# The Thick Market Effect on Housing Markets Transactions

**Li Gan and Qinghua Zhang**[1]

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**Abstract**

This paper provides a search model for housing market where the number of buyers and/or sellers plays very important role. The model makes three testable predictions: (1) the unemployment rate has a negative impact on the trading volume and the sale prices of the housing market; (2) a larger housing market has a lower average sale price, shorter time-to-sale and smaller price dispersion, in addition to a lower vacancy rate. (3) In a larger housing market, when the unemployment rate goes up (or down), the sale price decreases (or increases) by a smaller percentage than in a smaller market. All three predictions are supported by a panel dataset of the Texas city-level housing markets.

Key Words: price-transaction volume, search model

[1] Gan: Department of Economics, Texas A&M University, College Station, TX 77843-4228, and NBER. gan@econmail.tamu.edu; Zhang: Guanghua School of Management, Peking University, Beijing, China. zhangq@gsm.pku.edu.cn.

## 1. Introduction

Many authors have documented a positive correlation between housing prices and transaction volumes. Specifically, using aggregate data, Stein (1995) estimates that a decrease of 10 percent in price lowers transaction volumes by 1.6 million units, which is about 40% of total transaction volumes. The standard model such as Poterba (1984) has difficulty in explaining this counter-intuitive phenomenon.

Two alternative hypotheses are offered in the literature. The down-payment hypothesis, as modeled by Stein (1995) and empirically tested by Genesove and Mayer (1997) concentrates on the liquidity constraint of individual households. A household who wants to sell her house often needs the equity from the house to pay down-payments of the new house. When the house price is down, the equity of the current house may not cover the down-payment of the new house. Therefore, prospective sellers intend to hold their current houses longer. The loss-aversion hypothesis, on the other hand, is based on the prospect theory of Kahneman and Tversky (1979) who argue that the marginal disutility from a loss is larger than the marginal utility from a gain. Due to the loss aversion, sellers tend to hold their houses in hope of offers higher than the original purchasing prices when facing a down market, even though they would encounter additional financial loss by doing so. Thus a decline in price leads to reduced transaction volumes. Genesove and Mayer (2001) provide supportive evidence to the loss aversion hypothesis.

Both the liquidity constraint hypothesis and the loss-aversion hypothesis suggest additional costs (liquidity constraint and/or loss aversion) of selling a house when prices fall. They apply to a busted market where decreases in housing prices cause declines in transaction volumes. However, the positive relationship between housing prices and transaction volumes not only applies when the market falls, but also applies when the market rises. For example, in Texas, the housing prices have been steadily increasing since the late 1980s. The inflation-adjusted average housing price has increased by 28% from 1989 to 2004, while the transaction volume has increased by 66% during the same period.

In this paper, we provide a search model where the thick market effect can strengthen either an increase or a decrease in both transaction volumes and in housing prices in the presence of either a positive or a negative demand shock, respectively. It is worth noting that the thick market effect may complement the previously mentioned liquidity constraint effect and loss-aversion effect and together lead to a deeper downturn in a busted housing market.

In the model, houses are heterogeneous in their characteristics and people have heterogeneous preferences on houses. When the total number of buyers and sellers is smaller, the quality of matching between a buyer and a seller is lower on average. A lower matching quality leads to a lower price and a lower probability of selling and/or buying. This is the thick market effect.

The unemployment rate is incorporated into the model as the business cycle factor. Unemployment practically prevents a worker from entering the housing market as a buyer. Thus, a rise in unemployment gives a negative shock to housing demand while a decrease in unemployment produces a positive demand shock. More interestingly, a negative demand shock typically reduces both the number of buyers and the number of sellers, and this slows down the matching process between buyers and sellers thanks to the thick market effect, which in turn strengthens the decrease in transaction volumes and the sale price at the same time.

In addition, the thick market effect diminishes marginally as the market size increases. Thus a housing market of a smaller size should be more responsive to demand shocks. More specifically, the average sale price is more elastic with respect to the unemployment rate in abstract values when the market size is smaller.

The key factor in our model is the market size, defined as the total number of potential buyers and sellers in the market. A common intuition is that market size should matter in matching buyers and sellers, and a thicker market should facilitate the matching process. However, among relatively few papers that have studied the thickness effect on the market outcomes, there is no consensus regarding this intuition. For example, a thicker market has adverse effect in Burdett, Shi and Wright (2002), has no effect in Lagos (2001), and has a positive effect in Coles and Smith (1999). More recently, Gan and Li (2005) provide a model using the matching mechanism of Roth (1984) and show that the matching probability increases while the variance of the matching probabilities decreases as market becomes thicker. They also test their model using job markets for fresh PhDs in economics.

In a dynamic setting, Zhang (2002) develops a model to show how the thick market effect speeds up the relocation of used capital goods. Gan and Zhang (2005) propose a model to study how market size affects local labor markets, and show in empirical data that a thicker market (characterized by the number of labor force) has a lower average unemployment rate, shorter unemployment cycles, and a lower peak unemployment rate. Lying in the heart of the above models is the thick market effect improving the matching quality in a search-matching framework. The model in this paper is similar to the above models. However, Zhang and Gan and Zhang concentrate on the timing of matching and the corresponding cyclical fluctuations while the current model emphasizes the average selling and buying probabilities.

It is not new in the literature to apply search-matching models to study housing market. For example, Wheaton (1990) develops a search model to show how the price and time to sale adjust to the vacancy rate in the short run; and how in the long run the structural vacancy rate is determined through free entry. In his model, there are two types of households and two types of houses correspondingly. Households change types randomly, which generates mismatch and creates turnover. Arnott (1989) investigates rental housing vacancies. Because of the heterogeneity of both households and houses, mismatch incurs, which confers monopoly power on landlords who set rents above costs. Free entry drives the landlords' profits to zero, resulting in vacancies in equilibrium. The model predicts that when the rental market size is larger, landlords possess weaker monopoly power and thus set a lower rent, which leads to lower vacancy rate. Mayer (1995) presents a negotiated-sale model in the housing market following the setting of Arnott's. The simulations of his model show that a larger market has a lower vacancy rate, a shorter time-to-sale and a lower sale price.

