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SUPPLY DECISION OF EXISTING APARTMENT: CASE STUDY OF APARTMENT TRANSACTIONS IN GANGDONG DISTRICT, SEOUL, KOREA

Seongwon LEE, Seungwoo SHIN *, Yeonjae LEE

Department of Real Estate Studies, Konkuk University, Seoul, Korea

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Abstract. Despite its importance, homeowners' supply type decision has been under-researched due to data limitations. We construct a dataset of 4,037 apartment units in Gangdong district, Seoul, Korea over a 46-quarter period (2011Q1–2022Q2). We simultaneously analyse both the asset and space markets. The results show that the estimated probability and estimated volume of sale from supply type choice models are statistically significant in both the sales and rental price models. The key findings of our study are two. We find that the housing sales and rental markets interact and co-move together. We also demonstrate that the institution of the two-year lease contract period influences the transaction probabilities in both the sales and rental markets. For the supply type decision model, the estimated sale-transaction (rental-transaction) price significantly impacts the sale-transaction (rental-transaction) volume. However, no significant relationship was found between the estimated sale price and rental-transaction volume, nor between the estimated rental price and sale-transaction volume. The results of the forecast-performance comparison show that the integrated supply model_T/probability (calibrated) is the best for sales volume, whereas the two-year lagged value is the best for rental-volume estimation. This demonstrates institutional effects in the rental-housing market in Korea.

Keywords: existing apartment, apartment sales, lease, hedonic pricing model, panel multinomial logistic analysis, institutional effect.

* Corresponding author. E-mail: *ss244@konkuk.ac.kr*

1. Introduction

Much research on housing-transaction volume has explored its relationship with sales prices. The downpayment model (Stein, 1995) mainly analyses the effect of sale price on housing-transaction volume, while the search model (Berkovec & Goodman, 1996) analyses the effect of transaction volume on sale price. The loss-aversion model (Genesove & Mayer, 2001) partially explains the relationship between sales price and volume by suggesting that homeowners are reluctant to sell at lower prices. This study is theoretically grounded in existing research on the occurrence of home sales transactions and their price modeling. Nevertheless, there is a paucity of research examining home sales transactions and prices that considers the influence of the rental market. The principal contribution of this paper is to analyse both the home sales and rental markets simultaneously in a systemic fashion. The housing stock can be either self-occupied or rented. Therefore, in order to fully analyse the housing inventory market, both sales and rental activities need to be considered. This study provides a new framework to explain housing transactions (sales and rentals) and transaction prices (sales prices and rental rates). While previous studies have mainly focused on the sales market, this study offers a different perspective by also considering the rental market in a simultaneous manner.

Notably, in the context of constrained housing stock, this study emphasizes the potential for transitions between housing units intended for sale and rental markets, highlighting the inherent interconnectedness between these markets. Our findings are especially pertinent for urban areas pursuing apartment-centric housing supply policies. This is primarily because apartments, as a housing type, possess a standardized structural configuration that facilitates more straightforward quality assessment, thereby enabling more seamless transitions between sales and rental markets.

In analysing the relationship between the occurrence of transactions and resultant prices, our study attempts to build micro-level data to reflect owner and house characteristics and to integrate the sales and rental markets In particular, this study employs panel multinomial logistic analysis, which considers random effects and matched sales and lease contract data, to analyse the complex structure and dynamics of the housing market (sales and lease markets). This approach allows the authors to go beyond simple empirical analysis and contribute to understanding the underlying mechanisms of the housing market (sales and rental markets).

Housing is a typical durable goods that takes a long time to re-develop once it is newly supplied to the market. Therefore, the housing units traded in the market mostly comprise existing housing. In the case of apartments in Seoul, which includes Gangdong district, the subject area of this study, only 11.5% (approximately 210,000 units) are newly built and less than five years old, while 48.8% (approximately 890,000 units) are more than 20 years old. Individual homeowners decide to trade these existing housing units. The types of housing-supply decision that can occur for existing housing are sale, rental, and status quo. A sale contract transfers all rights to use, profit from, and dispose of the home through the transfer of ownership. Meanwhile, a lease contract transacts only the right to use the home for a period of time. The choice between these transaction types can be influenced by various factors, including the homeowner's individual circumstances, characteristics of the home, market conditions, and policy changes.

