2012 V40 S1: pp. S234–S272
DOI: 10.1111/j.1540-6229.2012.00347.x
REAL ESTATE
ECONOMICS

Optimal Pricing Strategy in the Case of Price Dispersion: New Evidence from the Tokyo Housing Market

Yongheng Deng,* Stuart A. Gabriel,** Kiyohiko G. Nishimura***
and Diehang (Della) Zheng****

We adopt a multistage search model, in which the home seller's reservation price is determined by her or his opportunity cost, search cost, discount rate and additional market parameters. The model indicates that a greater dispersion in offer prices leads to higher reservation and optimal asking prices. A unique dataset from the Tokyo condominium resale market enables us to test those modeled hypotheses. Empirical results indicate that a one percentage point increase in the standard deviation of submarket transaction prices results in a two-tenths of a percent increase in the initial asking price and in the final transaction price. Increases in the dispersion of market prices enhance the probabilities of a successful transaction and/or an accelerated sale.

Violation of the "law of one price" is common even among homogenous products. Sellers and buyers in many markets may possess information only regarding price distributions, rather than knowledge of a unique market-determined transaction price. Stigler (1961) was one of the first to articulate the importance of price dispersion to agents' search behavior. However, few subsequent studies have sought to explicitly evaluate the role of offer price dispersion in the determination of optimal seller pricing strategy.

In a perfectly competitive neoclassical world, with a large number of rational buyers and sellers of a homogeneous product, with full information and in the absence of transactions costs and capacity constraints, the Nash equilibrium yields a unique market price. Of course, in reality, this "ideal" market is hard to find. In contrast, for most goods, a range of prices is observed instead of a

*Institute of Real Estate Studies, National University of Singapore, Singapore 119613 or ydeng@nus.edu.sg.
**Anderson School of Management, University of California—Los Angeles, Los Angeles, CA 90095-1481 or sgabriel@anderson.ucla.edu.
***Policy Board, Bank of Japan, Chuo-Ku, Tokyo 103-8660, Japan or kiyohiko.nishimura@boj.or.jp.
****OneWest Bank, Pasadena, CA, 91101 or Della.Zheng@owb.com.

single market price.[1] This observation has generated numerous theoretical models that seek to explain equilibrium price dispersion on the basis of alternative market conditions. Explanations put forth in the literature include spatial competition (Hotelling 1929, Butters 1977, Shilony 1977), heterogeneity of sellers or consumers (Salop and Stiglitz 1977, Reinganum 1979, Wilde and Schwartz 1979, Braverman 1980, MacMinn 1980, Diamond 1987, Berkovec and Stern 1991, Reitman 1991, Postel-Vinay and Robin 2002), effect of buyer and seller bargaining (Harding, Rosenthal and Sirmans 2003), product differentiation (Perloff and Salop 1985, Nishimura 1995), search friction (Reinganum 1979, Sorensen 2000), imperfect information (Nelson 1970, Varian 1980, Burdett and Judd 1983) and seller capacity constrains (Dana 1999, Arnold 2000).

These models, however, ignore an important aspect of reality: in many markets, sellers post their asking price. These asking prices are an important source of information for buyers in search of the bestseller offer, and thus influence the probability that buyers visit sellers. In markets characterized by nondegenerate buyer offer prices (*i.e.*, there exists a distribution of buyer offer prices), the seller first needs to establish an asking price for the product. Thus, together with the reservation price, the asking price is an important component of an optimal pricing strategy aimed at maximizing the seller's return from search.[2] The outcome of a specific search strategy includes the transaction price and the search duration or time-on-the-market. The goal of a rational seller is to sell her or his product at the highest price possible and as quickly as possible, so as to maximize the seller's return from search.

The housing market provides an ideal setting in which to examine the effects of buyer offer price dispersion on sellers' optimal pricing strategy. This concern is particularly timely in light of recent marked cyclical fluctuations in housing evidenced in the United States and many other markets. The housing market further provides a substantial volume of asking price and transaction price data useful to such analysis. Also, sellers search for potential buyers in neighborhoods characterized by varying degrees of heterogeneity of housing stock and

[1] The examples include, but are not restricted to, the automobile industry (Stigler 1961), retail stores (Pratt, Wise and Zeckhauser 1979, Sorensen 2000, Lach 2002), securities (Garbade and Silber 1976, Hamilton 1987), housing (Leung, Leong and Wong 2006), insurance (Mathewson 1983, Dahlby and West 1986, Berger, Kleindorfer and Kunreuther 1989, Schlesinger and Schulenburg 1991, Seog 2002) and air travel (Borenstein and Rose 1994).

[2] McCall (1970) provides theoretical discussion of the role of reservation prices. In the case of job search, for example, if the job seeker knows the distribution of potential offers, he or she will stop searching whenever the arrived offer exceeds the seeker's reservation wage. Accordingly, the job search duration depends on an accurate understanding of prevailing wage distributions as well as the job searcher's reservation wage.

dispersion of prices. Accordingly, it is possible, controlling for characteristics of the housing stock, to parameterize the degree of price dispersion and to test for its differential impacts on pricing and transaction outcomes, both over time and across locations. Although we cannot directly observe the seller's reservation price, the availability of other relevant information on search outcomes, including asking price, transaction price and property's time-on-the-market, enables us to well specify and test for the impacts of price dispersion on pricing strategy.

There exists some prior literature on optimal pricing of housing and time on the market. Most studies acknowledged the importance of seller asking price to an agent's search procedure, as well as the distinction between asking price and reservation price. Stull (1978) and Guasch and Marshall (1985) provide early examples of search models in which asking prices are set. However, those models fail to consider the case where properties are transacted at below asking prices. Chinloy (1980) assumes the seller's reservation price is a constant fraction of the asking price. Horowitz (1992) and Chen and Rosenthal (1996a and b) show that the asking price serves not only as a resource allocation mechanism, but also as an upper bound to the transaction price. Arnold (1999) demonstrates that the asking price influences the rate at which potential customers arrive. However, none of these studies focuses on the role of price dispersion in agents' search and pricing strategy.

In recent articles, Haurin *et al*. (2010) and Genesove and Han (2012) advance this literature in assessment of the effects of asking price and reservation price on housing transaction price and time on the market. Genesove and Han (2012) show that demand generally leads to shorter seller time on the market and fewer homes that buyers visit, whereas buyer time on the market is much less sensitive to measures of demand. Furthermore, seller time on the market and homes visited are much more sensitive to demand growth than its level, consistent with sellers responding to demand with a lag. Haurin *et al*. (2010) employ a measure of the housing unit's atypicality to proxy heterogeneity of the housing stock and related house price distributions. However, atypicality is a limited, indirect measure of price dispersion. Further, price dispersion can be captured directly in the second moment of the relevant submarket transaction price distribution, rather than by a measure of property characteristics. Below we develop a model that suggests that higher offer price dispersion leads to a higher seller's asking price and further results in a higher expected transaction price. Under the assumption that offers prices are normally distributed, greater offer price dispersion also reduces the time on the market of overpriced properties. We then apply the model using data from the Tokyo condominium resale market.

Specifically, in our multistage search model, we assume that the seller possesses full information on the distribution of buyer offer prices. The seller first sets his or her reservation price and asking price so as to maximize the expected return from search. The reservation price is determined by the seller's costs of search, the seller's minimum required return or opportunity cost and other market conditions, including the buyer offer price distribution and, in particular, the offer arrival rate, of which the seller's asking price is an important determinant. During search, the seller will accept a purchase offer only if it is above her or his reservation price. On the other hand, the seller's asking price serves as the ceiling of the transaction price (Horowitz 1992, Chen and Rosenthal 1996a and b). Our model demonstrates that both the transaction price and asking price are positively related to the degree of offer price dispersion; moreover, for normally distributed offer prices, price dispersion leads to higher transaction prices and to a more rapid sale of overpriced properties.[3]

We use a unique dataset from the Tokyo condominium market for the 1992–2002 period to test these hypotheses. In particular, the empirical analysis seeks to ascertain the effects of local market price dispersion on (1) seller asking price, (2) market transaction price and (3) time on the market. We use the standard deviation in transaction prices for each submarket in central Tokyo as a proxy of the offer price dispersion in local markets. Results of regression analysis suggest that a greater dispersion in submarket offer prices is associated with a higher reservation price and a higher asking price. In addition, estimation of a Cox proportional hazard model indicates that properties in local markets characterized by higher price dispersion tend to have a higher likelihood of sale, and in turn experience relatively a shorter time on the market.

This article is organized as follows. The next section presents a simple search model in a market where sellers post their asking prices. The third section introduces Tokyo condominium resale market dataset. The fourth section reports results of empirical evaluation of the search model. The fifth section concludes the article.

Theoretical Model

Following early works by Mortensen (1970), Gronau (1971) and Moen (1997), in our multistage search model we assume that buyers' offer prices follow a distribution with a known cumulative distribution function, $F(p)$, and are

[3] We use normal distributed offering price to demonstrate the effect of price dispersion in properties time on the market. It can be easily extended to other forms of offering price distributions as well.

submitted for seller review in accordance to a Poisson process with parameter λ. The continuous discount rate is γ per period. If an offer of price p is accepted, the seller's expected payoff is $S = p - c$, where c is the seller's cost of search to bring forth the purchase offer.

Let P_a be the seller's asking price, which is hereafter called the list price. We assume that the offer arrival rateλ depends on the list price P_a, as will be discussed below.

Let's consider the determination of the seller's reservation price, P_r, given list price P_a. Following Horowitz (1992), Chen and Rosenthal (1996a and b) and Arnold (1999), we assume that P_a is the upper bound of transaction price p, *i.e.*, $p \leq P_a$. If the offer is not accepted, the payoff is $W = b - c + e^{-r/\lambda} E(\max\{p' - c, W'\})$, where b is the value of the property's second best use or the opportunity cost of sale; $p'$and $W'$are the values, respectively, of the subsequent forthcoming offer and the payoff of rejecting that offer. The value of having an offer in hand is

$$O(p) = \max\{S, W\} = \max\{p - c, b - c + e^{-r/\lambda} E(O(p'))\}. \tag{1}$$

The reservation price is defined as the unique price, at which the seller is indifferent between sale of the property and continued search, *i.e.*, $S(P_r) = W$. Accordingly, $P_r = b + e^{-r/\lambda} E(O(p'))$, or the difference between the reservation price and the value of the property's second best use is the discounted expected payoff from future search. Therefore, maximizing the return from search is equivalent to maximizingP_r for a specific b. Inserting the above formula into Equation (1) yields $E(O(P)) = E\,(\max\{p, P_r\}) - E(c)$. Further, we obtain

$$\begin{aligned} P_r &= b + e^{-r/\lambda} \int_0^\infty \max\{p, P_r\}\, dF(p) - e^{-r/\lambda} c. \\ &= b + e^{-r/\lambda} \left(\int_0^{P_r} P_r\, dF(p) + \int_{P_r}^{P_a} p\, dF(p) + \int_{P_a}^\infty P_a\, dF(p) - c \right) \end{aligned} \tag{2}$$

As suggested above, if the total cost of search for every period is fixed at C, then the average search cost for each offer is $c = C/\lambda$.