However, none of the above papers has modeled demand shocks due to changes in the status of the economy. Our model incorporates the unemployment rate through credit constraint into a search setting. It thus provides a framework to study how demand shocks affect housing market transactions; how the thick market effect strengthens the impact of demand shocks; and how markets of different sizes experience demand shocks differently because of the marginally diminishing thickness effect. Specifically, the model predicts that markets of larger size experience smaller percentage decrease (or increase) in price due to a negative (or positive) demand shock. This result is consistent with an empirical study of the Houston market by Smith and Tesarek (1991). Smith and Tesarek show that prices of more expensive houses rose by larger percentages during the housing market boom while drop by larger percentages during the bust. For example, high-quality houses (with a market value above $150,000 in 1970) increased in value at an annual rate of 9.0% during the period of 1970-1985, while lost 30% of the value during 1985-1987. In the meantime, low-quality houses (with a market value below $50,000 in 1970) increased in value by 8.3% per year over 1970-1985 while lost in value by 18% during 1985-1987. Since the maker of high quality houses is typically small in size, this finding is compatible with the prediction of the proposed model.

In addition, because Wheaton (1990) assumes there are only two types of households who are identical in number and behavior, there is no housing price dispersion generated by his model even though the sale price is determined through bargaining between buyers and sellers. In Arnott (1989), the rent is set in a Bertrand–Nash way by landlords. In the symmetric equilibrium, there is no dispersion in rent. For the same reason, Mayer (1995)'s negotiated-sale model does not study the dispersion of housing price either. Instead, our model has a continuum of heterogeneous buyers and sellers; and the sale price is determined through bargaining between buyers and sellers. The higher the average matching quality between the buyer and the seller, the lower is the price dispersion. Our model can thus demonstrate how the thick market effect influences price dispersion in the housing market due to improved matching quality.

In sum, our model makes the following three testable predictions: (1) the unemployment rate has a negative impact on the trading volume and the sale price of the housing market. (2) A larger housing market has a lower average sale price, shorter time-to-sale and smaller price dispersion, in addition to a lower vacancy rate. (3) In a larger housing market, when the unemployment rate goes up (or down), the sale price decreases (or increases) by a smaller percentage than in a smaller market.

Empirically, one way to test the thickness effect is to compare housing market transactions across different cities. A larger city typically has more buyers and more sellers in almost all categories of houses than a smaller city. Therefore, in a larger city, we expect a higher average sale price, lower price dispersion, a higher probability of selling and buying a house, and a smaller percentage swing in price when the demand fluctuates. It would be ideal to use the total number of potential buyers and sellers to measure the market size. However, such data is difficult to obtain in reality, although in our model, it is endogenously determined and can be obtained through simulations. Thus we use city size to approximate the size of housing markets in the empirical analysis. Using data from 30 Texas cities, our empirical results are supportive of the previous predictions of the model.

The rest of the paper is organized as follows. Section 2 describes the model in detail. Section 3 first calibrates and then applies the calibrated model to study the properties of the model. Section 4 provides empirical support of the model. Section 4 concludes the paper.

## 2. The Model

In this section, we develop a search model that captures the main characteristics of the housing market and demonstrates how the market size affects the market outcomes. The model shall be described in six parts, denoted as part (a) to (f).

(a) The environment

We first describe the environment. The number of households in a city, denoted *M*, is given. To simplify our discussions, we refer to a living unit as a "house" if it is owner-occupied, and an "apartment" otherwise. We assume that a house cannot become an apartment, and vice versa. In the short run, the total number of houses $T^H$ and the total number of apartments $T^R$ are fixed. All houses are different in terms of their hedonic characteristics. All the households are different in their preferences. We use a unit circle to model the characteristic space of houses. Each point on the circle represents a unique characteristic. To simplify the analysis, we let all the houses for sale be evenly spaced around the circle. And all the buyers are uniformly distributed around the circle. A buyer's location on the circle means that she prefers the characteristic represented by this point the most, or, any house located at the buyer's location would be a perfect match to her.

The matching mechanism between sellers and buyers is as follows. At the beginning of each time period, sellers post advertisements and announce the characteristics of their houses to the public. In order to buy a house, a buyer has to visit the house. We assume each buyer can visit at most one house for one time period. Each buyer then chooses to visit the house that best matches her. A seller may have multiple visitors. We assume each seller can negotiate with at most one buyer for one time period. The seller asks her visitors to make an initial offer each and chooses the one who makes the highest initial offer to negotiate with. We assume that the buyers' initial offers preserve the ordering of their preferences towards the seller's house, although the sellers cannot observe the preferences of buyers directly. If a deal is reached finally, the sale price is determined through bargaining between the seller and the buyer. Let $\theta$ be the bargaining power. Otherwise, the seller continues to search next time period.

Let $N_t^H$ be the total number of homeowners in the local area at the beginning of time $t$, and $N_t^R$ be the total number of renters at the beginning of time $t$. The total number of households in the city is the sum of renters and homeowners:

$$M = N_t^R + N_t^H . \qquad (2)$$

The total number of houses in the city is equal to the sum of the total number of occupied houses $N_t^H$ and the total number of vacant houses since the end of last period, $V_{t-1}$:

$$T^H = V_{t-1} + N_t^H \qquad (3)$$

During each time period, each current household may have exogenous probability of leaving the city. We assume that each household has an exogenous probability of $\mu$ to leave the city. Therefore, the total number of people who leave the city in each period is $\mu N_t^H + \mu N_t^R$. Meanwhile, there are a same number of households moving in.

The total number of sellers in the market, denoted $N_t^S$ , includes the houses that are still vacant since last period $V_{t-1}$, and those homeowners who will have to leave the city to move to a different city for exogenous reasons:

$$N_t^S = V_{t-1} + \mu N_t^H \tag{4}$$

In (4), we assume that people will not move from one house to another house within the same city. Implicitly, we include those people who move from one house to another house within the same city into both the group of leaving the city and the group of people who move into the city. In addition, equation (4) rules out other possibilities of selling such as cashing out investment.

During each time period, each household has a probability of $1-\gamma$ being unemployed. We assume that only the people who currently have jobs will be buyers in the housing market since it is more difficult for an unemployed worker to obtain mortgages.

The new comers look for houses to buy or places to rent while the households who are leaving need to sell the houses if they are homeowners. Each household either rents a place or owns a house. The total number of buyers in the market is given by:

$$\begin{aligned} N_t^B &= \gamma\left(\mu N_t^H + \mu N_t^R\right) + \gamma(1-\mu)N_t^R \\ &= \gamma\mu N_t^H + \gamma N_t^R \end{aligned} \tag{5}$$

Note in (5) the total number of the buyers is the sum of new comers who have jobs, $\gamma\left(\mu N_t^H + \mu N_t^R\right)$, and the number of employed renters who remains in the city, $\left(\gamma(1-\mu)N_t^R\right)$.