In addition to sale- and rental-transaction prices, transaction volume is an important measure of market liquidity and stability. In Korea, more than 80% of rental housing is provided by private individuals, with a significant proportion (56%, Supreme Court of Korea, 2021) being provided by Chonsei. Relatively standardised apartments (Condo in U.S. terminology) are the most common (64%) housing type in South Korea (Statistics Korea, 2022) and thus, for one apartment, it is a common practice to frequently switch between owner-occupied and rented housing. Apartments are defined by the Housing Act of Korea as buildings with five or more floors. Previous studies on housing-transaction (sale and rental) volumes have not simultaneously considered the dynamic relationship between the sales and rental markets. In our study, we consider both markets. Therefore, we use a strongly balanced panel analysis that combines sales and rental transactions on a unit-by-unit basis, while simultaneously performing pooled ordinary least squares (OLS) regression on transaction prices (sales and rental prices). The results of the analysis are used to predict future transaction volumes (sales and leases) at the town (and district) level (out-of-sample test).

Reconstruction and redevelopment are common urban development strategies around the world. Countries such as China (Li et al., 2019), Taiwan (Lan & Lee, 2020) and Australia (Huang et al., 2023) are taking different approaches to address the challenges of urban renewal or urban consolidation. A relocation measures for existing residents is essential for the implementation of such reconstruction or redevelopment (Popkin et al., 2021). A town in our study area, Dunchon, is currently undergoing the largest apartment re-development project in Korea (from 5,930 to 12,032 units). In 2017, when demolition and construction began, the area experienced a severe excess demand for rental units. Existing residents were forced to relocate, and they preferred neighbouring areas for work or school purposes. Changing schools is a source of extreme anxiety for children (Marlett, 1993). In addition, unlike the United States (USA), Seoul's apartment-rental supply is dominated by private individuals, with no large corporate landlords (Institutional multifamily investors in U.S. terminology). This makes predicting future supply (sale and rental) volumes much more difficult for planners. This study therefore provides important information for urban-regeneration policy planners and developers in older cities such as Seoul, where the re-development of old apartments is ongoing.

2. Theoretical analysis and research hypothesis

2.1. Literature

DiPasquale and Wheaton (1992) proposed a methodology for analysing the real-estate market based on the interrelationship between the space and asset markets, classifying the rental and asset markets, construction, and existing stock. According to the model, in the rental market, rents are determined by market variables and the total quantity supplied; in the asset market, rents and mortgage interest rates determine asset prices; in the construction quadrant, new construction occurs according to asset price and demand for space, which affects the total quantity of property stock in the fourth quadrant; and the total stock affects the rental market in the first quadrant. As shown in the DW four-quadrant model, the housing market is influenced by many different markets. Panel analysis that observes individual homes over a long period of time can better rigorously investigate how government policies and market changes have affected the housing market, and they can provide direction for future housing policy.

DiPasquale (1999) notes that in studying housing providers, very limited information is available on builders, investors, or homeowners, making analyses of the housing supply extremely difficult. According to DiPasquale's classification, housing-supply studies can be broadly divided into two categories: those on the new housing supply and those on the maintenance and repair choices for the existing housing stock. The latter category is mainly concerned with increasing the housing supply by improving the quality of housing through renovation (Potepan, 1989; Bogdon, 1992; Montgomery, 1992).

Figure 1 illustrates the supply type shift in the housing market.