As shown in Equation (2), the reservation price has two components. One is the value of the property's second best use in the absence of a sale, and the other is the discounted expected return from search. Note that search will not occur if the expected payoff from sale is less than the value of the property's second best use; or, equivalently, if the expected return from search is negative. Hence, $P_r \geq b$. Equation (2) reveals that the higher opportunity cost (from the second best use) is, the higher the reservation price is.[4] In addition, note that a higher seller's discount rate, γ,[5] is associated with a lower offer arrival rate, λ, and a higher search cost per period, C, will lead to a lower reservation price.[6]

Let us now consider the determination of the list price. We hereafter assume that (1) the offer arrival rate, λ, is a decreasing function of the list price, P_a, and (2) when offer distribution is a normal distribution, the offer arrival rate, λ, is an increasing function of the standard deviation σ of the offer distribution.[7]

Previous discussion indicates a dynamic relationship between the reservation price and the list price, P_a. Thus, the seller seeks to maximize his or her discounted expected return from search by choosing an appropriate list price, taking account of the dependency of the reservation price on the list price. The solution to that maximization problem is implied by the following first-order condition:

$$1 - F(P_a^*) = -\left[\frac{C}{\lambda^2} + \frac{\gamma}{\lambda^2}(G(p) - C/\lambda)\right]\frac{\partial \lambda}{\partial P_a^*}, \tag{3}$$

where $G(p) = \int_0^{P_r} P_r\, dF(p) + \int_{P_r}^{P_a} p\, dF(p) + \int_{P_a}^{\infty} P_a\, dF(p)$, and $(G(p) - C/\lambda)$ represents the expected return from search. As shown, the seller's optimal list price is related to market conditions (buyer offer price distribution, offer arrival rate function and cost of search), the seller's discount rate and the

[4]Genesove and Mayer (1997, 2001) provided evidence that equity status and loss aversion both play significant roles in property selling. We can extend the value of the property's second best use as a mix of rational financial valuation, effect of equity constraint and sentiment factors (loss aversion), *etc*.

[5]Glower, Haurin and Hendershott (1988) argued that sellers' level of motivation to sell is important as well.

[6]The impatient seller is represented by higher discount rate. She or he will consequently select lower list price and lower reservation price and will enjoy higher offer arrival rate and higher probability of match, and hence it is possible for an impatient seller to sell faster.

[7]The following consideration presents one rationale of these assumptions. The potential buyers are likely to decide to inspect the property only if it is likely that the transaction price is below buyer's reservation price (B_r). Let us define the transaction price discount rate as $\theta = P_s/P_a$. (1) If the buyer knows the prevailing transaction price discount rate ($\overline{\theta}$) and decides to inspect the property only if the list price satisfies $P_a \leq B_r/\overline{\theta}$, then a higher list price will result in losing more potential buyers and lead to lower offer arrival rate and thus we have λ as a decreasing function of P_a. (2) Suppose that the offer follows normal distribution with mean μ and standard deviation σ. Then, the potential buyers can be expressed in this case as $\int_{\overline{\theta} P_a}^{\infty} dF(p) = 1 - F(\overline{\theta} P_a) = 1 - \Phi(\frac{\overline{\theta} P_a - \mu}{\sigma})$, which is positively related to σ. This suggests that λ as an increasing function of the standard deviation σ.

expected return from search. Note that the value of the property's second best use is irrelevant to the choice of an optimal list price.

We now examine the implications of price dispersion for the seller's optimal strategy under the assumption that the buyer offer distribution is normal with mean μ and standard deviation σ, by taking the following derivatives: $\frac{\partial P_a^*}{\partial \sigma}$ and $\frac{\partial P_r}{\partial \sigma}$. As shown in Appendix A, we find that $\frac{\partial P_a^*}{\partial \sigma} > 0$, and $\frac{\partial P_r}{\partial \sigma} > 0$, that is, both the optimal list price and the reservation price are positively associated with the degree of price dispersion.[8]

Let us now consider the effect of price dispersion on the expected transaction price. The expected transaction price is a conditional expectation based on the acceptance of an offer in excess of the reservation price. Following McCall (1970), because offers are independently drawn, we have

$$E(P_s) = E(p|p \geq P_r) = \frac{\int_{P_r}^{P_a} p dF(p) + \int_{P_a}^{\infty} P_a \, dF(p)}{1 - F(P_r)}. \tag{4}$$

As show in Appendix A, $\frac{\partial E(P_s)}{\partial \sigma} > 0$. In other words, a higher expected transaction price is associated with higher price dispersion.

In general, price and duration are related outcomes. Although the seller's goal is to sell the house for as high a price as possible and as quickly as possible, the higher price is generally associated with a longer time on the market. As discussed by Belkin, Hempel and McLeavey (1976), time on the market is an important descriptor of market behavior. Consistent with the conventional search model (McCall 1970), the probability of match given the arrival of an offer is $M = 1 - F(P_r)$. Assuming offer arrivals follow a geometric distribution, the probability of sale at the nth offer is $(1 - M)^{n-1}M$, and the expected number of offers before sale is $E(n) = \frac{1}{M}$. As mentioned above, if we assume there are λoffers arriving in each period, then the expected number of periods that the house is on the market is

$$E(N) = \frac{1}{\lambda M} = \frac{1}{\lambda(1 - F(P_r))}. \tag{5}$$

Assuming that the buyer offer price follows a normal distribution $N(\mu, \sigma)$, the impact of price dispersion on time on the market is,

[8] $\frac{\partial P_r}{\partial \sigma} > 0$is derived under certain assumptions of the discount rate between two adjacent offers; *e.g.*, the discount rate between two expected offers is confined to $0.5 \leq e^{-\gamma/\lambda} \leq 1$, as in Appendix A.

$$\begin{aligned}\frac{\partial E(N)}{\partial \sigma} &= \{1/[\lambda(1-F(P_r))^2]\}[\partial F(P_r)/\partial \sigma].\\ &= -\frac{P_r-\mu}{\sigma^2}\varphi(z)\{1/[\lambda(1-F(P_r))^2]\} \qquad (6)\\ &= \begin{cases} <0 & \text{if } P_r > \mu \\ >0 & \text{if } P_r < \mu \end{cases}\end{aligned}$$

A higher price dispersion facilitates a more rapid sale of "over-priced" properties when the seller's reservation price exceeds the market value of the property; on the contrary, a higher price dispersion delays the successful transaction of an "underpriced" property.

Hence results of our derivations lead to the following testable hypotheses: (I) following Equation (3) and as shown in the appendix, higher price dispersion leads to higher list prices;[9] (II) a property's transaction price increases with the dispersion in offer prices; (III) as shown in Equation (6), for overpriced properties, a higher offer price dispersion is associated with reduced time on the market. In the empirical analysis below, we apply a rich and uniquely suited database from the Tokyo condominium resale market data to test those hypotheses.

Data

Our empirical study focuses on the condominium resale market in the central Tokyo metropolitan area from 1994–2002. As shown in Figure 1, this period was characterized by some fallback in the condominium prices in the wake of prior substantial run-up in Japanese asset values during the 1986–1990 "bubble economy."[10] The slowdown in the Japanese economy over the study period was broadly evidenced in a variety of indicators.[11]

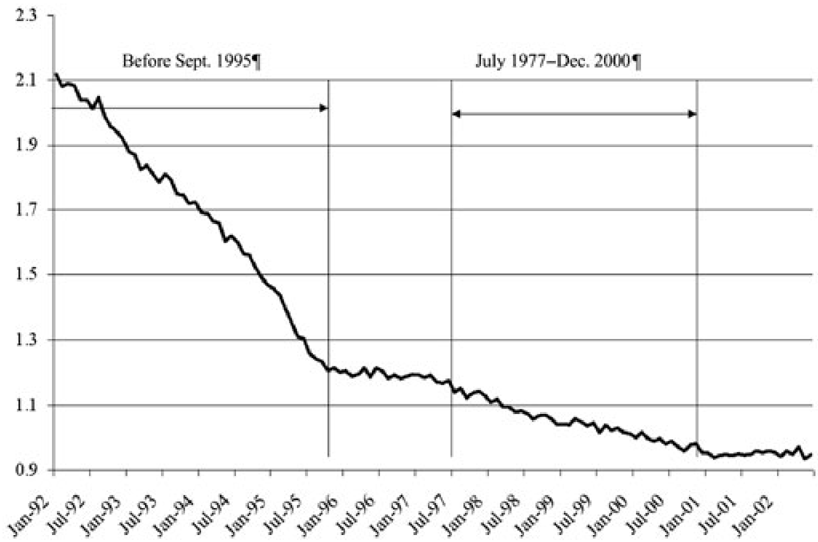
---

[9]Because of lack of availability of reservation price information, we cannot conduct the direct test on the relation between price dispersion and the reservation price.

[10]As indicated in Figure 1, our study timeframe can be divided into three distinct subperiods. The first, from January 1994–September 1995, reflects the significant downward adjustments to house prices that occurred in the immediate aftermath of the "bubble economy." A subsequent but less dramatic easing in condominium prices occurred between July 1997 and December 2000 in the wake of the Asian financial crisis. As similarly evidenced in Figure 1, the remaining sampled months, the control group in our empirical analysis (below), were characterized by relative price stability.

[11]From 1994 to 2002, the average annual growth rate of GDP was about 1.2%. During the latter half of the 1990s, Japan's unemployment rate trended up by about two percentage points to reach approximately 5% in late 2001. Average monthly household income moved up at a relatively stable 1.6% annual rate from 1994–1997, then declined by about 10% through the end of 2001. As would be expected, CPI fluctuations were well

Figure 1 ■ Recruit residential (condominium) price index: Tokyo special district 1992–2002 (2000 = 1.00).