Let $N_t^{BS}$ be the number of sales made during time *t*. The number of vacant houses $V_t$ at the end of this period equals to the difference between the total houses on the market and total number of houses sold:

$$V_t = N_t^S - N_t^{BS} \tag{6}$$

To summarize, in equations (2)-(6), we introduce six endogenous variables, $N_t^R$, $N_t^H$, $V_t$ and $V_{t-1}$, $N_t^S$, $N_t^B$, and $N_t^{BS}$. The exogenous variables are *M, μ,* and *γ*. Next, we will introduce more equations by studying matching between sellers and buyers.

(b) The Seller's Problem:

During each time period, seller *i* posts an advertisement to sell her house in the local housing market. The advertisement describes the characteristics (and therefore the location of the house on the unit circle). Buyers in the market make independent offers simultaneously to the seller. It is assumed that the buyer who evaluates the house the most shall make the best offer to the seller. We denote this buyer as buyer *j*. Seller *i* then negotiates with buyer *j* for the sale price. Part (c) describes the outcomes of the bargaining between seller *i* and buyer *j*. The seller's action set consists of two choices: "1" if she sells the house and "0" if she decides to wait until next time period. She has incentive to wait if the match between her house and the buyer is poor. Her objective function is as follows:

$$J_{it}^S(\pi_{ijt}^S; a_{-it}^S(\cdot), a_t^B(\cdot)) = \max_{a_{it}^S \in \{0,1\}} \pi_{ijt}^S a_{it}^S + \beta E(J_{it+1}^S; a_{-it+1}^S(\cdot), a_{t+1}^B(\cdot))(1 - a_{it}^S),$$

where $a_{-it}^S(\cdot)$ represents other sellers' decisions in the market, $a_t^B(\cdot)$ are buyers' decisions, and $a_{it}^S$ is seller *i*'s decision at *t*. If seller *i* decides to sell her house ($a_{it}^S = 1$), her utility surplus is $\pi_{ijt}^S$, discussed in detailed in part (f) of this proposal. If the seller decides to wait until next period ($a_{it}^S = 0$), her (discounted) payoff is $\beta E(J_{it+1}^S; a_{-it+1}^S(\cdot), a_{t+1}^B(\cdot))$.
The time discount rate is denoted as *β*.
The optimal decision rule of the seller is rather simple: Seller *i* will sell her house if and only if the utility surplus from selling is higher than the payoff of waiting, i.e.,

$$a_{it}^S = 1_{\left[\pi_{ij}^S \geq \beta E(J_{it+1}^S; a_{-i}^S(\cdot), a^S(\cdot))\right]}.$$

Let $\overline{\pi}_{it}^S$ denote the smallest surplus for which the seller will be willing to sell her house, and $\overline{\pi}_{it}^S = \beta E(J_{it+1}^S; a_{-it}^S(\cdot), a_t^B(\cdot))$. Following the search literature, $\overline{\pi}_{it}^S$ is called the reservation surplus of the seller. When the seller's surplus from a transaction is at least as large as $\overline{\pi}_{it}^S$, the seller will choose to sell her house. Otherwise, the seller will choose to wait until next period.

(c) The Buyer's Problem:

Buyers are heterogeneous in their preferences. Each time period, a buyer, denoted as buyer *j*, searches for houses in the market. Let the shorter arc distance between buyer *j* and house *i* be $d_{ij}$. This paper assumes that shorter the distance $d_{ij}$, the higher the utility that house *i* can bring to buyer *j*. When $d_{ij}=0$, the utility flow per time period for buyer *j* to live in house *i* is denoted $u^H$. In other words, $u^H$ represents the utility flow per time period from living in a perfect-matched house. In particular, we let the one-period utility of buyer *j* from living in house *i* be:

$$V_{ij}^{B} = u^{H} \exp(-c_1 d_{ij}^{\alpha}), \quad (7)$$

where $c_1>0$ and $\alpha>0$ are constants that determine the marginal disutility from mismatch. If $c_1 = 0$, there is no disutility from mismatch, which means the thick market effect on market outcomes through improving the matching quality is irrelevant.

Buyer *j*'s action set consists of two choices: "1" if she purchases the house during this time period and "0" if she does not purchase the house but rents an apartment for this time period. She has an incentive to wait if the current match is not good enough. Buyer *j*'s objective function is as follows:

$$J_{jt}^{B}(\pi_{ijt}^{B}; a_{-jt}^{B}(\cdot), a_{t}^{S}(\cdot)) = \max_{a_{jt}^{B}\in(0,1)} \pi_{ij}^{B} a_{jt}^{B} + \left[u^{R} + \beta\left(\gamma E(J_{jt+1}^{B}; a_{-jt+1}^{B}(\cdot), a_{t+1}^{S}(\cdot)) + (1-\gamma)E(J_{jt+1}^{BO}; a_{-jt+1}^{B}(\cdot), a_{t+1}^{S}(\cdot))\right)\right](1-a_{jt}^{B}),$$

where $a_{-jt}^{B}(\cdot)$ represents other buyers' decisions in the market and $a_{t}^{S}(\cdot)$ represents all sellers' decisions, and $a_{jt}^{B}$ is the decision made by buyer *j* at *t*. If the buyer purchases the house ( $a_{jt}^{B}=1$), her utility surplus is $\pi_{ijt}^{B}$. If the buyer decides to wait until next period ( $a_{jt}^{B}=0$ ), her payoff from waiting consists of two parts. One part is derived from the utility flows from renting this time period. Let $u_0^R$ be the gross utility flow per time from renting. Let the rent be $R_t$, given by $R_t = u_0^R - u_0^R \exp\left(-c_2 N_t^R / T_t^R\right)$. Thus the net utility flow from renting, denoted as $u_t^R$, is

$$u_t^R = u_0^R \exp\left( - c_2 N_t^R \big/ T_t^{\,R} \right) \quad , \tag{8}$$

where $T_t^R$ is the total number of apartments for rent. In (8), the net utility flow from renting an apartment depends on how many renters in the market. When more renters in the market so the occupancy rate of apartments is high, the rents will go up and hence the net utility flow decreases. Note that $c_2$ measures the crowding effect of the number of renters on the rental market.

