof. See Appendix. □

The aim is not to describe equilibria where sellers optimally take their houses off the market.[23] Rather Proposition 2 now identifies conditions where this is never optimal; i.e. immediately posting an auction with reserve price R is optimal for any $x > 0$. When this property holds, the equilibrium value function of each seller $x \in (0, \lambda N_B]$ is

$$V(x; \theta) = xe^{-x}R + [1 - e^{-x} - xe^{-x}][1 - V_B] + e^{-x}V_S. \tag{15}$$

This expression takes advantage of revenue equivalence – it describes seller x's expected payoff with a second price auction. The first term describes the seller's payoff if only one buyer likes the property

[23] Gilbukh (2023) and Carrillo and Williams (2015) find this strategy does occur in housing markets. Also see Smith (2007) in a labour market context.

and so trade occurs at price R, the second if more than one likes the property and the price is then bid up to $1 - V_B$, and the third if no-one likes the property and the seller then obtains value V_S in the continuation. Notice that $V = V_S$ when $x = 0$. Also notice the critical role played by the Candidate ITE. Given any $\theta \in [0, 1]$, Theorem 1 identifies R, V_S, V_B and (15) now yields a closed form solution for $V(x; .)$ for all $x \in [0, \lambda N_B]$.

Given $V(x; .)$ described by (15), seller $x \in [0, \lambda N_B]$ will deviate by taking his property off the market whenever $V'(x; .)\dot{x}(x) > rV(x; .)$, where the left hand side describes the marginal increase in value by accumulating more potential buyers, the right hand side describes the cost of deferring the auction.[24] Hence for any given $\theta \in [0, 1]$, consider

$$\begin{aligned} \Omega(x;\theta) &\equiv V'(x;\theta)\dot{x}(x) - rV(x;\theta) \\ &= \left\{ \begin{array}{c} \mu\left[\lambda N_B - x\right]\left\{e^{-x}[R - V_S] + xe^{-x}[1 - R - V_B]\right\} \\ -r\left\{xe^{-x}R + [1 - e^{-x} - xe^{-x}][1 - V_B] + e^{-x}V_S\right\} \end{array} \right\} \end{aligned}$$

with R, V_B, V_S given by Theorem 1. It is easy to show that $\Omega(0; \theta) = 0$ and $\Omega(\lambda N_B; \theta) < 0$. Lemma 4 now establishes its critical property.

Lemma 4. For any $\theta \in [0, 1]$, $\Omega(.; \theta)$ is a strictly quasiconcave function over the domain $x \in [0, \lambda N_B]$. Furthermore

$$\begin{aligned} (i) \frac{d}{dx}\Omega(x;\theta) &> 0 \text{ at } x = 0 \text{ if } \theta < \underline{\theta}; \\ (ii)\ \Omega(x;\theta) &< 0 \text{ for all } x \in (0, \lambda N_B] \text{ if } \theta \geq \underline{\theta}, \end{aligned}$$

where

$$\underline{\theta} = \frac{\lambda N_B}{\frac{r+\mu}{\mu} + 2\lambda N_B} < 1/2.$$