Our transactions data on the Tokyo condominium market derives from Recruit Co., which publishes *Shukan Jutaku Jouhou* (Weekly Housing Information).[12] The magazine is published weekly and contains information on residential property listings. The advertisements are classified into four categories: new detached houses, resale detached houses, new condominiums and resale condominiums. Each property listing published by Recruit Co. includes information on the location and a brief description of the property, the list price and the name of the seller or the broker.[13] The coverage of this Recruit Co. dataset is comprehensive, especially for resale condominiums.[14]

contained at an annualized average rate of about 0.06% over the course of the 1994–2002 study period. Finally, the Tokyo area experienced moderate population growth of about 1% per annum during this period.

[12]Recruit Co. publishes *Shukan Jutaku Jouhou* in seven areas in Japan, including the Tokyo Metropolitan Area.

[13]Regarding key institutional characteristics, note that sellers in the Japanese property market are supposed to make their property vacant before listing it on the market; otherwise, sellers suffer a sizable discount. Moreover, the Japanese existing home market is characterized by relatively lower turnover rates compared to the United States'. Housing transactions are subject to a series of taxes accounting for approximately 3% of property value, exclusive of capital gains taxation.

[14]In the central Tokyo area (23 special wards), the *Jutaku Tochi Toukei Chousa* (Housing and Land Survey) of the General Administration Agency of the Japanese Government

Table 1 ■ Property listing and delisting—annual counts.

Year	Units Listed	Units Delisted	Units Sold	Average Initial List Price (10,000 yen, 2000)	Average Time on the Market (week)
1994	9,435	7,096	3,033	3,866	13.21
1995	8,513	8,909	3,848	3,343	12.75
1996	9,841	9,296	4,385	3,295	12.31
1997	10,634	10,347	4,128	3,234	13.05
1998	10,518	10,430	3,886	3,180	13.15
1999	11,004	11,081	4,325	3,081	12.57
2000	11,887	11,587	4,692	3,087	12.56
2001	12,916	13,572	5,836	3,091	11.79
2002	6,289	6,234	2,977	3,273	7.36

Note: Statistics for 2002 end on June.

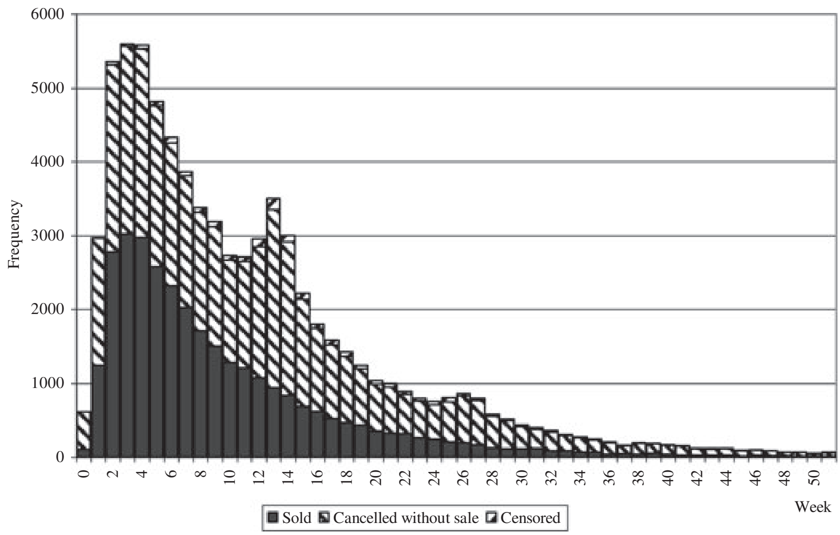
According to *Shukan Jutaku Jouhou*, there were 91,037 condominium properties listed for sale in central Tokyo from January 1994–June 2002. Of these properties, 37,110 were sold, 51,442 were cancelled without sale and 2,485 remained in the market (and hence were censored) at the end of June 2002 (Table 1). Each record contains the date of listing and the date of delisting, initial list price and delisting price, ward, distance to major/minor train station, average access time to metropolitan subcenters, unit size, top floor or ground floor, date of construction, real estate agent type (small, medium or large brokerage organization), structure type (steel framed or ferroconcrete) and an indicator of eligibility for government financing. We hereafter refer to the delisting price for those condominiums sold at delisting as their transaction price.[15]

As shown in Table 1, the average list price of sampled condominiums declined post-1994 and reached bottom in 2001. In the wake of Asian financial crisis, average time on the market increased and list prices declined for resale condominiums in 1997 and 1998. After 1999 and subsequent to significant downward adjustment in property prices, the data indicate some decline in duration of listing. As the economy began to revive, more units came into the market and more were finally sold as well.

estimated that there were 9,333 condominium resale transactions in 1998, whereas Recruit Co. reported 10,636. The Government figure is an estimate from a sample survey, whereas the Recruit Co. figure is based on actual transactions reported through *Shukan Jutaku Jouhou*.

[15] A follow-up survey conducted by Recruit Co. revealed that delisting prices for sold properties were in fact transaction prices, although there were some exceptions.

Figure 2 ■ Properties' time on the market, by status.



Note: This chart is limited to units remaining in the market up to 52 weeks.

Regarding the sampling algorithm, we deleted those properties with extreme initial asking and delisting prices (*i.e.*, the upper and lower one percentage of the observations). As the study focuses on the resale condominium market, new units are also excluded. We further confined our dataset on the multifamily properties with more than five units in the complex. Our final dataset has 83,165 observations, of which 34,129 units were sold, 46,843 units were cancelled without sale and 2,193 units otherwise (*i.e.*, remained on the market at the end of the sample period).

Figure 2 provides a histogram of property time on the market as measured in the number of weeks for all properties in our final dataset. For sold units, time on the market follows a lognormal distribution. Properties have the highest tendency to be sold at around four weeks after initial listing. More than 90% of the units delisted without sale are cancelled within the first 28 weeks, or within about half a year after initial listing. Sellers are more likely to discontinue their listing at around week four (end of first month), week 14 (after three months) and week 27 (after six months).

We then stratified the listed units among submarkets on the basis of key property characteristics including geographic area, proximity to rapid transit (train) stations, unit size and structure age.[16] In so doing, we constrained the minimum size of valid subsamples to 30 observations.[17] Then, for each submarket, we calculated transaction price dispersion (*i.e.*, the standard deviation of de-listing prices for condominiums actually sold), which we used as a proxy for buyer offer price dispersion in the particular submarket. Similarly, submarket thickness is represented by the number of listings in that area. We use these proxies in the empirical analysis below.

Table 2 presents the means and standard deviations of selected characteristic continuous variables of condominiums that we examine. The average condominium time on the market was 12.8 weeks, whereas sold units had shorter average duration of 10.7 weeks. Both the initial list price and the final delisting price of the sold units (*i.e*., transaction prices) averaged 9% lower than prices for cancelled units. The mean and the standard deviation of the buyer offer price dispersion of the submarket to which a particular condominium belongs are also shown for four categories (all, sold, cancelled without sale and other), with the standard deviation of transaction prices of the submarket assumed to proxy for the buyer offer price dispersion. The sold properties were more likely to be located in the submarkets with lower buyer offer price dispersion,[18] though the difference in the value of this indicator between sold and cancelled-without-sale units was only about 4%. The average age of the units (for the "all" category) was 186 months (15.5 years) at listing. Sold units were older than cancelled listings by just five months. The average travel time to the 40 busiest rail stations (from among the 1,600 stations in the Tokyo metropolitan area) was 24.9 minutes for the full sample. This travel time is slightly longer

[16]Regarding geography, the 23 special wards in central Tokyo are self-governing, special municipalities in the central and most populous part of Tokyo. Geographically, those wards can be divided into three areas. Area I covers CBD; whereas Area II, or the west segment, is another relatively more expensive residential component. Area I includes Chiyoda, Chuo, Minato, Shinjuku, Bunkyo, Taito, Shibuya and Toshima; Area II includes Shinagawa, Meguro, Ota, Setagaya, Nakano, Suginami and Nerima; Area III includes Sumida, Koto, Kita, Arakawa, Itabashi, Adachi, Katsushika and Edogawa. Given the vital nature of mass transit to mobility in central Tokyo, we further note whether the unit is within walking distance to the train station. Properties between 25 and 85 square meters are categorized as "family-type" condominiums; more than 80% of the listed properties fall into this category. Properties smaller than 25 square meters in size are largely studios, whereas units in excess of 85 m^2 are high-end condominiums. Age of the structure is another important characteristic. Certain buyers, called "the new property runners," are known to often trade up to new properties. Because of physical depreciation, homeowners often are required to pay higher maintenance fees for structures older than 10 years

[17]There are 43 submarkets in the final sample.

[18]To make it clear, we use the phrase *Transaction Price Dispersion in the Submarket to Which the Condo Belongs* for this entry in Table 2.

Table 2 ■ Mean and standard deviation of selected continuous variables.

	All	Sold	Cancelled without Sale	Other
No. of weeks on market	12.8	10.7	14.5	9.3
	(10.7)	(8.8)	(11.7)	(9.6)
Initial list price (10,000 yen)	3,258	3,094	3,368	3,458
	(1,631)	(1,504)	(1,693)	(1,907)
Delisting price (10,000 yen)	3,171	3,012	3,286	
	(1,576)	(1,458)	(1,646)	
Transaction price dispersion in the submarket to which the condo belongs[a]	1,011	989	1,024	1,060
	(275)	(263)	(281)	(307)
No. of months after construction when listed	186	189	184	186
	(94)	(92)	(95)	(116)
Average travel time to 40 busiest stations	24.9	25.2	24.7	24.6
	(4.9)	(4.9)	(5.0)	(4.8)
Size (square meters)	59.2	58.6	59.3	65.3
	(19.9)	(18.9)	(20.5)	(22.0)
No. of observations	83,165	34,129	46,843	2,193

Notes: Standard deviations are in parentheses.
[a]Transaction price dispersion in the submarket to which the condo belongs is proxy of buyer offer price dispersion in the corresponding submarket, serving as one of the market's characteristics.

among the sold units. The average size of unit was 59 m^2. Cancelled-without-sale properties were relatively larger compared to the sold units, and those still in the market (*i.e.*, in the "other" category) were the largest among the three status groups.[19]

We merged the transaction records with Japanese macroeconomic indicators and Tokyo condominium market information. Table 3 displays the means and standard deviations of selected time-varying covariates. Consistent with the economic slowdown during our sample period, the Nikkei 225 index was on average higher at initial listing than at delisting. This difference was more significant among the cancelled-without-sale properties. Similarly, average monthly household income was also higher at listing than at delisting. Further, the sold units were associated with less of a drop in household income than the cancelled listings (497 yen vs. 766 yen). The condominium price index also was generally higher at initial listing than at delisting.