The other part is the buyer's (discounted) expected payoff next time period. In the next period, the buyer has a probability $\gamma$ of being employed, and a probability of $(1\text{-}\gamma)$ of being unemployed. If she is employed, her expected payoff is represented by $E(J_{jt+1}^B; a_{-jt+1}^B(\cdot), a_{t+1}^S(\cdot))$. If she is unemployed, we let the expected payoff of buyer $j$ be $E\left(J_{jt+1}^{BO}\right)$. Note that if the buyer becomes unemployed next period, the buyer will not be active in the market since she may have difficulty to secure a loan with a favorable interest rate. However, in the period after next, if she finds a job, the she will become an active buyer again. Therefore, we have

$$E(J_{jt+1}^{BO}) = \frac{u_{t+1}^R + \beta\gamma E(J_{jt+2}^B)}{1-\beta(1-\gamma)}. \tag{9}$$

In sum, the buyer's payoff from waiting at time t must be the sum of the utility flow from renting i.e., $u_t^R$, and the (discounted) expected payoff next time period. Thus, the optimal decision rule of buyer $j$ at $t$ is:

$$a_{jt}^B = 1_{\left[\pi_{ij}^B \geq u^R + \beta\left(\gamma E(J_{jt+1}^B; a_{-jt}^B(\cdot), a_t^S(\cdot)) + (1-\gamma)E(J_{jt+1}^{BO}; a_{-jt+1}^B(\cdot), a_{t+1}^S(\cdot))\right)\right]}.$$

Similar to the discussion in the seller's case, we let the minimum surplus for which a buyer will be willing to purchase a house be reservation surplus, denoted $\overline{\pi}_{jt}^B$.

Apparently, $\overline{\pi}_{jt}^B = \left[ u_t^R + \beta\left(\gamma E(J_{jt+1}^B; a_{-j}^B(\cdot), a^S(\cdot)) + (1-\gamma)E(J_{jt+1}^{BO}; a_{-j}^B(\cdot), a^S(\cdot))\right)\right]$.

Again, a buyer will purchase a house if and only if her surplus from the purchase is at least as large as $\overline{\pi}_{jt}^B$.

(d) Surpluses of buyers and sellers

When a trade occurs between buyer $i$ and seller $j$ at time $t$, we let the total surplus generated by the sale be $\Sigma_{ijt}$. The buyer's surplus from buying a house is

$$\pi_{ijt}^{B} = A_{ijt} - P_{ijt} \quad , \tag{10}$$

where $A_{ijt}$ is the valuation of buyer $i$ of house $j$ and $P_{ijt}$ is the sale price. And the seller's surplus from selling a house is simply the sale price:

$$\pi_{ijt}^{S} = P_{ijt}. \tag{11}$$

Thus the total surplus is just equal to the valuation of buyer $i$ of house $j$,

$$\Sigma_{ijt} = A_{ijt} = \frac{u^H}{1-(1-\mu)\beta}\exp(-c_1 d_{ijt}^{\alpha}) + \frac{\mu\beta E(J_{jt}^{S})}{1-(1-\mu)\beta}, \tag{12}$$

where $d_{ij}$ is the shorter arc distance between $i$ and $j$ on the circle, and $u^H$ is the utility flow per time period from owning a house that is a perfect match. The first part in (12) is the present value of the sum of utility flows from owning the house over time. The second part in (12) is the expected resale value of the house when the buyer moves out of the city in the future, where $E(J_{jt}^{S})$ is the value of searching for a buyer to sell the house in the market.

The total surplus from the trade has to be larger than the sum of the reservation surplus of both the buyer $\overline{\pi}_{jt}^{B}$ and the seller $\overline{\pi}_{it}^{S}$. The remaining surpluses will be shared through bargaining. Thus, the buyer's surplus from the transaction is equal to

$$\pi_{ijt}^{B} = \overline{\pi}_{it}^{B} + \theta(\Sigma_{ijt} - \overline{\pi}_{it}^{B} - \overline{\pi}_{jt}^{S}), \tag{13}$$

and the seller's surplus is equal to

$$\pi_{ijt}^{S} = \overline{\pi}_{it}^{S} + (1-\theta)(\Sigma_{ijt} - \overline{\pi}_{it}^{B} - \overline{\pi}_{jt}^{S}), \tag{14}$$

where $\theta$ is the bargaining power between the seller and the buyer.

(e) The Market Equilibrium:

We only consider the symmetric and stationary equilibrium that all buyers adopt the same decision rule over time and all sellers adopt the same decision rule over time.[2] Thus from now on, for expositional simplicity, we will omit the subscript of each variable as long as it does not cause any confusion.

According to (6), the seller's equilibrium decision rule is to sell her house if and only if the surplus from trade is at least as high as $\beta E\left(J^S\right)$. Thus, the seller's reservation surplus is:

$$\bar{\pi}^S = \beta E(J^S). \tag{15}$$

Similarly, according to (9), the buyer's equilibrium decision rule is to buy a house if and only if her surplus from trade is at least as high as $u^R + \beta\left(\gamma E\left(J^S\right) + (1-\gamma)E\left(J^{BO}\right)\right)$. Thus, the buyer's reservation surplus is:

$$\bar{\pi}^B = u^R + \beta\left(\gamma E\left(J^S\right) + (1-\gamma)E\left(J^{BO}\right)\right). \tag{16}$$

According to (12), the shorter the mutual distance between the buyer and the seller, the better the match between them and thus the higher the total surplus generated if they reach a deal. Thus, by adding (16) to (15), we can see that a sale will be made if and only if the total surplus is above a certain level, which is equivalent to say that a deal will be reached if only if the match between the buyer and the seller is good enough, namely, if and only if the mutual distance between them is short enough. Let us denote $\bar{d}$ as the maximum distance corresponding to the minimum total surplus. According to (12), (15) and (16), we have:

$$\bar{\pi}^B + \bar{\pi}^S = \frac{u^H}{1-(1-\mu)\beta}\exp(-c_1\bar{d}^{\alpha}) + \frac{\mu\beta E(J^S)}{1-\beta(1-\mu)} \tag{17}$$

From (8), we get

$$E(J^{BO}) = \frac{u^R + \beta\gamma E(J^B)}{1-\beta(1-\gamma)}. \tag{18}$$

In equations (15)-(18), we have six endogenous variables: the reservation surpluses $\bar{\pi}^S$ and $\bar{\pi}^B$, the minimum distance $\bar{d}$, and payoffs $E(J^S)$, $E(J^B)$, and $E(J^{BO})$.

[2] Most search literature, including Arnott (1989) and Wheaton (1990), only discuses symmetric equilibrium.

(f) The Solution of the Model:

The market equilibrium condition indicates that a buyer and a seller will trade if and only if they are located close enough to each other on the circle. This means that each seller will only accept offers from buyers who fall within her adjacent interval on the circle, which is $2\overline{d}$ in length. Consider a house that is located at point $s_0$, only the buyers located in the interval $\left[s_0 - \overline{d}, s_0 + \overline{d}\right)$ are matches good enough to the seller of the house.