Proof. See Appendix. □

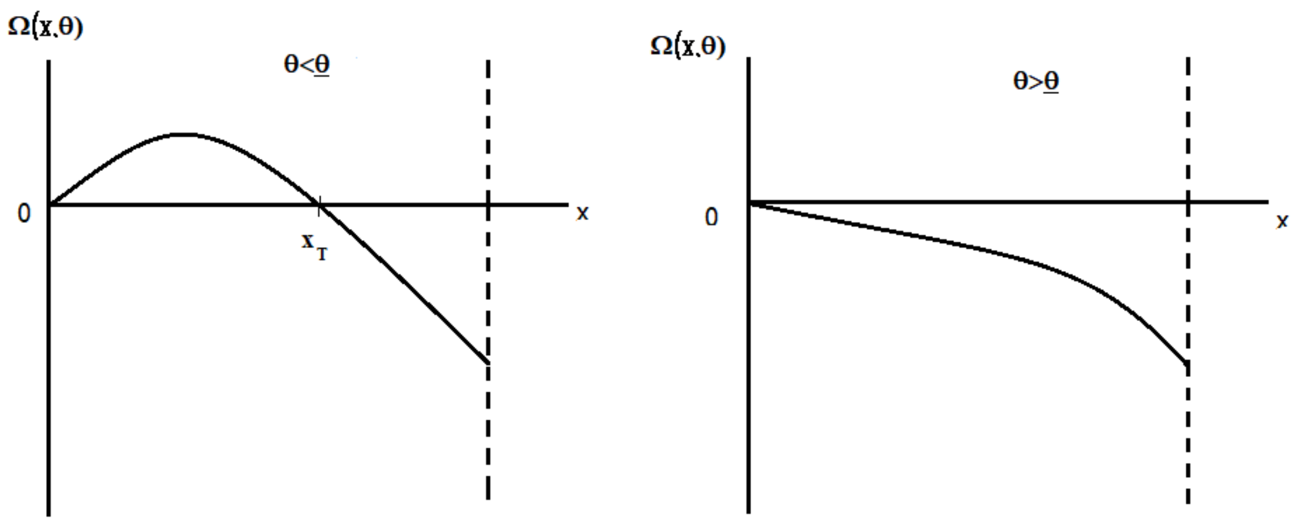
Figure 1 illustrates $\Omega(.; \theta)$ for the two cases $\theta < \underline{\theta}$ and $\theta > \underline{\theta}$. For low $\theta < \underline{\theta}$, (i) in Lemma 4 implies there exists a region $x \in (0, x_T)$ where $\Omega(x; .) > 0$ over that domain. An ITE does not exist for such θ because a waiting seller with $x = 0$ strictly prefers to deviate and take his house off the market for re-auctioning at date T where accumulated $x(T) = x_T$. He does not delay beyond T because $\Omega(x; \theta) < 0$

[24] Whenever delay is optimal, the optimal auction date T maximises $e^{-rT}V(x(T); \theta)$.

thereafter. In contrast for sufficiently high $\theta > \underline{\theta}$, Lemma 4 implies $\Omega(x;\theta) < 0$ for all $x \in (0, \lambda N_B]$. In this case it is never value increasing for any seller $x \in [0, \lambda N_B]$ to take their property off the market.

For $\theta \geq \underline{\theta}$, Proposition 2 now establishes a key result: a first price auction with reserve price R is optimal for all sellers $x \in (0, \lambda N_B]$. Note as well that sellers $x = 0$ are indifferent to $p_s \in [\underline{p}_s, R]$.

Figure 1: Properties of $\Omega(.)$



Proposition 2. For $\theta \in [\underline{\theta}, \overline{\theta}]$, a Bayesian equilibrium exists where the optimal strategy of any seller $x \in (0, \lambda N_B]$ is to post a first price auction with reserve price R.

Proof. See Appendix. □

The proof of Proposition 2 not only describes each seller's optimal strategy, it also describes buyer beliefs: when $x > 0$, each buyer expects a first price auction with reserve price R. Conditional on any $x \in (0, \lambda N_B]$, the proof of Proposition 2 first shows each interested buyer draws an offer $p \sim F_B(.|x)$. If the seller posts asking price $p_s > R$, then interested buyers with draws $p \geq p_s$ make their offer, but those with $p < p_s$ choose silence. If no offers are received, the updated expected number of interested buyers is $x' = xF_B(p_s|x)$. But $p_s > R$ then implies $x' > 0$ and so buyers expect, in the very next instant, a first price auction with reserve price R. An easy intuition is that buyers simply expect a Dutch descending price auction where, following a failure to sell at the current asking price $p_s > R$, the seller reduces the asking price (arbitrarily quickly) to the reserve R until a bid is a received. Given these expectations, buyer bids do not change because the Dutch auction is payoff equivalent to an immediate first price auction with reserve R. And because $\theta \geq \underline{\theta}$ ensures it is never optimal to take the house off the market, discounting then implies the seller's optimal pricing strategy is indeed the Dutch auction.

6.3 A Continuum of Equilibria

Proposition 1 determines the equilibrium asking price path $p_s(\tau)$ described by (16). The condition that in equilibrium $\theta < \overline{\theta}$ ensures the price path is dynamically consistent; i.e. buyers never wait for lower asking prices. Proposition 2 then establishes that posting reserve price R is always optimal if and only if $\theta \geq \underline{\theta}$, which establishes seller strategy [S1] below and so Theorem 2.