[19]The statistics for the "other" or the censored lists indicate that as the market starts picking up, the more recent lists are relatively bigger and more expensive.

Table 3 ■ Mean and standard deviation of selected time-varying covariates.

	All	Sold	Cancelled without sale	Other
(a) At Initial Listing				
Japanese Nikkei 225 index	16,651	16,736	16,846	11,160
	(3,240)	(3,251)	(3,078)	(484)
Average monthly household income (2,000 yen)	481,202	481,382	481,939	462,654
	(9,653)	(9,465)	(9,129)	(1,802)
Recruit residential (condominium)	1.117	1.120	1.124	0.926
Price index: Tokyo special district (23 wards)	(0.18)	(0.18)	(0.18)	(0.01)
No. of observations	83,165	34,129	46,843	2,193
(b) At Delisting				
Japanese Nikkei 225 index	16,362	16,522	16,497	10,966
	(3,339)	(3,360)	(3,188)	
Average monthly household income (2,000 yen)	480,520	480,854	481,134	462,207
	(10,074)	(9,918)	(9,610)	
Recruit residential (Condominium)	1.114	1.120	1.118	0.947
Price index: Tokyo special district (23 wards)	(0.18)	(0.18)	(0.18)	
No. of observations	83,165	34,129	46,843	2,193

Notes: Standard deviations are in parentheses.

Table 4 provides the frequencies of selected discrete variables. Area I, Area II and Area III comprise 27.4%, 44.1% and 28.4% of the central Tokyo condominium market, respectively. The transaction rate varies from a low of 36.1% in Area I to 46.1% in Area III. The vast majority of listed properties were within walking distance of a train station (98.6%), but those properties also have a lower transaction rate compared to other properties (42.3% vs. 49.3%). Over the course of the listing period, about one-third of sellers adjusted their list price; among them, 98% reduced the list price.[20] Further, the transaction rate for price-adjusted properties is lower than those without any price adjustment units (40% vs. 45%). Also, 92.6% of listed properties were in thick markets (defined as 1,000+ listed properties). The transaction rate in thick markets was higher than in other markets (41% vs. 39%).

Among other regularities in the data, note that agents affiliated with small and mid-size firms had less than a 40% market share but succeeded in selling

[20] As Horowitz (1992) mentioned, the increase in list price rarely happens. It may happen when the seller receives multiple offers at the same time. Under those conditions, auction theory may be applied.

Table 4 ■ Frequency of selected discrete variables.

	All	Sold	Cancelled without Sale	Other
Area				
Area I—Central business	22,814	8,241	13,888	685
	(27.4)	(36.1)	(60.9)	(3.0)
Area II—Southwest	36,710	14,987	20,765	958
	(44.1)	(40.8)	(56.6)	(2.6)
Area III—Northeast	23,641	10,901	12,190	550
	(28.4)	(46.1)	(51.6)	(2.3)
Train station within walking distance	82,040	33,595	46,286	2,159
	(98.6)	(40.9)	(56.4)	(2.6)
Ever adjust list price	28,173	11,270	14,710	2,193
	(33.9)	(40.0)	(52.2)	(7.8)
Ever adjust list price—increase	581	273	308	0
	(0.7)	(47.0)	(53.0)	(0.0)
Ever adjust list price—decrease	27,592	10,997	14,402	2,193
	(33.2)	(39.9)	(52.2)	(7.9)
Thick market	76,990	31,723	43,293	1,974
	(92.6)	(41.2)	(56.2)	(2.6)
Real estate agent category				
Big	51,864	19,076	31,383	1,405
	(62.4)	(36.8)	(60.5)	(2.7)
Middle	15,247	7,283	7,623	341
	(18.3)	(47.8)	(50.0)	(2.2)
Small	16,054	7,770	7,837	447
	(19.3)	(48.4)	(48.8)	(2.8)
Delisting season				
Spring	22,043	9,320	12,634	89
	(26.5)	(42.3)	(57.3)	(0.4)
Summer	21,572	9,253	12,281	38
	(25.9)	(42.9)	(56.9)	(0.2)
Fall	19,705	7,294	10,793	1,618
	(23.7)	(37.0)	(54.8)	(8.2)
Winter	19,845	8,262	11,135	448
	(23.9)	(41.6)	(56.1)	(2.3)
Size (square meter)				
Less than 25	2,469	856	1,573	40
	(3.0)	(34.7)	(63.7)	(1.6)
25-85	73,318	30,661	40,834	1,823
	(88.2)	(41.8)	(55.7)	(2.5)
More than 85	7,378	2,612	4,436	330
	(8.9)	(35.4)	(60.1)	(4.5)
Structure age				
1-4 years	8,081	2,728	5,013	340
	(9.7)	(33.8)	(62.0)	(4.2)

Table 4 ■ Continued.

	All	Sold	Cancelled without Sale	Other
4-10 years	13,495	5,436	7,593	466
	(16.2)	(40.3)	(56.3)	(3.5)
10-22 years	44,454	18,881	24,799	774
	(53.5)	(42.5)	(55.8)	(1.7)
More than 22 years	17,135	7,084	9,438	613
	(20.6)	(41.3)	(55.1)	(3.6)
No. of observations	83,165	34,129	46,843	2,193

Notes: Column percentages are in parentheses for all in column 1; row percentages by sold, cancelled without sale and other are in parenthesis in columns 2-4.

almost half their listings, well in excess of the sales rate among agents affiliated with large firms. More properties were listed in the spring and summer than in the fall and winter. Further, a majority of listed properties were "family-type" condominiums, of size between 25 and 85 m^2. The midsized properties also had relatively higher transaction rates compared to both studios and luxury units (41.8% vs. 34.7% and 35.4%, respectively). More than half of the listed properties were between 10- and 22-year old; those properties also had the highest transaction rate (42.5%). The newer structures, between one- and four-year old, had the lowest transaction rates (33.8%).

We turn now to estimation of the market value of each condominium. Because only one-third of the listed properties were ultimately sold, whereas another two-thirds were cancelled without sale, we used the Heckman two-step procedure to correct for sample selection in the estimation of each condominium's market value. In the first step, we used the full sample to estimate a probit model of the probability of transaction and in so doing also estimated an inverse Mill's Ratio.[21] In the second step, the estimated inverse Mill's Ratio was included as an additional explanatory variable in an OLS regression on property value. The expected market value for each property was estimated accordingly, controlling for well-established structural, locational and time of sale characteristics.[22]

[21] Heckman one-step estimation results are presented in Appendix B.

[22] The number of monthly transactions in our sample period varied from 25 to 524 but were typically in excess of 200. The adjusted R^2 for the monthly OLS regressions are higher than 0.7. The logarithm of transaction price is negatively related to the average travel time to the 40 busiest rail stations (*Access*) and the age of the building, but positively related to property's size. A unit located in central business district (CBD) is associated with higher transaction price as well. To conserve space, results of estimation of the expected market value of each property are not displayed but are available from the authors on request.

Empirical Results

List Prices and Transaction Prices

According to Equation (3) above, sellers' choice of optimal list price varies with market conditions including buyer offer price distribution, buyer offer arrival rate,[23] sellers' cost of search and the expected returns from search. Further, as shown in Appendix A, the optimal list price is an increasing function of the offer price dispersion. Also as indicated in Appendix A, the expected transaction price defined in Equation (4) increases with the price dispersion. The following analysis focuses on tests of these hypotheses.

Both the list price and the transaction price are closely related to the property's fundamental value as represented by the property's estimated quality-adjusted market value. Further, the market conditions, including price dispersion and market thickness, as well as indications of seller behavior (adjustment of list price and selection of real estate agent) may have an impact on list price selection and the final transaction price.

Table 5 displays results of OLS regressions of the log of the list price for the full sample. Table 5A shows results at initial listing, whereas Table 5B presents results at delisting. Model 1 in Table 5A provides a parsimonious specification in which the list price is regressed on the quality adjusted market value (as explained in the previous section). As expected, the property's estimated market value is positive and highly significant in the determination of the initial list price. Model 2 includes a proxy for the measure of offer price dispersion, which is the standard deviation of transaction prices in the relevant submarket. Results here are highly significant and indicate that a 1% increase in the standard deviation of the submarket transaction price dispersion results in an approximate 26% ($\text{Exp}(0.23) - 1 \approx 26\%$) increase in the initial list price. Accordingly, empirical findings support our theoretical assertion that the list price is higher in a market with greater price dispersion.

Model 3 further expands on the specification to include a control for thick markets. As suggested by Lazear (1986), prices may vary with submarket thickness, as proxied by the number of listed properties. After controlling for both condominium estimated market value and submarket price dispersion, results of Model 3 indicates a pricing premium of 0.06% in thick markets. Model 4 provides a control for whether the seller adjusts the list price. In that

[23]It should be noted that the offer arrival rate is a function of the list price. Thus it is more precise to refer to "parameters determining offer arrival rate function" than simply "offer arrival rate" here. However, to avoid cumbersome terminology, we hereafter use "offer arrival rate" instead of "parameters determining offer arrival rate function."

Table 5A ■ OLS regressions on price for the full sample.

Dependent variable: Logarithm of list price, at initial listing.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	0.10	−0.77	−0.82	−0.81	−0.78	−0.75	−0.75
	(7.16)	(−44.44)	(−47.24)	(−46.51)	(−44.63)	(−42.22)	(−41.04)
Logarithm of estimated market value at listing	0.99	0.90	0.92	0.92	0.91	0.91	0.91
	(541.79)	(444.82)	(425.98)	(424.57)	(421.83)	(402.52)	(402.06)
Logarithm of transaction price dispersion of the submarket to which the condo belongs		0.23	0.21	0.21	0.21	0.22	0.22
		(85.71)	(74.94)	(75.18)	(75.33)	(75.38)	(75.24)
Thick market			0.06	0.06	0.06	0.06	0.06
			(21.14)	(20.88)	(20.49)	(19.41)	(19.41)
Ever adjust list price				0.03	0.03	0.03	0.03
				(20.97)	(20.02)	(20.65)	(20.67)
Middle size agent					−0.01	−0.02	−0.02
					(−7.69)	(−7.87)	(−7.88)
Small size agent					−0.03	−0.03	−0.03
					(−14.31)	(−14.23)	(−14.22)
Delist year							
1995						−0.03	−0.03
						(−7.70)	(−7.57)
1996						−0.01	−0.01
						(−2.71)	(−2.22)

Table 5A ■ Continued.