Remember we assume that all the houses for sale are evenly spaced around the circle. In addition, according to our matching mechanism, each buyer visits only the house that she prefers most every time period. Thus, a house located at $s_0$ will be visited only by those buyers who are located in the interval $[s_0 - 1/2N^S, s_0 + /2N^S)$. Therefore we may focus on the equilibria with $2\overline{d} \le 1/N^S$ next. Note that our setup excludes the possibility of which any two different sellers compete for the same buyer.

Although sellers are evenly spaced around a circle, buyers are assumed to be uniformly distributed on the circle. For a seller at $s_0$, it is possible that no buyers are located in the interval $\left[s_0 - 1/2N^S, s_0 + 1/2N^S\right)$ at all. In this case, no buyers visit the seller's house and the house is not sold this time. If multiple buyers fall in the interval, the seller has multiple visitors and she will choose the one who is located closest to herself to negotiate with this time, and the rest of the buyers will have to wait until next time. Finally, if the chosen buyer turns out to be within the seller's acceptable interval $\left[s_0 - \overline{d}, s_0 + \overline{d}\right)$, a sale will be made this time. Otherwise, the seller will hold her house until next time. Therefore, given $\overline{d}$ and $N^B$ buyers, the probability of which the seller sells her house this time is

$$q^S = 1 - \left(1 - 2\overline{d}\right)^{N^B} . \tag{19}$$

The expected number of sales each time period is:

$$N^{BS} = N^S q^S \tag{20}$$

For any seller, the value of searching for a buyer to sell her house is:

$$E(J^S) = E\left(\pi^S \mid \pi^S \ge \overline{\pi}^S\right) q^S + \beta E(J^S) \cdot (1 - q^S)$$

Re-arranging the previous equation, we get:

$$E(J^S) = \frac{E\left(\pi^S \mid \pi^S \geq \overline{\pi}^S\right) q^S}{1-\beta\left(1-q^S\right)} \qquad (21)$$

When there are more than one buyers interested in the seller's house, the seller selects the closest one to herself to negotiate with. Let the location of any buyer *i* be $Z_i$, $i=1,2,\ldots,N^B$. The shorter arc distance between the closest buyer and the house, denoted *X*, is

$$X = \min\{\ 0.5 - |\,0.5 - |\,Z_i - s_0\,|\,|\ \}, \quad i = 1, 2, \ldots, N^B .$$

Because $Z_i$ is a random draw from the unit circle, *X* is the first order statistic of a random variable uniformly distributed on [0,1/2]. Thus the density function of *X* is given by $f(x) = 2N^B(1-2x)^{N^B-1}$. As $N^B \to \infty$, *X* converges in distribution to an extreme value distribution, i.e., $X \xrightarrow{d} 2N^B \exp\left(-2N^B x\right)$. Since *X* converges to the extreme value distribution very fast (the rate of convergence is N), we use the extreme value distribution to approximate the distribution of *X*. Furthermore, the density function of *X* conditional on the closest buyer falling in the seller's acceptable interval $[s_0 - \overline{d}, s_0 + \overline{d})$ is $f(x \mid \pi^S \geq \overline{\pi}^S) = 2N^B \exp\left(-2N^B x\right)/q^S$. Therefore, according to (14), the conditional expected surplus if the seller sells her house, i.e., $E\left(\pi^S \mid \pi^S \geq \overline{\pi}^S\right)$ is given by

$$E\left(\pi^S \mid \pi^S \geq \overline{\pi}^S\right) = \overline{\pi}^S - (1-\theta)\left(\overline{\pi}^S + \overline{\pi}^B\right) +$$
$$(1-\theta)\left[\frac{u^H}{1-\beta(1-\mu)} \cdot \frac{\int_0^{\overline{d}} \exp\left(-c_1 x^\alpha\right) 2N^B \exp(-2N^B x)\,dx}{q^S} + \frac{\mu\beta E(J^S)}{1-\beta(1-\mu)}\right] \qquad (22)$$

where the last term in (22) is the total surplus generated by the trade. Similarly, a buyer's probability of buying a house is:

$$q^B = N^{BS} / N^B. \qquad (23)$$

The buyer's value of searching for a house is given by

$$E\left(J^B\right) = E\left(\pi^B \mid \pi^B \geq \overline{\pi}^B\right) q^B + \left(\frac{u^R + \beta\gamma E(J^B)}{1-\beta(1-\gamma)}\right)(1-q^B).$$

Re-arranging the previous equation, we get:

$$E\left(J^B\right) = \frac{E\left(\pi^B \mid \pi^B \geq \overline{\pi}^B\right) q^B (1-\beta(1-\gamma)) + u^R(1-q^B)}{1-\beta+\beta\gamma q^B} \qquad (24)$$

The conditional expected surplus if the buyer buys a house is:

$$E\left(\pi^B \mid \pi^B \ge \overline{\pi}^B\right) = \overline{\pi}^B - \theta(\overline{\pi}^B + \overline{\pi}^S) +$$
$$\theta\left[\frac{u^H}{1-\beta(1-\mu)} \cdot \frac{\int_0^{\overline{d}} \exp(-c_1 x^\alpha) 2N^B \exp(-2N^B x) dx}{q^S} + \frac{\mu\beta E(J^S)}{1-\beta(1-\mu)}\right]. \quad (25)$$

In equations (19)-(25), we introduce four new endogenous variables: the probabilities of selling house ( $q^S$ ) and buying a house ( $q^B$ ), and the conditional expected surpluses $E\left(\pi^S \mid \pi^S \ge \overline{\pi}^S\right)$ and $E\left(\pi^B \mid \pi^B \ge \overline{\pi}^B\right)$.

In summary, part (a) introduces six endogenous variables in five equations. Part (e) introduces six endogenous variables in four equations. Part (f) has four endogenous variables in seven equations. Therefore, by solving this equation system of fifteen endogenous variables and fifteen equations, we can solve for the endogenous variables as functions of the exogenous variables.

In particular, we are interested in how the endogenous variables respond to changes in city size *M* and changes in the unemployment rate 1-*γ*. By changing *M*, we can show how the thick market effect influences the transactions of the housing market in terms of average prices, price dispersion, buying probability and selling probability.

In addition, the model also can show how the housing market responds to an aggregate shock, which is reflected in the change of the unemployment rate *1-γ*. When the unemployment rate rises, the demand for housing will decrease. This will lead to a thinner market with fewer buyers and fewer sellers as well. And the average sale price thus drops and the time-to-sale increases.

Since no closed-form solution exists in this paper, we first calibrate the model to match with basic statistics of the housing market, and then we use simulation to draw predictions of the model.