Theorem 2. A Steady State Bayesian Candidate Immediate Trade Equilibrium exists for all $\theta \in [\underline{\theta}, \overline{\theta}]$ with central price $R = R(\theta)$ defined by (3) and with the following strategies and beliefs:

1. All new sellers post the same asking price $p_s(0) = R$;

2. Any buyer who does not like any other properties on the market (a waiting buyer) but likes a new listing with asking price $p_s(0) = R$, makes an offer $p' \geq R$ with distribution F_B given by (6);

3. A new listing accepts the highest offer $p' \geq R$. If the new seller who sets $p_s(0) = R$ receives no offers, he infers no current buyers like his property;

4. Along their equilibrium path, sellers who believe no current buyers like their property (waiting sellers) utilise the asking price path $p_s(\tau)$ which is continuous, strictly decreasing and convex with seller time on the market $\tau > 0$, where

$$p_s(\tau) = \underline{p}_s + [R - \underline{p}_s]e^{-\alpha\lambda\tau}; \tag{16}$$

   with $\underline{p}_s = e^{-\lambda N_S}R + (1 - e^{-\lambda N_S})V_S < R$;

5. A buyer who likes several properties with asking prices below R, contacts that seller posting the lowest asking price p_s and offers that asking price p_s. The seller accepts and trade occurs at the asking price.

The following strategies and beliefs support this equilibrium path:

S1 If the seller ever deviates with asking price $p_s \neq p_s(\tau)$, the seller thereafter sets asking price R;

B1 If a new listing sets an asking price $p_s > R$, interested buyers do not change their bids $p' \sim F_B$ because they expect the asking price to fall immediately to R and trade is consistent with a Dutch descending price auction;

B2 If a new listing deviates to an asking price $p_s < R$, interested buyers change their bids p' reflecting the lower reserve price but, being revenue equivalent to a second price auction, the seller is strictly worse off;

B3 If a house for sale is not a new listing and the seller posts $p_s \leq R$, an interested buyer offers $p' = p_s$ if and only if it is the lowest asking price in the set of houses liked;

B4 If a house for sale is not a new listing and the seller posts $p_s > R$, an interested buyer expects the seller to immediately cut his asking price to R. If she likes any other house with an asking price $p_s \leq R$, she buys elsewhere.

Similar to McAfee (1993), posting the equilibrium reserve price R is always an optimal pricing strategy. Should any seller deviate from the equilibrium path $p_s(.)$, S1 simplifies because buyers thereafter expect asking price R. The construction of equilibrium, however, requires equilibrium asking price dispersion. Equilibrium finds that waiting sellers are indifferent to posting any price $p_s \in [\underline{p}_s, R]$ as long as F_S, the price distribution across waiting sellers, satisfies (8). The equilibrium price path $p_s(\tau)$, given by equation (16), and steady state turnover ensures that this is the case. It also ensures that asking prices $p_s(\tau)$ fall sufficiently slowly with time on the market so that no buyer prefers to wait for a lower asking price. Notice that unlike the large economy case, all sellers post $p_s \geq \underline{p}_s$ which is strictly greater than their continuation value V_S; i.e. sellers have market power and the market outcome is not competitive.

7 Conclusion

This paper considers equilibrium trade in a durable goods (housing) market with turnover. Despite the absence of conventional search frictions, the stochastic overlapping generations structure arising from some traders needing to wait for a suitable match to enter the market generates positive match surplus. Private information about buyers' idiosyncratic preferences adds a second trading friction. The stock-flow trading structure that emerges from this stylized framework results in a thin market setting in which some houses are sold in bidding wars while others are sold in a slower search-like fashion.[25]

Although the proposed directed search trading protocol highlights important aspects of the housing market, it also abstracts from salient and quantitatively important matching elements of housing markets. For example, there are no rental markets or lifecycle consumption patterns; the joint buyer-seller problem which complicates the turnover externality present in stock-flow matching is absent here as are intermediation by real estate agents and mortgage financing costs.[26] Despite these abstractions, Smith (2020a), Gilbukh (2023), and Smith et al. (2022) demonstrate the empirical validity of the stock-flow approach in capturing hazard rates, time on the market, and other observables.