Dependent variable: Logarithm of list price, at initial listing.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
1997						−0.01	−0.01
						(−3.61)	(−2.02)
1998						−0.02	−0.02
						(−7.21)	(−2.90)
1999						−0.03	−0.03
						(−9.94)	(−4.12)
2000						−0.03	−0.02
						(−7.92)	(−3.19)
2001						−0.03	−0.03
						(−7.73)	(−4.94)
2002						−0.03	−0.03
						(−8.04)	(−5.38)
Logarithm of transaction price dispersion × period: January 1994–September 1995							−0.0006
							(−0.82)
Logarithm of transaction price dispersion × period: July 1997–December 2000							−0.0010
							(−1.68)
R^3	0.779	0.797	0.798	0.799	0.800	0.800	0.800
Number of observations	83,165	83,165	83,165	83,165	83,165	83,165	83,165

Notes: t-statistics are in parentheses.

Table 5B ■ Continued.

Dependent variable: Logarithm of list price, at delisting. (Transaction price for sold as well as delisting price for withdrawn.)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	0.13	−0.75	−0.81	−0.82	−0.80	−0.77	−0.77
	(8.59)	(−42.70)	(−45.40)	(−46.54)	(−44.79)	(−42.61)	(−41.23)
Logarithm of estimated market value at delisting	0.99	0.90	0.91	0.92	0.92	0.91	0.91
	(528.07)	(434.47)	(416.09)	(418.61)	(415.85)	(396.67)	(396.36)
Logarithm of transaction price dispersion of the submarket to which the condo belongs		0.23	0.21	0.21	0.21	0.21	0.22
		(84.73)	(74.10)	(74.24)	(74.38)	(73.81)	(73.68)
Thick market			0.06	0.06	0.06	0.06	0.06
			(20.56)	(21.14)	(20.78)	(20.00)	(20.01)
Ever adjust list price				−0.04	−0.04	−0.04	−0.04
				(−25.98)	(−26.86)	(−26.31)	(−26.26)
Middle size agent					−0.01	−0.01	−0.01
					(−6.82)	(−6.99)	(−6.99)
Small size agent					−0.03	−0.03	−0.03
					(−13.25)	(−13.18)	(−13.17)
Delist year							
1995						−0.03	−0.03
						(−8.74)	(−8.66)
1996						−0.01	−0.01
						(−2.24)	(−2.34)

Table 5B ■ Continued.

Dependent variable: Logarithm of list price, at delisting. (Transaction price for sold as well as delisting price for withdrawn.)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
1997						−0.01	−0.01
						(−2.70)	(−1.93)
1998						−0.02	−0.02
						(−6.46)	(−2.89)
1999						−0.03	−0.03
						(−8.97)	(−3.99)
2000						−0.02	−0.02
						(−6.91)	(−3.06)
2001						−0.02	−0.03
						(−6.61)	(−4.64)
2002						−0.02	−0.03
						(−5.38)	(−4.27)
Logarithm of transaction price dispersion × period: January 1994–September 1995							−0.0010
							(−1.33)
Logarithm of transaction price dispersion × period: July 1997–December 2000							−0.0010
							(−1.69)
R^2	0.775	0.793	0.794	0.796	0.797	0.797	0.797
Number of observations	80,972	80,972	80,972	80,972	80,972	80,972	80,972

Note: t-statistics are in parentheses.

regard, various authors have suggested that some sellers may experiment with a higher list price early on and then subsequently adjust that price upon learning more about the market (see, *e.g.*, Sass 1988, Taylor 1999, Chade and Serio 2002). Model 5 additionally considers the effects of different of real estate agents affiliated with firms of different sizes. Agents affiliated with both small and mid-size firms appear to be less aggressive than those affiliated with larger entities. Model 3 to Model 7 show that the price dispersion effects are robust.

Subsequent iterations of the model provide additional controls for macroeconomic and housing market conditions. Indeed, the annual delist fixed effects (Model 6) are highly significant in the determination of list prices. Finally, Model 7 further considers interactions of the price dispersion term with categorical controls for the two subperiods in which the condominium price index recorded a significant downward adjustment. Both interactive terms were negative and insignificant.

Table 5B displays results of similar specifications of the log of list price at the time of delisting (including both sold and withdrawn properties). Results here are similar to those in Table 5A. As expected, the delisting price is positively related to the estimated market value of the property, price dispersion in the sub-market and an indicator of thick markets. Similarly, units listed with agents affiliated with large firms are also more likely to be delisted at a higher price. Note, however, that *ex ante* less informed sellers who "post high and adjust later" do not necessarily delist their property at a higher price.

As described above, only 41% listed properties are ultimately sold. In Table 6, we report on results of above specifications for a sample that includes only sold units, so as to assess robustness of results to sample selection. As is evident, results are largely similar to those contained in Table 5. Of importance to our theory, the price dispersion effects are quite robust; a 1% increase in the standard deviation of the submarket transaction price dispersion results in an approximate 25% ($\text{Exp}(0.22) - 1 \approx 25\%$) increase in the initial list price. Similarly, results here reveal negative and significant coefficients for the interaction of the degree of price dispersion with controls for periods of decline in the condominium price index. Results then suggest damped effects of the price dispersion term during periods of market weakness.

Time on the Market: Estimating the Hazard Rate of Sale

In this section, our empirical analyses focus on the estimation of a property's time on the market. As discussed above, time on the market is another important outcome of search. Equation (5) expresses the expected time on the market as a function of the offer arrival rate, the seller's reservation price and the offer price

Table 6 ■ OLS regressions on price for the sold units.

Dependent variable: logarithm of list price.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(A) Dependent variable: logarithm of list price, at initial listing.							
Intercept	0.09	−0.85	−0.92	−0.90	−0.90	−0.86	−0.86
	(3.84)	(−31.24)	(−33.52)	(−32.75)	(−32.55)	(−30.39)	(−29.46)
Logarithm of estimated market value at listing	0.99	0.90	0.92	0.92	0.92	0.91	0.91
	(343.62)	(288.57)	(277.66)	(276.09)	(273.80)	(258.97)	(258.87)
Logarithm of transaction price dispersion of the submarket to which the condo belongs		0.24	0.22	0.22	0.22	0.22	0.22
		(57.57)	(50.84)	(51.25)	(51.33)	(51.23)	(51.25)
Thick market			0.07	0.07	0.07	0.07	0.07
			(15.44)	(15.04)	(14.96)	(14.30)	(14.32)
Ever adjust list price				0.04	0.04	0.04	0.04
				(16.86)	(16.81)	(17.14)	(17.21)
Middle size agent					0.01	0.01	0.01
					(2.74)	(2.48)	(2.49)
Small size agent					0.00	0.00	0.00
					(−0.79)	(−1.02)	(−1.01)
Delist year							
1995						−0.04	−0.04
						(−7.04)	(−7.20)
1996						−0.02	−0.03
						(−3.40)	(−3.40)
1997						−0.02	−0.03
						(−3.48)	(−2.64)
1998						−0.03	−0.03
						(−5.13)	(−2.40)
1999						−0.03	−0.03
						(−5.96)	(−2.75)

Table 6 ■ Continued.

Dependent variable: logarithm of list price.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
2000						−0.03	−0.03
						(−6.13)	(−2.81)
2001						−0.03	−0.04
						(−6.23)	(−4.93)
2002						−0.02	−0.03
						(−3.63)	(−3.63)
Logarithm of transaction price dispersion × period: January 1994–September 1995							−0.002
							(−1.81)
Logarithm of transaction price dispersion × period: July 1997–December 2000							−0.002
							(−2.03)
R^2	0.776	0.796	0.797	0.799	0.799	0.799	0.799
Number of observations	34,129	34,129	34,129	34,129	34,129	34,129	34,129
(B) Dependent variable: logarithm of list price, at delisting (transaction prices).							
Intercept	0.12	−0.83	−0.90	−0.92	−0.92	−0.89	−0.88
	(5.36)	(−30.20)	(−32.31)	(−33.14)	(−33.02)	(−31.00)	(−29.96)
Logarithm of estimated market value at delisting	0.98	0.90	0.91	0.92	0.92	0.91	0.91
	(339.11)	(284.48)	(273.35)	(274.57)	(272.35)	(257.90)	(257.82)
Logarithm of transaction price dispersion of the submarket to which the condo belongs		0.24	0.22	0.22	0.22	0.22	0.23
		(57.97)	(51.49)	(51.51)	(51.58)	(51.18)	(51.20)
Thick market			0.07	0.07	0.07	0.07	0.07
			(14.44)	(14.88)	(14.83)	(14.34)	(14.37)
Ever adjust list price				−0.04	−0.04	−0.04	−0.03
				(−15.31)	(−15.26)	(−14.87)	(−14.78)

Table 6 ■ Continued.

Dependent variable: logarithm of list price.	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Middle size agent					0.01	0.01	0.01
					(3.07)	(2.82)	(2.84)
Small size agent					−5.27E-04	−1.07E-03	−1.03E-03
					(−0.19)	(−0.38)	(−0.37)
Delist year							
1995						−0.04	−0.05
						(−7.96)	(−8.23)
1996						−0.02	−0.03
						(−3.18)	(−3.65)
1997						−0.02	−0.03
						(−2.94)	(−2.73)
1998						−0.03	−0.03
						(−4.89)	(−2.65)
1999						−0.03	−0.03
						(−5.42)	(−2.87)
2000						−0.03	−0.03
						(−5.69)	(−2.97)
2001						−0.03	−0.04
						(−5.73)	(−5.04)
2002						−0.02	−0.03
						(−2.75)	(−3.46)
Logarithm of transaction price dispersion × period: January 1994–September 1995							−0.0025
							(−2.26)
Logarithm of transaction price dispersion × period: July 1997–December 2000							−0.0018
							(−1.93)
R^2	0.771	0.792	0.793	0.794	0.794	0.795	0.795
Number of observations	34,129	34,129	34,129	34,129	34,129	34,129	34,129

Note: t-statistics are in parentheses.

distribution. Assuming the offer price follows normal distribution, Equation (6) shows that the expected time on the market for an overpriced property (with a reservation price in excess of the property's market value) is reduced in a market with higher levels of price dispersion. To the extent that most of the mispriced properties in the marketplace tend to be overpriced, then shorter average time on the market or higher probability of sale should be expected in submarkets with higher price dispersion. We test this hypothesis below.