## 3. Calibration, Simulation and Empirical Tests

### (a) Calibration and Simulation

Next we calibrate the model. In this paper, our model is calibrated according to the statistics of the Texas real estate market because of easy access to data. Table 1 lists the parameter values we use in our calibration; and it also compares some key statistics based on Texas data with our calibrated results.

We begin with the numbers of houses and apartments:

$$T^H = (1+\eta^H)\lambda M, \qquad T^R = \left(1+\eta^R\right)\left(1-\lambda\right)M \tag{26}$$

In (26), the total number of houses is proportional to the total number of households. In the state of Texas, there are 64% of households are homeowners, thus the coefficient $\lambda$ is roughly equal to 0.64. And the housing vacancy rate is about 1.8%, thus the coefficient $\eta^H$ is roughly 0.0183. In (26), the total number of apartments is larger than $(1-\lambda)M$, reflecting the fact of the existence of equilibrium vacancy rate for rental properties. The value of $\eta^R$ is about 0.1 because the rental vacancy rate is about 8.5%. Other parameter values we adopt are in Table 1.

Figure 1 plots the simulation results against market size. Figure 1-1 shows that the average price is positively correlated with the market size. In Figure 1-2, the price dispersion is defined as standard deviation of prices divided by the mean of the prices. It shows that price dispersion is smaller for a larger market. In Figure 1-3, time-to-sale is simply the inverse of probability of selling, $q^S$. The larger the market size, the higher the probability of selling a house, or, the shorter the waiting period in the market to sell a house. Similarly in Figure 1-4, the probability of purchasing a house within a period is also higher in a larger market. Finally, Figure 1-5 shows that the vacancy rate is smaller for a larger market while Figure 1-6 shows that the sales volume is larger for a larger market.

Figure 2 plots the simulation results against the unemployment rate. When the unemployment rate rises (the employment rate decreases), the average price decreases, price dispersion increases, the probability of selling and buying a house both decrease as well as the transaction volume, and the vacancy rate rises.

Since we claim in section 1 that the thick market effect magnifies the fluctuations of housing market transactions in the presence of demand shock, next, we illustrate how large this magnifying effect is on the average sale price particularly. Figure 3 plots the elasticity of average price with respect to the unemployment rate for two distinctive situations. The elasticity is negative in sign. In one situation, $c_I$=10, and the circled curve of figure 3 corresponds to this situation. In the other situation, $c_I$=100, and the dotted curve of figure 3 corresponds to this situation. If $c_I$ is lower, the marginal disutility from mismatch is lower and thus the thick market effect through improving the matching quality becomes less relevant. We can see from figure 3 that the dotted curve (where $c_I$=10) is located above the circled curve (where $c_I$=100). This means that the average sale price is more elastic to demand shocks when the matching quality matters more and thus the thick market effect is significant.

Figure 4 plots the elasticity of average price with respect to the unemployment rate for two communities of different sizes. The elasticity is negative in sign. There are two curves in the figure. The dotted one corresponds to a community size of 10,000 households. And the circled one corresponds to a community size of 20,000 households. It is clear from the figure that the dotted curve is located above the circled one, which means that a larger housing market is less elastic in price with respect to the unemployment rate. In other words, a larger market experiences a smaller percentage drop in price than a smaller market when facing a negative demand shock.

(b) Empirical Tests.

We obtain data from Texas Real Estate Center at Texas A&M University (http://www.recenter.tamu.edu). The variables provided by the center include yearly summary statistics on total number of houses sold, the total number of listings in that year, and the average price of the sold houses. In addition, Texas Real Estate Center provides data (based on US census and Current Population Survey) on total employment and unemployment rates for each city in Texas. Mortgage rates are obtained from Freddie Mac.

To test the total effect of city size on market transaction outcome, we use average of the total employment in a year as the size of the local city for that year. Our sample period is from 1993-2002. In particular, we consider the following empirical specification:

$$y_{it} = \alpha_i + \beta_1 \log L_{it} + \beta_2 u_{it} + \beta_3 \left(u_{it} \cdot \log L_{it}\right) + Z_{it}\eta + \varepsilon_{it} \qquad (26)$$

In (26), the dependent variable $y_{it}$ takes three different values, representing three endogenous outcomes: the probability of selling a house, the logarithm of average prices, and the ratio of the standard deviation of prices to its average prices. The probability of selling a house is defined as total number of sales/(total number of sales + total number of listings). The independent variables include the size of the local market, $\log L_{it}$, the unemployment rate $u_{it}$, the interaction term of $u_{it}$ and $\log L_{it}$ , and other control variables $Z_{it}$. According to the theories developed earlier, the probability of selling a house and the average prices increases as the city size increases and/or the unemployment rate decreases. The ratio between the standard deviation of prices and the average price decreases as both the city size and the city unemployment rate decrease. Further, according to the model, when the dependent variable is the logarithm of average prices, an increase in unemployment rate causes a smaller percentage decrease in prices in a larger market than in a smaller market. Therefore, the coefficient of the interaction term, $\beta_3$, is positive.

Table 2 provides evidence supporting these claims. In particular, if the city unemployment rate increases by 1 percentage point, the probability of selling will decrease by 0.5 percentage points, the log of average price will be lowered by 0.004, which corresponds to a decrease of 0.4%, and the price dispersion ratio will be lowered by 0.6 percentage points. To better understand the magnitude of the results, consider the period between September, 2000 and September 2001 in which the total number of employment in the US has been reduced by roughly 5.5%. The thick market effect alone would have reduced the average housing price by about 2.2%. When the log of city size increases by 1, the probability of selling a house will increase by 8.4 percentage points, the log of average price will increase by 0.56, which corresponds to an increase of 56%, and the price dispersion ratio will be lowered by 34 percentage points. According to Gan and Zhang (2005), the standard deviation of the log of city sizes in the US is 1.07. Therefore, from a median city to one of the largest cities (two standard deviations away), the thick market effect alone would have increased the average housing price by 1.07*2*0.56 = 120%.

## IV. Conclusions

In this paper, we develop a search model on housing market. The model explicitly studies the effect of the size of the market. According to the model, it is easier to obtain a good match in a thicker market with more buyers and sellers. This thick market effect has important implications in describing some of the housing market outcomes. In this model, being unemployed prevents a worker from entering the housing market as a buyer.

Therefore, an increase in unemployment rate reduces the size of demand in the market and therefore leads to a thinner market. A thinner market implies a lower price and a lower transaction volume.