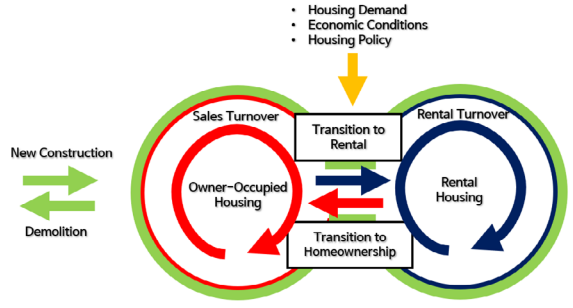

Figure 1. Supply type shift between owner-occupied and rental housing of existing homes

However, despite its critical role in the housing market, research on the dynamics of existing housing stock, particularly its interaction between sales and rental markets, has been relatively scarce due to data limitations. Our study addresses this gap by systematically analyzing existing housing stock's supply and transaction decisions within the context of sales and rental market integration.

If the housing market is divided into a for-sale and a rental market, there may be a change in stock between the two markets (for-sale and rental) even if there is no change in physical stock quantity. Furthermore, it is not uncommon for an apartment to be listed in both the for-sale and rental markets simultaneously in Korea. DiPasquale and Wheaton (1992) present the relationship between the two markets as a simple price relationship. However, it may be more complex, with adjustments causing lags (Colwell, 2002). Adjustments in the housing stock can occur as follows: when rental prices rise, the stock of owner-occupied housing shifts more frequently to rented housing, other things being equal. If the stock of owner-occupied housing falls, house prices rise as a result. Our study considers this and systematically analyses the occurrence and pricing of transactions in both the housing sales and rental markets. This underscores how our study addresses a significant empirical gap in the current literature.

Previous studies have indicated that housing transaction and price are interrelated (Rothenberg, 1991). The research questions include whether price affects transaction volume and whether transaction volume affects price. Stein (1995) examined the relationship between house price and transaction volume by focusing on the importance of the downpayment to purchase a house. The study found that changes in downpayment due to households' financial constraints could affect not only an individual's ability to purchase a home but also the price stability of the market and frequency of transactions. Stein (1995) found that when financial constraints were relaxed and individuals' investment power increased, house prices rose and housing-transaction volumes increased, i.e. the previous year's house-price changes had a defining effect on current transaction volumes. Miller and Sklarz (1986) argue similarly. However, Follain and Velz (1995) found a negative correlation. Clayton et al. (2010) analysed housing markets in 114 metropolitan statistical areas in the USA from 1990 to 2002. A panel vector autoregressive (VAR) model was constructed to analyse how house prices and transaction volumes co-moved against external shocks. The results showed that both house prices and transaction volumes were affected by the status of the labour market, housing finance market, and financial stock market, with house prices affecting transaction volumes. This effect was characterised by a decrease in transaction volume when prices fell, while the effect was different for rising prices, depending on the market-supply elasticity.

Meanwhile, price can also affect trading volume. Genesove and Mayer (2001) analyse sellers' loss aversion in the housing market of Boston, USA, in the 1990s. According to this study, if a price decrease causes sellers to lose money, they are reluctant to incur losses by trading their homes at a lower price. Therefore, the study found that volume decreased during price decreases due to sellers' loss aversion. Berkovec and Goodman (1996), based on the search model, found that transaction turnover positively impacted changes in housing demand. They argue that if a seller's willingness to sell is higher than the buyer's willingness to buy, the buyer will not buy and will continue to search. According to the search model, when transaction volume decreases, sellers may lower their expected price. As the number of listings on the market and the time it takes to sell increase, the probability of sellers' accepting a lower price increases, and finally prices decrease. In other words, their research shows that volume positively affects price. Based on Swedish housing-market data, Hort (2000) analysed house-price movements and transaction volumes from the late 1980s to the early 1990s. The study investigated how buyers' and sellers' price expectations responded to demand shocks under imperfect information. The study's exploratory model assumes that buyers react to demand shocks earlier than sellers, and therefore transaction volumes precede price changes. The study analysed monthly and quarterly panel data from the Swedish regional housing market using a VAR model. The results showed that transaction volumes tended to react faster than prices to changes in mortgage rates. de Wit et al. (2013) use a vector error correction model (VECM) to analyse the pathways through which mortgage-rate shocks affected prices and volumes.