Adding to this consistency with the data, the twin roles of asking prices – one in bidding wars of old buyers and the other to compete for new buyers – together conform with the outcome that asking prices drop with time on the market and quick sales are associated with variable prices above the asking price.[27] Moreover, the estimated price spike in Gilbukh (2023) provides direct information for a lower bound calculation of housing match surplus. Match surplus in the real estate market is calculated to be, at a minimum, 3.3% of house prices, while simple examples suggest that the surplus is around the 10% mark. This method of directly calculating match surplus is new and refining these calculations is clearly an opportunity for future research.

Equilibrium price indeterminacy exists when the inflows of buyers and sellers are exogenous. The limiting frictionless case, however, suggests that price indeterminacy is not an issue with endogenous entry. On the other hand, the proposed endogenous entry example restricted equilibrium to steady state outcomes. A degree of freedom remains. Consider a candidate equilibrium $\theta = \widehat{\theta} \in [0, 1]$. With endogenous entry, the market clearing condition (10) and the (BC) uniquely determine market composition $(N_B(\widehat{\theta}), N_S(\widehat{\theta}))$. Theorem 2 further describes a non-degenerate range of equilibrium values $[\underline{\theta}, \overline{\theta}]$ where $\underline{\theta} < 1/2 < \overline{\theta}$. The restriction to steady state, reduces equilibrium to a fixed point problem: if candidate $\widehat{\theta} \in [\underline{\theta}, \overline{\theta}]$, this describes a steady state Bayesian equilibrium with market composition $(N_B(\widehat{\theta}), N_S(\widehat{\theta}))$, market clearing price $R^C = p^c$ and equal inflows $\alpha_B = \alpha_S = \alpha$.

[25] Piazzesi et al. (2020) find that buyers look in narrow market segments within metropolitan areas whereas Han and Strange (2015) note the relevance of thin markets in housing.

[26] Halket and di Custoza (2015) considers the impact of the rental sector. Anenberg and Bayer (2020), Moen et al. (2021) and Grindaker et al. (2026) evaluate the impact of the joint buyer-seller decision. Stein (1995), Genesove and Mayer (2020), Ortalo-Magné and Rady (2006), Hedlund (2016a), Hedlund (2016b), and Garriga and Hedlund (2020) address borrowing constraints and credit frictions whereas Hendel et al. (2009)) addresses intermediation from real estate agents.

[27] The insights into the role, determination, and evolution off asking prices are set in steady state which will complicate empirical validation using data from an evolving market. Price indeterminacy then compounds these empirical challenges as well as calculating comparative statics.

It follows there is a continuum of equilibrium $\widehat{\theta}$. It should not then be surprising that non-steady state sunspot equilibria exist where θ is time varying. Indeed with exogenous entry as considered here, it is easy to construct examples of sunspot equilibria with aggregate price dynamics. Extending the approach to endogenous entry, market frictions and aggregate shocks is clearly important. Nevertheless sunspot equilibria with θ shocks will exist because market composition (N_{B_t}, N_{S_t}) becomes part of the aggregate state space. Specifically a "shock" increase in current θ_t implies an increase in current trading prices (sellers extract more of the match surplus) which, with endogenous entry, causes the inflow of new buyers to fall due to higher prices. Because the stock N_{S_t} increases as N_{B_t} falls, market prices with this higher θ_t gradually fall back to "clearing" levels. In the extended framework with endogenous entry and aggregate shocks, real estate prices will depend not only on market fundamentals but also on market composition (N_{B_t}, N_{S_t}) and sunspots θ_t. Tractability will likely require a switch to second price auctions which are revenue equivalent.

A second possible extension is that conditional on liking a good, the buyer's utility u from owning the good becomes $u \in [\underline{u}, 1]$ considered as some *iid* draw. This extension is natural and possibly important because the price distributions F_B, F_S identified here do not match the data: although prices are centred around R, the density of trading prices is U shaped rather than bell shaped (see also the discussion on residual prices in Rekkas et al., 2025). Unfortunately this is not a simple extension because it directly raises Coase conjecture issues.[28]

A simpler and more natural empirical route might be to consider unobserved heterogeneity in turnover rates; e.g. the market for rural mansions in Kentucky has lower turnover than the market for one bedroom apartments in New York City. Theorem 1 shows that greater (unobserved) turnover rates $\alpha = \alpha_i$ in market i reduces market i surplus and so price dispersion. And so with aggregated data, trade flows are higher in market "New York City" with prices more tightly distributed around R. This suggests heteroskedasticity in price residuals is important. Interestingly seller i's time on the market τ_i, which is observed, is directly correlated with the underlying turnover rates in $i's$ market, which is unobserved; for example the unsold rural mansion might be on the market for a long time.