The model further implies that a larger housing market has a lower average sale price, shorter time-to-sale and smaller price dispersion, in addition to a lower vacancy rate. Furthermore, when the unemployment rate goes up (or down), the sale price decreases (or increases) by a smaller percentage in a larger market than in a smaller market. All these implications are supported by a panel dataset of the Texas city-level housing markets.

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Table 1: Parameter Values Used in the Simulation and Simulation Results

| Descriptions of Some Exogenous Parameters | Values | |
|---|---|---|
| Maximum utility flows from renting $u_0^R$ | 500 | |
| Coefficient of crowding effect $c_2$ | 10 | |
| Utility flow from living in a perfectly matched house $u^H$ | 650 | |
| Monthly Time discount rate $\beta$ | .997 | |
| Probability of households of moving out of the city $\mu$ | 0.0065 | |
| Bargaining power of buyers $\theta$ | .5 | |
| Share of houses in total households | .6517 | |
| Number of households in the city *M* (in figure 3) | 130,000 | |
| Employment Rate $\gamma$ (in figure 1) | .95 | |
| Coefficients $\alpha$ | .48 | |
| Coefficients $c_1$ | 100 | |
| **Endogenous Variables** | **Observed[a]** | **Calibrated** |
| Average Price | $143,000 | $153,450 |
| Number of sales/Number of listings | 22.9% | 21.6% |
| Rental vacancy rate (not endogenous in the model) | 8.5% | |
| Housing vacancy rate | 1.8% | 2.3% |

(a) Based on city average in Texas in April 2000.

Table 2: Results from Fixed Effect Regressions

| Dependent variables | Probability of selling in a year | Log of average price | Ratio of std dev *to* average price | Summary Statistics |
|---|---|---|---|---|
| Last year unemployment | -.00455 | -.00428 | -.00592 | 6.218 |
| Rates | (-2.74)[a] | (-1.51) | (-2.16) | (2.979) |
| Log of current year | .0841 | 0.563 | -.341 | 12.855 |
| Population | (1.462) | (5.732) | (-3.584) | (1.052) |
| Average mortgage | .0068 | .00159 | .0162 | 7.531 |
| Interest rate | (1.732) | (.213) | (2.480) | (.551)[b] |
| Mortgage points paid | -.0446 | .00414 | -.00698 | 1.311 |
| | (-3.92) | (.213) | (-.589) | (.431) |
| Year | 1.063 | -1.344 | -1.396 | |
| | (.742) | (-.549) | (-.590) | |
| $Year^2/1000$ | -.267 | -.345 | .350 | |
| | (-.745) | (.564) | (.590) | |
| Summary statistics | .134 | 2.254 | .661 | |
| | (.042) | (.231) | (.090) | |
| Number of observations | 221 | 221 | 221 | |
| Number of cities | 30 | 30 | 30 | |
| $R^2$ | .771 | .977 | .860 | |