Many studies suggest a correlation between price and volume. Shi et al. (2010) analysed the dynamics of house prices and transaction volumes in 12 New Zealand cities from 1994 to 2004 using a VECM with Granger causality tests. The study found that sales prices and transaction volumes were correlated, with the search model dominating in large cities, where causality from transaction volumes to prices was found in the long run, and the downpayment and loss aversion models dominating in small cities, where causality from prices to transaction volumes was found. Tsai (2019) analysed the dynamic causal relationship between price and transaction volume in the USA housing market using data from 1999 to 2015. The study used several models from prior research to interpret the relationship between price and volume, suggesting that price could be an informative market indicator when volume was stable.

In recent years as well, a number of papers have examined the relationship between the occurrence of transactions and transaction prices in both the sales and rental markets. Sagner and Voigtländer (2023) analysed the impact of a rent control policy in Germany and found that rents decreased, but the decrease in rental supply was more significant. They also analysed the spillover effect of rent control on the sales market, but found no effect on sales prices and the number of units sold, which may be due to the fact that homeowners expected the policy to be reversed and therefore adopted a wait-and-see attitude, rather than reacting to the policy immediately. The study

applies a DID method, so it does not take into account the transition of stock between for-sale and rental housing markets.

Wu et al. (2021) use a PVAR model to analyse house sales and rental prices in 26 tier 1 and tier 2 cities in China. Their study analyses the relationship between sales and rental prices before and after China's policy intervention to promote the rental market ("Notice on Accelerating the Development of the Rental Housing Market in Large and Medium Cities with a Net Inflow of Population"). Before the policy was implemented, sales prices and rental prices were relatively independent of each other, but after the policy was implemented, rental prices had a positive effect on sales prices. Although their study aims to analyse the dynamics of the sales and rental markets, it does not take into account the housing stock and has limitations in structurally explaining the relationship between the two markets due to the limitations of the reduced form model.

Although it is not a study of homeowner decision-making, Clark and Lomax (2020) analysed the ratio of rental to sale prices of housing by matching sales and rental data for the same dwelling in the United Kingdom. The study analysed how the rental/sales price ratio varied by the number of bedrooms, the length of time between sale and rental (less than 8 months), the economic conditions of the neighbourhood, and access to commercial areas. Their research also doesn't take into account housing stock. Considering these price-volume studies in the context of the relationship between the sales and rental markets (DiPasquale & Wheaton, 1992), it is possible that prices and transaction volume in the sales market and prices and transaction volume in the rental market influence each other. The first hypothesis of our study analyses these effects.

The supply of new homes can affect the existing housing market. Chau et al. (2003) found that the market for new homes sold under the pre-sale system was like a financial futures market for the existing housing market, and the presale price had the price-discovery function of the existing housing-market price. This study analysed the price relationship between existing and pre-sale housing through a repeated-sales model using market data for a 10-year period from 1991 to 2001. They found that the expected spot prices derived from futures-contract prices closely tracked the actual prices of existing housing. Ooi and Le (2012) analysed the interaction between the price of pre-sale units and the price of existing units in Singapore. The study used a VAR model to estimate the pre-sale- and existing housing- price functions, with the quantity of existing housing, interest rate, and income as variables in both functions. The results showed that the impact was stronger in the simultaneous case without a time lag than in the case with one.

Park (2013) analysed the interaction between pre-sales and existing apartment prices in Korea using a fixed-effects two-stage least squares (2SLS) model. The study divided the market into existing housing-dominated and pre-sale dominated markets, and into price-rising and price-stable periods. He found that the price elasticity of existing housing prices was less sensitive than that of pre-sale prices in all periods. His study indicates that very large existing housing markets are more influential than newly developed ones, and therefore, analysing existing housing markets is important for policy decisions.

Homeowners make decisions about their homes based on changes in the market during the holding period. Homeowners may choose to stay in their homes or sell them. While relatively little research has been conducted directly on these homeowner decisions, some studies provide ideas about owner choice. Genesove and Mayer (1994) find that homeowners with relatively high mortgages take longer to sell their homes. Using brokerage listing data for Boston, USA, from May 1990 to December 1992, a period of declining house prices following one of rapid house-price appreciation, they conducted a time-on-market analysis. They found that time on market was longer for those with less equity (or higher loan-to-value [LTV]). The study also found that these owners were more sensitive to changes in equity-to-collateral value changes.