[28]If $\underline{u} \simeq 1$ then the above results likely go through. But for intermediate values of $\underline{u}$, the conjecture is that ITE exist with $R = \underline{u}$. In this scenario if a new seller posts an asking price above $\underline{u}$, interested buyers then expect an immediate Dutch (descending price) auction where the seller (arbitrarily quickly) lowers the asking price until $p_s = \underline{u}$. But if $\underline{u}$ is very small, say zero, then waiting sellers will take their house off the market because $R = 0$ implies $V_S = 0$. For $\underline{u}$ too small, Lemma 4 instead suggests a central price of the form $R = R(\underline{\theta}) > 0$ where sellers are just indifferent to taking their house off the market. Characterising such equilibria, however, is much more complex and not considered here.

Gilbukh (2023) finds residual errors are correlated with time on the market. Heteroskedastic errors further suggests the variance of residual prices will also be correlated not only with the seller's time on the market but also with (time varying) aggregate sales flows over the business cycle.

The competing auctions framework rules out lowball offers. But given this equilibrium trading structure, it is straightforward to conjecture how sellers might respond to such offers. Suppose a new listing posts the equilibrium asking price $p_s = R$ but an interested buyer makes a lowball offer $p < R$. If any other buyer offers price $p \geq R$, the seller accepts the highest bid, trades and exits the market. But if no other offers are received the property remains on the market. In that case the interested buyer now believes she is the only interested buyer, though the lowball offer also reveals to the seller that he has buyer interest. In this scenario, a lowball offer might be interpreted as an invitation to bargain. In a previous version of this paper, the central price R was determined by a strategic bilateral bargaining game and, given an assumed seller bargaining power $\tilde{\theta} \in [\underline{\theta}, \overline{\theta}]$, equilibrium was then as described in Theorem 2 and uniquely determined given $\tilde{\theta}$. With equal bargaining powers $\tilde{\theta} = 1/2$, such an equilibrium always exists and the symmetric case motivates the 9% ballpark surplus estimate.

On the other hand, if seller bargaining power is too low, $\tilde{\theta} < \underline{\theta} < 1/2$, Lemma 4 shows the seller will not trade at a negotiated price $R(\tilde{\theta}) < R(\underline{\theta})$ because he instead takes his house off the market to re-auction at a future date. The outside option principle then suggests equilibrium $R = R(\underline{\theta})$; i.e. the interested buyer must offer a price premium so that the seller does not take his house off the market.

Now suppose seller bargaining power is too high, such that $\tilde{\theta} > \overline{\theta}$, so that bilateral bargaining would yield a too high price $R(\tilde{\theta})$. Anticipating lower asking prices $p \sim F_S$, interested buyers presumably deviate by choosing silence, to wait for lower asking prices. Coase conjecture type issues then imply equilibrium R must fall to an $R \leq R(\overline{\theta})$ in which case bargaining with asymmetric information plays no role: when the seller's asking price is too high, interested buyers do not reveal interest with a lowball offer - they instead wait for a lower asking price. Personal experience from selling a house found that each time the asking price was reduced (twice), new potentially interested buyers came round to inspect the property. The interesting question is why did they not previously inspect and make lowball offers?

8 Appendix

Proof of Lemma 2.

In steady state, the outflow of waiting sellers is $\alpha[1-e^{-\lambda N_S}]$: this outflow of sellers equals the inflow of new buyers who like at least one waiting seller's property and trade implying one waiting seller leaves the market. The inflow of waiting sellers is instead $\alpha e^{-\lambda N_B}$: it is the inflow of new sellers who fail to attract a waiting buyer. Because these flows must be equal, this yields the condition stated. Repeating the analysis instead for the stock of waiting buyers yields the same condition. This completes the proof of Lemma 2.

Proof of Proposition 1.