Our empirical models are estimated based on the Cox Partial Likelihood approach (Cox 1975). As is well appreciated, the hazard function in the Cox model is defined as the product of a baseline hazard function and a set of proportional factors such that

$$h(t_{ij}; z_j(t_{ij})) = h_{0j}(t_{ij}) \exp(z_j(t_{ij})'\beta_j), \quad j = 1, 2, \tag{7}$$

where $h_{0j}(t_{ij})$ is a baseline hazard function that describes the overall shape of time on the market of the listed properties, *i.e.*, list termination risks by sale or cancellation.[24] Note that j indicates sale if $j = 1$ and withdrawal from the market without sale or censored listing if $j = 2$ or 3, respectively. The hazard rate of termination is the probability that a listed property is sold or cancelled at any given time$t$, given that it has not been sold or cancelled before t.

Note that $z_j(t_{ij})$ is a vector of proportional factors capturing time-varying or time-invariant covariates. In our empirical example, $z_j(t_{ij})$ includes a measure of the degree of offer price dispersion in the relevant submarket, represented by the logarithm of transaction price dispersion in the corresponding submarket, as before. Also included among proportional factors in the estimating equation are (1) the logarithm of the list price, serving to be proxy for the offer arrival rate,[25] (2) the degree of overpricing and an indicator of whether the seller revises her or his list price, to proxy variations in seller behavior, (3) the real estate agent affiliation type, representing different opportunities of search assistance and varying knowledge of the local market and (4) economic and household

[24]Green and Shoven (1986) are among the first to apply the Cox model to study mortgage outcomes. Since then, researchers have developed more sophisticated and realistic applications of the Cox proportional hazard model in assessment of mortgage termination behaviors (see Schwartz and Torous (1989), Deng, Quigley and Van Order (2000), Deng, Pavlov and Yang (2005) and Deng, Zheng and Ling (2005) for more sophisticated applications). In housing market analysis Zuehlke (1987) employed a Weibull hazard model to examine the relationship between probability of sale and market duration in housing markets. Kluger and Miller (1990) developed a liquidity measure for real estate based on the Cox proportional hazard technique. More recently, Genesove and Mayer (2001) applied the Cox proportional hazard model to study the determinants of properties' time on the market.

[25]It should be remembered that the fundamental assumption of our model is that the offer arrival rate is negatively related to the list price.

conditions, including indicators of thick markets, month/year of delisting, index of stock values, average household income, condominium price index and the like. These latter factors may also affect the offer arrival rate and in turn influence the property's time on the market.

Estimates of a number of specifications of the proportional hazard model are presented in Table 7. Model 1 includes the logarithm of the list price, a control for overpricing of the property (the ratio between the list price and the estimated market value) and a control for price dispersion in the local market. Results suggest that a higher list price results in a longer time on the market or a lower likelihood of sale; a larger deviation of the list price form the estimated market value results in a longer time on the market. Also, consistent with modeled hypotheses as shown in Equation (6), the estimated coefficient on the price dispersion term was positive and significant, suggesting that listed properties in areas of higher price dispersion are associated with shorter time on the market.

Also, due perhaps to variations in affordability, the market for small condominiums may behave differently from the market for larger properties. We distinguish those larger properties by flagging the upper three quantiles of the distribution of units' size, or units in excess of 46.4 m^2, and interacting this large unit indicator with the logarithm of submarket transaction price dispersion. Results of Model 2 show that the estimated interactive term is also positive and significant. Accordingly, submarket price dispersion has an even greater impact on larger properties.

The following tests show the robust relationship between price dispersion and properties' time on the market. From Model 3 to Model 6, we test the hypotheses as regards the roles of market thickness,[26] seller adjustment of the property list price, real estate agents affiliation, seasonal factors and economy-wide conditions as captured in the delisting year. Model 3 shows that a thick submarket, characterized by larger numbers of sellers and buyers, enhances property liquidity by increasing the offer arrival rate. As expected, market thickness is positively related to the likelihood of a sale. Model 4 controls for sellers who adjusted the list price of their properties. Those sellers who have adjusted the list price of the property are less likely to quickly sell their properties. In Model 5, real estate agents affiliated with mid-sized agencies exhibit the highest likelihood of sale, whereas properties listed with the largest agencies are associated with the longest time on the market. Model 6 provides controls for seasonality in condominium sales. Results here indicate that properties are more likely to be sold in March, June and November and are less likely to be sold in January.

[26]As described above, this control is specified as the submarkets with more than 1,000 listed properties.

Table 7 ■ Time on the market: Proportional hazard models.
Dependent variable: Number of weeks in the market.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Logarithm of List Price	−0.3	−0.5	−0.46	−0.42	−0.41	−0.41	−0.56	−0.43	−0.43
	(−20.08)	(−26.74)	(−23.39)	(−20.99)	(−20.70)	(−20.80)	(−25.77)	(−19.76)	(−19.48)
List Price/Hedonic Price	−0.52	−0.42	−0.46	−0.44	−0.43	−0.43	−0.34	−0.4	−0.41
	(−19.46)	(−15.21)	(−15.92)	(−15.42)	(−15.11)	(−15.09)	(−11.57)	(−13.81)	(−13.90)
Logarithm of Transaction Price Dispersion of the Submarket to Which the Condo Belongs	0.05	0.08	0.05	0.03	0.04	0.04	0.15	0.06	0.02
	−2.47	−4.23	−2.45	−1.66	−1.87	−2.04	−6.74	−2.76	−0.58
Units above 46.4 Sq. M. × Logarithm of Transaction Price Dispersion -Submarket		0.04	0.04	0.05	0.05	0.05	0.06	0.05	0.05
		−18.27	−17.26	−19.87	−19.91	−19.98	−23.93	−18.83	−18.48
Thick Market			0.11	0.14	0.13	0.13	0.08	0.13	0.11
			−4.76	−5.85	−5.71	−5.63	−3.51	−5.45	−4.87
Ever Adjust List Price				−0.7	−0.69	−0.68	−0.68	−0.68	−0.68
				(−58.57)	(−57.45)	(−56.77)	(−56.69)	(−56.68)	(−56.69)
Size of Real Estate Agent									
Middle Size Agent					0.18	0.18	0.18	0.18	0.18
					−13.07	−12.93	−12.69	−13.04	−12.98
Small Size Agent					0.08	0.09	0.08	0.08	0.08
					−6.13	−6.28	−5.61	−5.5	−5.57

Table 7 ■ Continued.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
De-list Month									
February						0.28	0.29	0.31	0.31
						−10.61	−10.74	−11.54	−11.56
March						0.38	0.38	0.4	0.4
						−14.4	−14.34	−15.03	−15.04
April						0.31	0.31	0.32	0.32
						−11.53	−11.38	−11.99	−11.99
May						0.3	0.29	0.29	0.29
						−10.93	−10.54	−10.7	−10.72
June						0.36	0.33	0.34	0.34
						−13.33	−12.26	−12.6	−12.58
July						0.23	0.22	0.26	0.26
						−8.2	−7.55	−9.06	−9.1
August						0.17	0.15	0.16	0.16
						−5.88	−5	−5.47	−5.46
September						0.18	0.15	0.18	0.18
						−6.52	−5.35	−6.21	−6.22
October						0.27	0.25	0.34	0.34
						−10.13	−9.04	−12.54	−12.55
November						0.33	0.3	0.39	0.39
						−11.97	−10.76	−14.13	−14.16
December						0.25	0.22	0.31	0.31
						−8.64	−7.63	−10.68	−10.66

Table 7 ■ Continued.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
De-list Year									
1995							−0.28		
							(−11.04)		
1996							−0.15		
							(−5.80)		
1997							−0.4		
							(−15.48)		
1998							−0.54		
							(−20.65)		
1999							−0.49		
							(−18.99)		
2000							−0.44		
							(−16.96)		
2001							−0.38		
							(−15.08)		
2002							−0.31		
							(−10.30)		
Macro and Housing Market Indicators									

Table 7 ■ Continued.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Logarithm of Nikkei 225								0.26	0.26
Index								−6.1	−6.12
Logarithm of Average								1.77	1.71
Monthly Household								−3.81	−3.68
Income (2000 yen)									
Recruit Residential								−1.32	−1.32
Condominium Price Index:								(−13.76)	(−13.76)
Tokyo Special District (23 wards)									
Sub-periods									
Period: Jan. 1994 – Sept.								0.56	−1.47
1995								−15.61	(−4.42)
Period: July 1997 – Dec. 2000								−0.25	−0.13
								(−18.48)	(−0.52)
Interaction with Logarithm of Transaction Price Dispersion									
Period Jan. 1994 – Sept. 1995									0.3
									−6.15
Period: July 1997 – Dec. 2000									−0.02
									(−0.49)
-Log (likelihood)	359,322	359,152	359,141	357,327	357,240	357,078	356,730	356,752	356,729
SBC	359,325	359,156	359,146	357,333	357,248	357,097	356,757	356,776	356,755

Model 7 further includes the delisting year indicator so as to control for macro trends in the condominium market from 1994 to 2002. As suggested above, the early years following the 1991 downward breakpoint in the Japanese economy have been characterized as a hard economic landing. Those years were followed by some improvement in macro and housing conditions in the mid-1990s, followed by further easing in economic activity in the wake of the 1997 Asian financial crisis. We hypothesize that improved macroeconomic and housing market conditions are associated with an elevated potential buyers' arrival rate, λ, as described in Equation (5).

Model 8 provides a more explicit specification of those macro and housing market effects. Instead of entering the delisting year dummies, that model explicitly includes controls for time-varying macroeconomic and housing market indicators, including the Nikkei 225 index, average monthly household income and the Tokyo condominium price index. The latter condo price index is also interacted with indicators of the two subperiods of significant price declines. Results here conform to expectations. In that regard, upon inclusion of time-related fixed effects or the explicit macroeconomic variables, the transaction price dispersion in the corresponding submarket remains positively associated with property likelihood of sale.

Finally, Model 9 also includes interactions of the logarithm of transaction price dispersion with subperiods of significant price decline. Upon inclusion of the two interactive terms, the estimated coefficients associated with the two subperiods of price decline are negative, whereas the interactive term for the early period price decline indicator, before 1995, is positive. Results here suggest, as expected, that although the probability of sale was damped during the subperiods of condominium price decline, even in the context of the larger slowing in activity, higher probabilities of sale were evidenced in submarkets characterized by higher levels of price dispersion.