Ferreira et al. (2010) use data from the American Housing Survey (AHS) to examine house prices and population migration. The AHS used in their study has been a regular household panel survey every two years since 1985. Ferreira et al. analysed the probability of resident mobility using a probit model and concluded that a lock-in effect could occur for several reasons. First, on the economic side, the use of fixed-rate mortgages and property taxes affected the probability of moving, with a $1,000 reduction in interest costs associated with a fixed-rate mortgage reducing the probability of moving by approximately 1.4%, and a $1,000 higher property-tax benefit associated with long-term residence reducing the probability of moving by 1%. In addition to economic factors, the study also found that the probability of moving varied with "years in the same house and residents' age". In the case of holding period, the probability of moving increases up to nine years, whereafter it decreases, creating a lock-in effect, and in the case of age, the probability of moving decreases until age 53, whereafter it increases.

Waltl and Lepinteur (2023) analysed the psychological impact of housing supply. They tracked homeowners' sentiment and constructed a subjective price index using a hedonic model and repeated observations of house prices. The study found that several homeowner biases affected the housing market: the endowment effect, anchoring, and loss aversion. Endowment bias refers to homeowners' tendency to overestimate the value of their home, while anchoring bias refers to their tendency to anchor to a certain price and judge the rise or fall of home prices based on that anchor price. Finally, loss aversion is the tendency to demand a higher price after a price drop.

Meanwhile, homeowners may choose to purchase their homes and rent them out. Miceli and Sirmans (1999) argue that homeowners choose tenants based on the risk of vacancy and costs associated with replacing tenants, and it is therefore in a landlord's interest to rent to long-

term tenants who can minimise these costs. Clauretie and Wolverton (2006) used data on 55,202 home sales in Nevada, USA, from 2001 to 2004 to examine homeowners' decision to leave their homes vacant or rent them out before listing. They used the sale price as the dependent variable and rental status, owner-occupancy, and time on market as the main research variables. In addition, the square footage, number of bathrooms, parking space, fireplace, and swimming pool were used as control variables and analysed by regression for each year. Their findings showed that homes that were rented had a lower sale price and took approximately 66 days longer to sell than those that were not rented. According to their findings, renters are generally less likely to maintain their homes, which can lead to agency problems. Renters may also be reluctant to show their homes to new buyers as they may be concerned about moving and incurring moving costs if the home is traded. Their findings suggest that if one wants to sell their home, it is not an optimal decision to sell it while it is rented.

Houses that are currently rented have lower sales prices and longer listing periods (Clauretie & Wolverton, 2006). Landlords seek to minimise vacancy risk and tenant replacement costs (Miceli & Sirmans, 1999) and may prefer holding (Waltl & Lepinteur, 2023), meaning that rental status may affect the likelihood of a transaction. In addition, mortgage interest rates (Ferreira et al., 2010) and size of current loan balance (Genesove & Mayer, 1994) may also affect the probability of selling a house. In other words, institutional and contractual structures can affect the likelihood of transactions in the housing market, and our second research hypothesis analyses these effects.