For each price point $p \in [\underline{p}_s, R]$, steady state requires the exit flow of waiting sellers who successfully trade must be replaced by an equivalent inflow. Now the trading rate of an waiting seller who sets asking price $p' \leq R$.is $\alpha\lambda e^{-\lambda N_S F_S(p')}$, because $N_S F_S(p')$ is the measure of sellers announcing a lower price and so an waiting seller, to successfully trade at price p', requires the interested new buyer does not like any of those cheaper properties. Hence over a short time period Δ, the measure of waiting sellers announcing price less than p who trade and exit the market is

$$X(p) = \Delta \int_0^p \alpha\lambda e^{-\lambda N_S F_S(p)} N_S dF_S(p')$$

where $N_S dF_S(p')$ is the measure of waiting sellers who set price p'. Integration implies the outflow is

$$X(p) = \alpha\Delta[1 - e^{-\lambda N_S F_S(p)}]$$

which has a simple interpretation: $\alpha\Delta$ is the inflow of new buyers and $[1 - e^{-\lambda N_S F_S(p)}]$ describes the probability each likes at least one waiting seller's property at a price below p and the cheapest waiting seller in this set successfully trades and exits the market.

Steady state requires an offsetting inflow for every $p \in [\underline{p}_s, R]$. Because $p_s(\tau)$ is a continuous, strictly decreasing function there exists a unique duration τ^* such that $p_s(\tau^*) = p \in [\underline{p}_s, R]$. Over short period Δ, the measure of waiting sellers who at the start of the period announced a price $p_s > p$, failed to trade and then announce a price $p_s \leq p$ is:

$$N_S \left[F_S(p_s(\tau^* - \Delta)) - F_S(p_s(\tau^*))\right] [1 - \alpha\lambda e^{-\lambda N_S F_S(p)} \Delta] + 0(\Delta^2).$$

Setting this inflow equal to the outflow $X(p)$ and dividing both sides by Δ implies

$$\alpha[1-e^{-\lambda N_S F_S(p)}] = N_S\left[\frac{F_S(p_s(\tau^*-\Delta))-F_S(p_s(\tau^*))}{\Delta}\right][1-\alpha\lambda e^{-\lambda N_S F_S(p)}\Delta]+0(\Delta).$$

Letting $\Delta \to 0$ yields the differential equation

$$\alpha[1-e^{-\lambda N_S F_S(p_s)}] = -N_S F_S'(p_s)\frac{dp_s(\tau)}{d\tau}.$$

But (8) implies

$$\begin{aligned} e^{-\lambda N_S F_S(p)} &= \frac{[R-V_S]e^{-\lambda N_S}}{p-V_S} \\ &\Rightarrow \lambda N_S F_S'(p) = \frac{1}{p-V_S}, \end{aligned}$$

and substitution now yields the linear differential equation:

$$\frac{dp_s(\tau)}{d\tau} = -\alpha\lambda[p_s - V_S - [R-V_S]e^{-\lambda N_S}]$$

which is trivial to solve. The boundary condition $p_s(0)=R$ implies (16) is its solution.

Given this solution for $p_s(\tau)$, then

$$e^{-r\tau}[1-p_s(\tau)] = e^{-r\tau}\left[1-\underline{p}_s-[R-\underline{p}_s]e^{-\alpha\lambda\tau}\right].$$

Differentiating wrt τ, this expression is strictly decreasing in τ for all $\tau \geq 0$ if and only if:

$$(r+\alpha\lambda)[R-\underline{p}_s]e^{-\alpha\lambda\tau} < r\left[1-\underline{p}_s\right]\forall\tau\geq 0$$

Because this LHS term decreases with τ, this condition is satisfied if and only if

$$(r+\alpha\lambda)[R-\underline{p}_s] < r\left[1-\underline{p}_s\right].$$

Substituting out $\underline{p}_s = e^{-\lambda N_S}R+(1-e^{-\lambda N_S})V_S$ and using Theorem 1 to substitute out R, V_S now implies (13) for θ. This completes the proof of Proposition 1.

Proof of Lemma 3.