Conclusions

In the wake of the recent implosion in housing activity, substantial media and professional debate has focused on optimal seller pricing strategies. Although sellers often observe a range of transaction prices in the marketplace, there exists little theoretical analysis or empirical test of the role of house price dispersion in the determination of optimal seller pricing strategies. Such insights could prove useful to seller profit maximization and to allocative efficiency.

Existing static models on price dispersion at the aggregate level fail to explain sellers' behavior in markets with pronounced uncertainty. In the housing market, theoretical and empirical studies of the dynamic interaction between price dispersion and agents' selling strategy have become increasingly relevant in the wake of the substantial cyclical fluctuations of recent years. This study provides a first step in this promising research agenda.

We adopt a multistage search model, in which the seller's reservation price is determined by opportunity costs, search costs, the seller's discount rate and additional market parameters including the anticipated buyer offer arrival rate and buyer offer price distribution. The optimal asking price is chosen so as to maximize the return from search. Results of our derivations indicate that higher price dispersion leads to higher reservation and asking prices, which in turn result in a higher expected transaction price. Under the assumption that offer prices are normally distributed, transaction price dispersion also accelerates the timing of sale of overpriced properties.

We apply a unique dataset from the Tokyo condominium market for the 1992–2002 period to test model hypotheses. Empirical results indicate that offer price dispersion is an important determinant of both pricing strategy and pricing outcomes. A one percentage point increase in the dispersion of offer prices, as proxied by the standard deviation of housing transaction prices in the relevant submarket, results in two-tenths of a percent increase in both the initial list price and the final transaction price. Although overpriced properties tend to stay on the market longer, an increase in the dispersion of offer prices enhances the probability of a successful transaction and/or an accelerated sale. Moreover, less well-informed sellers are more likely to list their properties at significantly higher prices and to later reduce their offer price. Those properties stay on the market longer and sell at about a 3% discount relative to the properties of better informed sellers.

Earlier versions were presented at Tsinghua University, National University of Singapore, and University of Southern California Symposium on Real Estate Research, Beijing, China and the Annual Meetings of the American Real Estate and Urban Economics Association. A substantial part of this study was completed before Nishimura joined the Policy Board of the Bank of Japan. The authors are grateful to Yuming Fu, Charles Ka Yui Leung, an anonymous referee and the editor of this journal for helpful comments and suggestions. The authors dedicate this article to the memory of Dr. James Berkovec, our dear friend and most accomplished colleague.

References

Arnold, M.A. 1999. Search, Bargaining and Optimal Asking Prices. *Real Estate Economics* 27: 453–481.

Arnold, M.A. 2000. Costly Search, Capacity Constrains, and Bertrand Equilibrium Price Dispersion. *International Economic Review* 41: 117–131.

Belkin, J., D.J. Hempel and D.W. McLeavey. 1976. An Empirical Study of Time on Market Using Multidimensional Segmentation of Housing Markets. *AREUEA Journal* 4: 57–75.

Berger, L.A., P.R. Kleindorfer and H. Kunreuther. 1989. A Dynamic Model of the Transmission of Price Information in Auto Insurance Markets. *Journal of Risk and Insurance* 56: 17–33.

Berkovec, J. and S. Stern. 1991. Job Exit Behavior of Older Men. *Econometrica* 59: 189–210.

Borenstein, S. and N.L. Rose. 1994. Competition and Price Dispersion in the U.S. Airline Industry. *Journal of Political Economy* 102: 653–683

Braverman, A. 1980. Consumers Search and Alternative Market Equilibria. *Review of Economic Studies* 47: 487–502.

Burdett, K. and K.L. Judd. 1983. Equilibrium Price Dispersion. *Econometrica* 51: 955–969.

Butters, G.R. 1977. Equilibrium Distributions of Sales and Advertising Prices. *Review of Economic Studies* 44: 465–491.

Chade, H. and V. Vera de Serio. 2002. Pricing, Learning, and Strategic Behavior in a Single-Sale Model. *Economic Theory* 19: 333–353.

Chen, Y. and R.R. Rosenthal. 1996a. Asking Prices as Commitment Devices. *International Economic Review* 37: 129–155.

——. 1996b. On the Use of Ceiling-Price Commitments by Monopolists. *RAND Journal of Economics* 27: 207–220.

Chinloy, P.T. 1980. An Empirical Model of the Market for Resale Homes. *Journal of Urban Economics* 7: 279–292.

Cox, D.R. 1975. *Partial Likelihood. Biometrika* 62: 269–276.

Dahlby, B. and D.S. West. 1986. Price Dispersion in an Automobile Insurance Market. *Journal of Political Economy* 94: 418–438.

Dana, J.D. Jr. 1999. Equilibrium Price Dispersion under Demand Uncertainty: The Roles of Costly Capacity and Market Structure. *RAND Journal of Economics* 30: 632–660.

Deng, Y., A. Pavlov and L. Yang. 2005. Spatial Heterogeneity in Mortgage Terminations by Refinance, Sale and Default. *Real Estate Economics* 33: 739–764.

Deng, Y., D. Zheng and C. Ling. 2005. An Early Assessment of Residential Mortgage Performance in China. *Journal of Real Estate Finance and Economics* 31: 117–136

Deng, Y., J.M. Quigley and R. Van Order. 2000. Mortgage Terminations, Heterogeneity and the Exercise of Mortgage Options. *Econometrica* 68: 275–307.

Diamond, P. 1987. Consumer Differences and Prices in a Search Model. *Quarterly Journal of Economics* 102: 429–436.

Garbade, K.D. and W.L. Silber. 1976. Price Dispersion in the Government Securities Market. *Journal of Political Economy* 84: 721–740.

Genesove, D. and C.J. Mayer. 1997. Equity and Time to Sale in the Real Estate Market. *American Economic Review* 87: 255–269.

——. 2001. Loss Aversion and Seller Behavior: Evidence from the Housing Market. *Quarterly Journal of Economics* 116: 1233–1260.

Genesove, D. and L. Han. 2012. Search and Matching in the Housing Markets. *Journal of Urban Economics* 72: 31–45.

Glower, M., D.R. Haurin and P.H. Hendershott. 1988. Selling Time and Selling Price: The Impact of Seller Motivation. *Real Estate Economics* 26: 719–740.

Gronau, R. 1971. Information and Frictional Unemployment. *American Economic Review* 61: 290–301.

Green, J. and J.B. Shoven. 1986. The Effect of Interest Rates on Mortgage Prepayment. *Journal of Money, Credit and Banking* 36: 41–58.

Guasch, J.L. and R.C. Marshall. 1985. An Analysis of Vacancy Pattern in the Rental Housing Market. *Journal of Urban Economics* 17: 208–229.

Hamilton, J.L. 1987. Market Information and Price Dispersion: Unlisted Stocks and NASDAQ. *Journal of Economics and Business* 39: 67–80.

Harding, J.P., S.S. Rosenthal and C.F. Sirmans. 2003. Estimating Bargaining Power in the Market for Existing Homes. *Review of Economics and Statistics* 85: 178–188.

Haurin, D.R., J.L. Haurin, T. Nadauld and A. Sanders. 2010. List Prices, Sale Prices, and Marketing Time: An Application to U.S. Housing Markets. *Real Estate Economics* 38: 1–27.

Horowitz, J.L. 1992. The Role of the List Price in Housing Markets: Theory and an Econometric Model. *Journal of Applied Econometrics* 7: 115–129.

Hotelling, H. 1929. Stability in Competition. *Economic Journal* 39: 41–57.

Kluger, B.D. and N.G. Miller. 1990. Measuring Residential Real Estate Liquidity. *AREUEA Journal* 18: 145–159.

Lach, S. 2002. Existence and Persistence of Price Dispersion: An Empirical Analysis. *Review of Economics and Statistics* 84: 433–444.

Lazear, E.P. 1986. Retail Pricing and Clearance Sales. *American Economic Review* 76: 14–32.

Leung, C.K.Y., Y.C.F. Leong and S.K. Wong. 2006. Housing Price Dispersion: An Empirical Investigation. *Journal of Real Estate Finance and Economics* 32: 357–385.

MacMinn, R.D. 1980. Search and Market Equilibrium. *Journal of Political Economy* 80: 308–327.

Mathewson, G.F. 1983. Information, Search, and Price Variability of Individual Life Insurance Contracts. *Journal of Industrial Economics* 32: 131–148.

McCall, J.J. 1970. Economics of Information and Job Search. *Quarterly Journal of Economics* 84: 113–126.

Moen, E.R. 1997. Competitive Search Equilibrium. *Journal of Political Economy* 105: 385–411.

Mortensen, D.T. 1970. A Theory of Wages and Employment Dynamics. in *Microeconomic Foundations of Employment and Inflation Theory*, Phelps, E. S., A. A. Alchian, C. C. Holt, *et al.* (eds.), W.W. Norton: New York.

Nelson, P. 1970. Information and Consumer Behavior. *Journal of Political Economy* 78: 311–329.

Nishimura, K.G. 1995. Product Innovation with Mass-Production: Insufficient or Excessive? *Japan and the World Economy* 7: 419–442.

Perloff, J.M. and S.C. Salop. 1985. Equilibrium with Product Differentiation. *Review of Economic Studies* 52: 107–120.

Postel-Vinay, F. and J.-M. Robin. 2002. Equilibrium Wage Dispersion with Worker and Employer Heterogeneity. *Econometrica* 70: 2295–2350.

Pratt, J.W., D. Wise and R. Zeckhauser. 1979. Price Differences in Almost Competitive Markets. *Quarterly Journal of Economics* 93: 189–211.

Reinganum, J.F. 1979. A Simple Model of Equilibrium Price Dispersion. *Journal of Political Economy* 87: 851–858.

Reitman, D. 1991. Endogenous Quality Differentiation in Congested Markets. *Journal of Industrial Economics* 39: 621–647.

Salop, S. and J. Stigliz. 1977. Bargains and Ripoffs: A Model of Monopolistically Competitive Price Dispersion. *Review of Economic Studies* 44: 493–510.

Sass, T.R. 1988. A Note on Optimal Price Cutting Behavior under Demand Uncertainty. *Review of Economics and Statistics* 70: 336–339.

Schlesinger, H. and J. Schulenburg. 1991. Search Costs, Switching and Product Heterogeneity in an Insurance Market. *Journal of Risk and Insurance* 58: 109–119.

Schwartz, E.S. and W.N. Torous 1989. Prepayment and the Valuation of Mortgage-Backed Securities. *Journal of Finance* 44: 375–392.