Other studies provide the theoretical basis for determining the house-pricing model. Loewenstein and Willen (2023) did not analyse the occurrence of transactions but decomposed the variation of transaction prices into several components; in particular, they examined the variation of house prices by considering rents. To explain the causes of house-price fluctuations, they classified the causes into several categories and analysed them using micro data at the household level. They found that house-price fluctuations could be caused by interest rate, preference, house price expectation, supply, and redistribution shocks, each of which had a different degree of impact on the decomposed price; these shocks interacted in a complex manner. To analyse this, the authors decomposed the sale price of owner-occupied housing into the ratio of the price of owner-occupied housing to the price of renter-occupied housing, the ratio of the price of renter-occupied housing to the price of owner-occupied housing, and the rent. This is similar to the data in our study in that the rental and sale prices of units are matched for each individual apartment unit. However, their study considered that the impact of transitions between owner-occupied and renter-occupied housing in the existing housing market was likely to be limited. Therefore, they analysed owner-occupied and renter-occupied housing separately. Their rationale for this separation was as follows. Following the USA housing market boom in the early 2000s, there were few buy-to-rent investors until 2012, and these were small investors who were not expected to significantly impact prices. Buy-to-rent investments are largely auction acquisitions, which are excluded from the data because auction prices are formed differently from open market sale prices. In contrast to Loewenstein and Willen (2023), we expect the impact on sales and rental prices to be significant as supply type changes occur, and we attempt to capture some of the price effects of changes in the supply type of existing housing in our pricing model. In Korea, existing owner-occupied housing units are shifted into rental-housing units through rental transactions, which means that an impact of the transition between owner-occupied and renter-occupied housing units in the existing housing market can be expected, and the occurrence of sales and rental transactions can affect sales and rental prices.

In the housing market, house prices are affected by expectations of potential redevelopment. Lee et al. (2005) conducted an empirical analysis in the Korean housing market using a hedonic price model to investigate these expected redevelopment profit effects. Their study found a non-linear effect of redevelopment expectations on housing prices, showing that prices tend to rise over time when redevelopment expectations emerge after a certain period (e.g., 30 years old). Clapp and Salavei (2010) conducted a similar study in Greenwich, Connecticut. They introduced a hedonic pricing model incorporating redevelopment options to assess the effects of depreciation on property values. Their results suggest that the standard hedonic model may underestimate the depreciation of newer properties and overestimate it for older ones if redevelopment potential is not taken into account. The study highlights that the value of the redevelopment option increases with the age of the building, showing that properties with higher redevelopment potential retain their value better over time than those with lower potential.

A study by Loewenstein and Willen (2023) suggests that institutions and contractual structures of housing markets may have different effects in the sale and rental markets. In the rental market, institutions and contractual structures are likely to play a more dominant role, whereas in the sales market other factors such as development option may play a more critical role. Our third research hypothesis considers institutional aspects in the market.

Another research strand suggests that a shortage of new housing supply affects housing transactions. Myers et al. (2023) integrate USA AHS data with housing-supply data to show that a shortage of housing supply in the USA limits mobility opportunities for those seeking affordable housing, reduces the liquidity of the housing market, and ultimately reduces residential mobility. Their study uses city-level data and performs regressions that consider factors such as housing supply, employment growth, and housing prices. One study examines flipping, which considers housing supply from a different perspective. Frequently buying and reselling properties for very short-term profit can be seen as speculation, called flipping (LaCour-Little

& Yang, 2023). By analysing the frequencies of housing transactions in a certain period, buyers' demand can be identified for housing consumption or housing investment in the housing market (Depken et al., 2009). To the best of our knowledge, ours is an early study that investigates both housing rental and sale markets in an integrated manner and practically estimates future sub-market housing-transaction volumes.

2.2. Research hypothesis

Research Hypothesis 1: The transaction outcomes (volume and price) in the sales market affect volume and price in the rental market. Since the existing housing stock is fixed in the short run, an increase in the supply of sales may result in a decrease in the supply of rentals. We show that the probability of a supply type decision (sale or lease), or the proportion of units available for either sale or lease at the town level, derived from our model of the supply type decision, will affect not only the sale price but also the rental price. This is because, unlike in Loewenstein and Willen (2023), who separate owner-occupied and renter-occupied housing in their analysis of the USA market, there is a strong transition between owner-occupied and renter-occupied housing in Korea.