(a) t-statistics are in parenthesis.
(b) Standard deviation

**Figure 1 Market Outcomes as Market Size Varies**

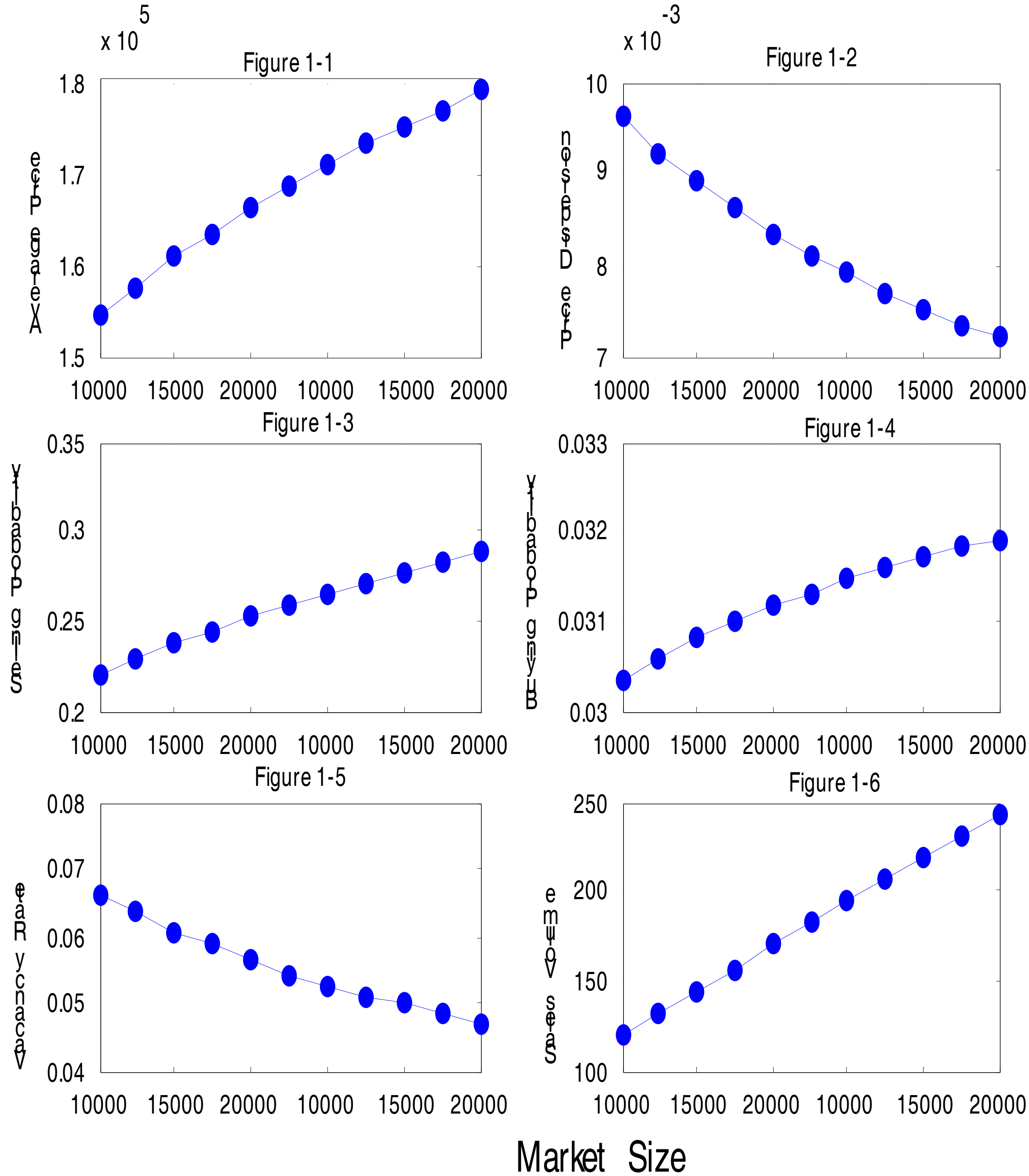
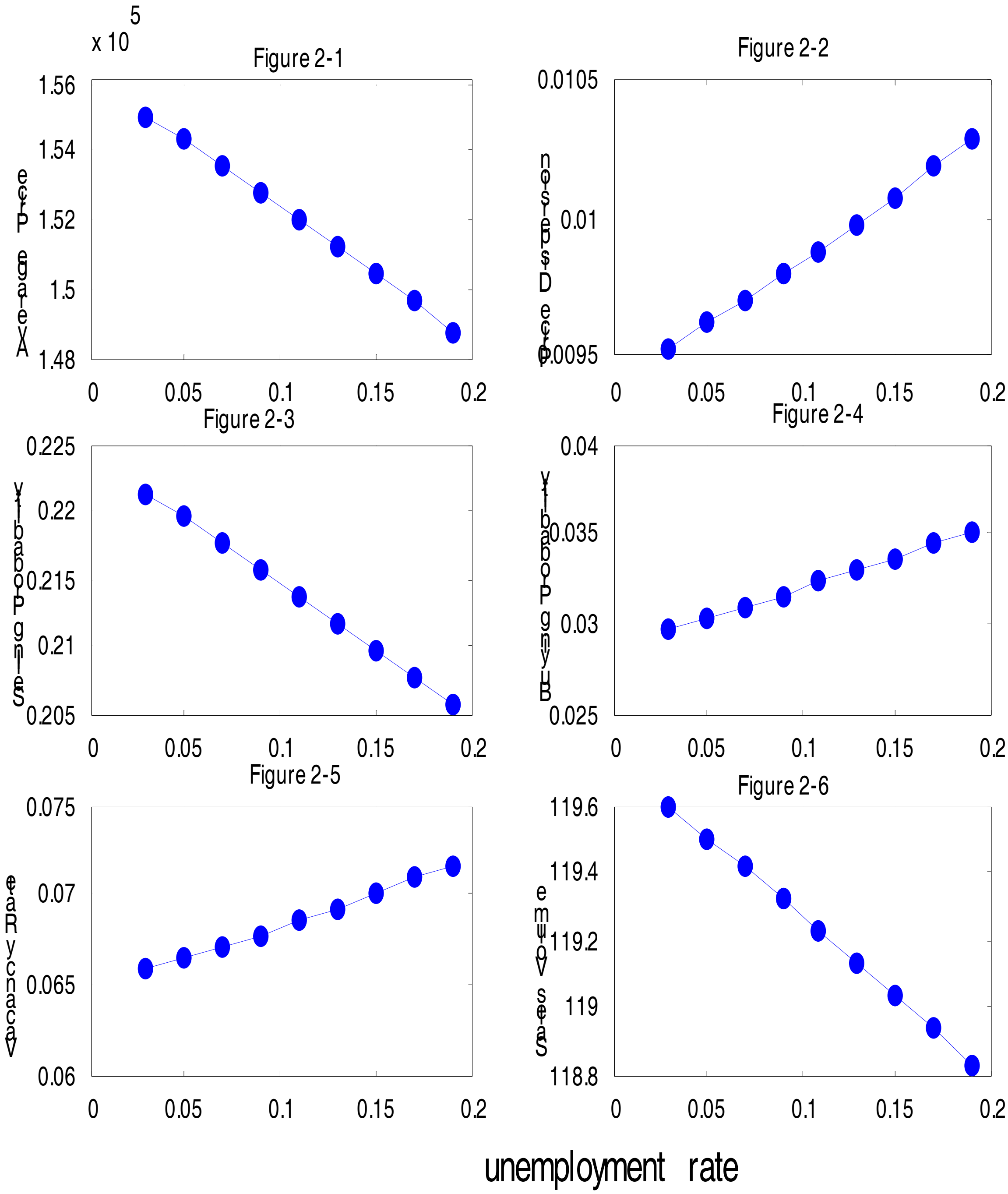
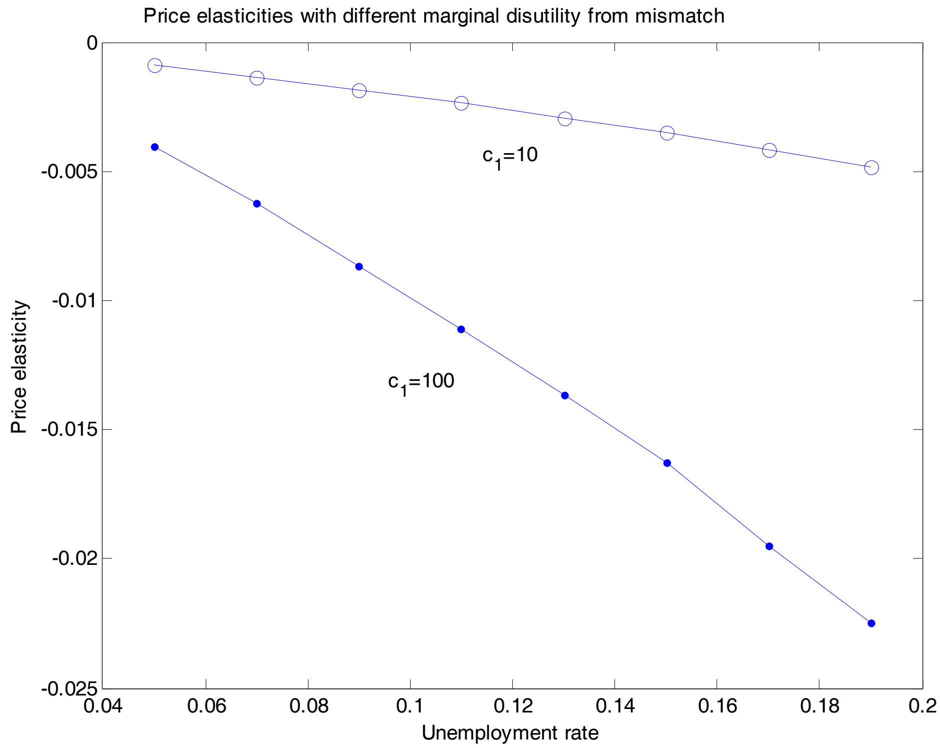


**Figure 2 Market Outcomes as Unemployment Rate Varies**



## Figure 3 Price Elasticity with Different Marginal Disutilities from Dismatch



## Figure 4 Price Elasticity with Different Market Sizes