Seog, S.H. 2002. Equilibrium Price Dispersion in the Insurance Market. *Journal of Risk and Insurance* 69: 517–536.

Shilony, Y. 1977. Mixed Pricing in Oligopoly. *Journal of Economic Theory* 14: 373–388.

Sorensen, A.T. 2000. Equilibrium Price Dispersion in Retail Markets for Prescription Drugs. *Journal of Political Economy* 108: 833–850.

Stigler, G.J. 1961. The Economics of Information. *Journal of Political Economy* 69: 213–225.

Stull, W.J. 1978. The Landlord's Dilemma: Asking Rent Strategies in a Heterogeneous Housing Market. *Journal of Urban Economics* 5: 101–115.

Taylor, C.R. 1999. Time-on-the-Market as a Sign of Quality. *Review of Economic Studies* 66: 555–578.

Varian, H.R. 1980. A Model of Sales. *The American Economic Review* 70: 651–659.

Wilde, L.L. and A. Schwartz. 1979. Equilibrium Comparison Shopping. *Review of Economic Studies* 46: 543–554.

Zuehlke, T.W. 1987. Duration Dependence in the Housing Market. *Review of Economics and Statistics* 69: 701–709.

Appendix A: Price Dispersion and the Optimal Pricing Strategy

We define price dispersion as the standard deviation of the offer price distribution (that is assumed to be distributed normally with mean μ and standard deviation σ), of which standard deviation in the properties' transaction prices in the corresponding real estate sub-market is used as being proxy in the empirical analysis of this article's third section.

Let us first look at $\frac{\partial G(p)}{\partial \sigma}$:

$$\begin{aligned}\frac{\partial G(p)}{\partial \sigma} &= \frac{\partial \left(\int_0^{P_a} p dF(p) + \int_{P_a}^{\infty} P_a dF(p) - \int_0^{P_r} (p - P_r) dF(p)\right)}{} \partial \sigma \\ &= (1-F(P_a))\frac{\partial P_a}{\partial \sigma} + F(P_r)\frac{\partial P_r}{\partial \sigma}.\end{aligned} \tag{A1}$$

According to formula (2), we have $\frac{\partial P_r}{\partial \sigma} = \frac{\partial e^{-\gamma/\lambda}}{\partial \sigma}(G(p) - C/\lambda) + e^{-\gamma/\lambda}\frac{\partial (G(p)-C/\lambda)}{\partial \sigma}$. Then, we insert the calculated $\frac{\partial G(p)}{\partial \sigma}$ into $\frac{\partial P_r}{\partial \sigma}$ and rearrange to obtain

$$\frac{\partial P_r}{\partial \sigma} = \frac{e^{-\gamma/\lambda}(1 - F(P_a))\frac{\partial P_a}{\partial \sigma} + e^{-\gamma/\lambda}\left[\frac{\gamma}{\lambda^2}(G(p) - C/\lambda) + C\right]\frac{\partial \lambda}{\partial \sigma}}{1 - e^{-\gamma/\lambda}F(P_r)} \tag{A2}$$

According to formula (3), we get $-f(P_a^*)\frac{\partial P_a^*}{\partial \sigma} = -\frac{\partial \lambda}{\partial P_a^*}[\frac{\partial \frac{C}{\lambda^2}}{\partial \sigma} + \frac{(\frac{C}{\lambda^2} + \frac{r}{\lambda^2}(G(p) - C/\lambda))}{\partial \sigma}]$.

Then, we insert the expression for $\frac{\partial G(p)}{\partial \sigma}$ and $\frac{\partial P_r}{\partial \sigma}$ and rearrange to obtain:

$$\frac{\partial P_a^*}{\partial \sigma} = \frac{\frac{\partial \lambda}{\partial P_a^*} \cdot \frac{\partial \lambda}{\partial \sigma} \cdot \frac{1}{\lambda^4}\left\{-2C\lambda - 2\gamma\lambda(G(P) - C/\lambda) + C\gamma + \frac{\gamma F(P_r)e^{-\gamma/\lambda}[\gamma(G(P) - C/\lambda) + C]}{1 - F(P_r)e^{-\gamma/\lambda}}\right\}}{\frac{f(P_a^*)\left(1 - e^{-\gamma/\lambda}F(P_r)\right) - \frac{\gamma}{\lambda^2}(1 - F(P_r))\frac{\partial \lambda}{\partial P_a^*}}{1 - e^{-\gamma/\lambda}F(P_r)}} \tag{A3}$$

The numerator is:

$$\frac{\partial \lambda}{\partial P_a^*} \cdot \frac{\partial \lambda}{\partial \sigma} \cdot \frac{1}{\lambda^4}\left\{-2C\lambda - 2\gamma\lambda(G(P) - C/\lambda) + C\gamma + \frac{\gamma F(P_r)e^{-\gamma/\lambda}[\gamma(G(P) - C/\lambda) + C]}{1 - F(P_r)e^{-\gamma/\lambda}}\right\} = \frac{\partial \lambda}{\partial P_a^*} \tag{A4}$$

$$\cdot \frac{\partial \lambda}{\partial \sigma} \cdot \frac{1}{\lambda^4}\left\{[\gamma(G(P) - C/\lambda) + C]\left(\frac{\gamma}{1 - B} - 2\lambda\right) - \gamma^2(G(P) - C/\lambda)\right\},$$

where $B = e^{-\gamma/\lambda}F(P_r)$. Note $\frac{\partial \lambda}{\partial P_a^*} < 0$, $\frac{\partial \lambda}{\partial \sigma} > 0$, and $(G(P) - C/\lambda) > 0$.

Further assume the discount rate between two expected offers is confined to $0.5 \le e^{-\gamma/\lambda} \le 1$. Then, on one hand, it is straightforward to show that if $\frac{\gamma/\lambda}{1-B} \le 2$,[27] so then the numerator is positive (> 0). On the other hand, the denominator is $\frac{f(P_a^*)(1-e^{-\gamma/\lambda}F(P_r)) - \frac{\gamma}{\lambda^2}(1-F(P_r))\frac{\partial \lambda}{\partial P_a^*}}{1-e^{-\gamma/\lambda}F(P_r)} > 0$. Accordingly, we get $\frac{\partial P_a^*}{\partial \sigma} > 0$. As to $\frac{\partial P_r}{\partial \sigma}$ expressed in Equation (4), note that $\frac{\partial P_a}{\partial \sigma} > 0$, $(G(P) - C/\lambda) > 0$ and $\frac{\partial \lambda}{\partial \sigma} > 0$, hence we obtain $\frac{\partial P_r}{\partial \sigma} > 0$.

[27] For function $f(x) = \frac{x}{1-e^{-x}F(p)}$, where $F(p)$ is a cumulative distribution function with $0 \le F(p) \le 1$. $\frac{\partial f(x)}{\partial x} = \frac{1-e^{-x}F(p)(1-x)}{\left(1-e^{-x}F(p)\right)^2} > 0$, if $e^{-x}F(p)(1-x) < 1$, which includes the range $0 < x < 1$. When we define $x = \gamma/\lambda$, then $e^{-x}$is the discount rate. The range in the discount rate $0.5 \le e^{-\gamma/\lambda} \le 1$ is equivalent to $0 \le x \le 0.693$. Hence the maximum value of $f(x)$is obtained with $x = 0.693$ at 1.386.

Thus, both reservation price and list price increase with price dispersion. Moreover, the expected return from searching, $G(P)$, will also be higher with greater price dispersion.

Expected Transaction Price and Time on the Market

Taking derivatives in terms of σ on both sides of Equation (4) yields:

$$\frac{\partial E(P_s)}{\partial \sigma} = \frac{f(P_r)}{[1-F(P_r)]^2}\left(\int_{P_r}^{P_a} pdF(p) + \int_{P_a}^{P_a} P_a dF(p) - \int_{P_r}^{\infty} P_r dF(p)\right) \times \frac{\partial P_r}{\partial \sigma} + \frac{1-F(P_a)}{1-F(P_r)}\frac{\partial P_a}{\partial \sigma}. \quad \text{(A5)}$$

As previously shown, a higher price dispersion results in a higher list price and a higher reservation price, or $\frac{\partial P_r}{\partial \sigma} > 0$ and $\frac{\partial P_a}{\partial \sigma} > 0$. We can in turn state that a higher price dispersion will consequently lead to higher transaction price as well, or $\frac{\partial E(P_s)}{\partial \sigma} > 0$.

Equation (5) expresses the expected time on the market. The reservation price, P_r, determines the probability of match for each offer. The higher reservation price leads to a longer expected time on the market as the result of the lower probability of a match, as shown in $\frac{\partial E(N)}{\partial P_r} = f(P_r)/[\lambda(1-F(P_r))^2] > 0$. On the other hand, when the offer arrival rate is a decreasing function in P_a, the higher list price results in longer time on the market because of the lower offer arrival rate as stated above, or $\frac{\partial E(N)}{\partial P_a} = -[1/(\lambda^2(1-F(P_r)))]\frac{\partial \lambda}{\partial P_a} > 0$.

Assume that the offer price follows a normal distribution $N(\mu, \sigma)$, then higher variance (σ^2) indicates fatter tail, or $\partial F(p)/\partial \sigma = -\frac{p-\mu}{\sigma^2}\varphi(z)\{ {}^{<0 \text{ if } P>\mu}_{>0 \text{ if } P<\mu}$, where $z = \frac{p-\mu}{\sigma^2}$. So the impact of price dispersion on the time on the market is,

$$\begin{aligned} \frac{\partial E(N)}{\partial \sigma} &= \left\{1/\left[\lambda\,(1-F(P_r))^2\right]\right\}[\partial F(P_r)/\partial \sigma] \\ &= -\frac{P_r-\mu}{\sigma^2}\varphi\,(z)\left\{1/\left[\lambda\,(1-F(P_r))^2\right]\right\} \\ &= \begin{cases} <0 & \text{if} \quad P_r > \mu \\ >0 & \text{if} \quad P_r < \mu \end{cases}. \end{aligned} \quad \text{(A6)}$$

Appendix B: Heckman Two-Stage Estimation of Condominium Market Value

Table B1 ■ Probit estimates.

Dependent variable: dummy variable of sale of unit.	Estimates and *t*-Statistics
Intercept	−0.41
	(12.17)
Average travel time to 40 most busiest stations	0.009
	(8.51)
Central business district	−0.13
	(9.24)
Size	−0.0016
	(7.34)
No. of months after construction at delist	0.0004
	(8.36)
Log likelihood	57,333