Consider a waiting seller with $x=0$ who takes his property off the market, say at date $t=0$, and note N_B describes the measure of current buyers who, by not previously making an offer, have revealed they do not like his property. Let $\widehat{N}(t)$ denote the measure of these agents who remain unmatched at date t. $\widehat{N}(t)$ then evolves according to

$$\frac{d\widehat{N}(t)}{dt} = -\alpha[1 - e^{-\lambda N_B}]\frac{\widehat{N}(t)}{N_B}$$

because $\alpha[1 - e^{-\lambda N_B}]$ is the exit flow of waiting buyers [who match with the inflow of new sellers] and $\widehat{N}(t)/N_B$ describes the probability the winner of each auction is one of our original buyers. Solving with $\widehat{N}(0) = N_B$, implies

$$\widehat{N}(t) = N_B e^{-\mu t}. \tag{17}$$

Note then that $[N_B - \widehat{N}(t)]$ describes the accumulation of potentially interested buyers by date t. The expected number of buyers who like the seller's property is thus $x(t) = \lambda[N_B - \widehat{N}(t)]$. Hence if the house is taken off the market at date $t = 0$, (17) implies $x(.)$ is given by

$$x(t) = \lambda N_B[1 - e^{-\mu t}]. \tag{18}$$

Given any $x = x(t) \in [0, \lambda N_B]$, (18) now implies (14). This completes the proof of Lemma 3.

Proof of Lemma 4.

Because the algebra is arduous, some simplifications are useful. Fix any $\theta \in [0, 1]$ and for notational simplicity drop reference to θ in the value functions. Define $A = r/\left[\theta[r + \alpha\lambda e^{-\lambda N_S}] + (1-\theta)[r + \alpha\lambda e^{-\lambda N_B}]\right]$, which is a positive constant. Given $V(x)$ defined by (15), differentiation and using Theorem 1 to substitute out R, V_S, V_B yields the following functional forms:

$$\begin{aligned}
V'(x) &= A\left[\theta e^{-x} + (1-\theta)xe^{-x}\right] > 0 && (19)\\
V''(x) &= A\left[(1-2\theta)e^{-x} - (1-\theta)xe^{-x}\right] && (20)\\
V'''(x) &= A\left[(-2+3\theta)e^{-x} + (1-\theta)xe^{-x}\right]. && (21)
\end{aligned}$$

Given $\Omega(x) = \mu V'(x)[\lambda N_B - x] - rV(x)$, differentiation further implies

$$\begin{aligned}
\Omega'(x) &= \mu V''(x)[\lambda N_B - x] - (r+\mu)V'(x)\\
\Omega''(x) &= \mu V'''(x)[\lambda N_B - x] - (r+2\mu)V''(x).
\end{aligned}$$

with V', V'', V''' defined above. With this in hand, it is now straightforward to prove Lemma 4.

Inspection finds $\Omega(0) = 0$ and $\Omega(\lambda N_B) < 0$. Furthermore at $x = 0$,

$$\Omega'(0) = A\left[\mu(1-2\theta)\lambda N_B - (r+\mu)\theta\right].$$

By definition of $\underline{\theta}$, it follows that $\Omega'(0) > 0$ if $\theta < \underline{\theta}$ and $\Omega'(0) \le 0$ if $\theta \ge \underline{\theta}$.

The first step in proving that $\Omega(.)$ is strictly quasiconcave for $x \in [0, \lambda N_B]$, is to establish that if a turning point $x \in [0, \lambda N_B)$ exists where $\Omega'(x) = 0$, then $\Omega''(x) < 0$ and $\Omega(.)$ is thus single-peaked and so quasi-concave.

Because $\Omega'(\lambda N_B) < 0$, suppose a turning point $x \in [0, \lambda N_B)$ exists where

$$\Omega'(x) = \mu V''(x)[\lambda N_B - x] - (r+\mu)V'(x) = 0.$$

Such a turning point requires $V''(x) > 0$ with x given by

$$\lambda N_B - x = \frac{(r+\mu)V'(x)}{\mu V''(x)}.$$

Calculating the second derivative at any such turning point implies

$$\begin{aligned}
\Omega''(x) &= \mu V'''(x)[\lambda N_B - x] - (r+2\mu)V''(x) \\
&= (r+\mu)\frac{V'(x)V'''(x)}{V''(x)} - (r+2\mu)V''(x).
\end{aligned}$$

Because $V''(x) > 0$ at the turning point, then $\Omega''(x) < 0$ if and only if

$$(r+2\mu)[V''(x)]^2 - (r+\mu)V'(x)V'''(x) > 0.$$

The next step is show that this is true for all $x \in [0, \lambda N_B]$. Using the above expressions for V', V'', V''' finds

$$(r+2\mu)[V''(x)]^2 - (r+\mu)V'(x)V'''(x) = A^2 e^{-2x}\left[\begin{array}{c} (r+2\mu)\left[(1-2\theta)-(1-\theta)x\right]^2 \\ -(r+\mu)\left[\theta+(1-\theta)x\right]\left[-2+3\theta+(1-\theta)x\right] \end{array}\right],$$

where the bracketed term is a quadratic in x. Expanding and collecting terms appropriately finds:

$$(r+2\mu)[V''(x)]^2 - (r+\mu)V'(x)V'''(x) = A^2 e^{-2x}\left\{\begin{array}{c} \mu\left[1-2\theta-(1-\theta)x\right]^2 \\ +(r+\mu)[1-\theta]^2 \end{array}\right\} > 0$$

because the bracketed term is the sum of two squares. Hence any turning point $x \in [0, \lambda N_B]$ must be a strict local maximum which establishes the Lemma. This completes the proof of Lemma 4.

Proof of Proposition 2.

Consider seller $x \in (0, \lambda N_B]$ and a candidate equilibrium where all interested buyers expect an immediate first price auction with reserve price R. Let $p \sim F_B^x$ denote the distribution of bids p made by a representative interested buyer with $x \in (0, \lambda N_B]$. Using previous arguments, a bid $p \geq R$ yields the buyer expected payoff

$$W_B^x(p) = e^{-x[1-F_B^x(p)]}[1-p] + [1-e^{-x[1-F_B^x(p)]}]V_B,$$

The equilibrium bid distribution $\mathrm{F}_B^x(.)$ is given by

$$e^{-x[1-F_B^x(p)]}[1-p] + [1-e^{-x[1-F_B^x(p)]}]V_B = e^{-x}[1-R] + [1-e^{-x}]V_B, \tag{22}$$

and its supremum $\overline{p}(x)$ is given by

$$1 - \overline{p}(x) = e^{-x}[1-R] + [1-e^{-x}]V_B. \tag{23}$$

Given this distribution of bids $p \sim F_B^x$, what is seller x's optimal asking price strategy?

Because $\theta \geq \underline{\theta}$, Lemma 4 implies auction strategy $p_s = R$ dominates $p_s \geq \overline{p}(x)$ which is payoff equivalent to taking the house off the market. Also being revenue equivalent to a second price auction, setting $p_s = R$ strictly dominates setting reserve $p_s < R$. Suppose then the seller posts initial asking price $p_s^0 \in (R, \overline{p}(x))$. Given buyer price expectations (an immediate first price auction with reserve R but now anticipated as a Dutch descending price auction) the distribution of first price bids $p \sim F_B^x$, described by (22), is unchanged. Given posted reserve price $p_s^0 \in (R, \overline{p}(x))$, interested buyers with bids $p \sim F_B^x$ and $p \geq p_s^0$, make an offer p and the good is sold to the highest bidder. But if the good is not sold then, in the continuation, the expected number of buyers who like the good is revised down to

$$x' = xF_B^x(p_s^0),$$

because those who would have made an offer $p \geq p_s^0$ have revealed they do not like the good. In this continuation x', interested buyers potentially update their bids according to $p \sim_B^{x'}$ where $\overline{p}(x') = p_s^0$. However it is obvious in a Dutch auction that the original bids of these continuation buyers remain equilibrium bids. If the seller posts an asking $p_s^1 \in (R, p_s^0)$ then those with original bids $p \geq p_s^1$ make an offer and the good is sold to the highest bidder. But if the good is not sold then updated $x'' = xF_B^x(p_s^1)$, the seller posts a new $p_s^2 \in (R, p_s^1)$ and so on. The seller keeps cutting his asking price while the property remains unsold. With strictly positive discounting and rational buyer expectations, a Dutch auction is optimal because the seller trades immediately with the highest bidder $p \sim F_B^x$ where $p \geq R > V_S$. This completes the proof of Proposition 2

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