Research Hypothesis 2: We expect that the term structure of these lease contracts will affect the transaction probabilities in both the sales and lease markets. The rental markets in South Korea have two-year contract terms to protect the renters. In Korea's housing market, lease contracts are signed on a two-year basis. We expect that the term structure of these lease contracts will affect the transaction probabilities in both the sales and lease markets. According to Clauretie and Wolverton (2006), selling a home while it is still under lease is not in the seller's best interest; therefore, if sellers are rational, the probability of a transaction during the lease period should be low, and the arrival of the maturity day of a two-year lease term can be expected to significantly increase the probability of a transaction in either the sale or the lease. These regimes also have implications for forecasting future sales volumes, and investors, developers, and policy makers tend to rely on the quantity of past lease agreements to forecast future market liquidity.

Research Hypothesis 3: We expect the predictive power of the model to be different in the sales and rental markets. In the case of the leasing market, predictions that consider only the institutional effect will have a higher predictive power than our model, whereas in the case of the sales market, the predictive power of our model will be superior to predictions that consider only the institutional effect. This is because in the case of rentals, past transaction history may be more predictive due to the contractual structure of the two years of lease terms, whereas in the case of sales there is no such institutional constraint. If there is a fixed pattern or momentum, any sophisticated modelling will have no or little effect. The current best practice of using transaction volumes from the same quarter of the previous year or the same quarter of two years previously as a predictor of future transaction volumes will have less predictive power than in our study, which uses sophisticated models.

3. Research design

3.1. Empirical models

The empirical models used in this study are the supply type and transaction price determination models. The supply-type determination model analyses the decision process for supply types (sale, lease or no transaction) based on owner characteristics. The supply type determination model includes a model that does not include transaction price information (named as supply model_T-1) and one that includes transaction price information of the previous quarter (T-1) as an independent variable (named as integrated supply model_T). Integrated supply model incorporates sales and rental prices from previous quarter to predict current quarter's supply type decisions, mitigating potential endogeneity issues by using lagged price variables. The reason for the lag in our integrated supply model is that homeowners' price discovery and their subsequent transaction choice (selling, renting or no transaction) cannot be modelled simultaneously due to endogeneity issues. Matching times introduces the problem of endogeneity (simultaneous causality), where the dependent variable (supply type decisions) and the independent variable (price) are determined at the same time. Transaction-price models include the sales-price model_T-1 and rental-price model_T-1, depending on the type of transaction, as well as information on the determination of the type of supply at the same time (T-1). This is consistent with the search model's rationale that the volume of housing transactions can affect prices. The results obtained by Hort (2000), Leung et al. (2002), Shi et al. (2010), and Tsai and Peng (2016) show that the transaction volume of a house can affect its price. Since supply type and supply price are simultaneously determined, transaction-price models that include information on supply type will suffer from endogeneity problems. However, in this study, the integrated supply model_T is the main model, and from the perspective of the main model, the transaction-price model is a degenerate that utilises information on the previous quarter; thus, the potential problem might be negligible. However, there may be a multicollinearity problem because a significant amount of information about apartments does not change considerably over time. Therefore, the supply type decision model mainly uses information about the owner, and the transaction-price model mainly uses information about the properties of the apartment as inputs. It is reasonable in a sense that what interests buyers and renters is not owners' characteristics but the apartment itself.

Transaction-price models are divided according to whether the input supply type information is probability (probability of sale or lease) or town-level volume information: sales-price model_T-1/probability; sales-price

Table 1. Model classification

Model	Dependent variable	Time	Input variable	Unit of measurement
Supply model_T-1	Supply type	T-1		
Sales price model_T-1/probability	Sales price	T-1	Probability of each supply type	Individual apartment
Sales price model_T-1/volume	Sales price	T-1	Relative transaction volume	Town
Rental price model_T-1/probability	Rental	T-1	Probability of each supply type	Individual apartment
Rental price model_T-1/volume	Rental	T-1	Relative transaction volume	Town
Integrated supply model_T/probability	Supply type	T	Sales price model_T-1/probability and Rental price model_T-1/probability	Individual apartment
Integrated supply model_T/volume	Supply type	T	Sales price model_T-1/volume and Rental price model_T-1/volume	Town

Note: The time frame of "T-1" means that the analysis uses values from Q1 2011 to Q2 2021. "T" means that the analysis uses values from Q2 2011 to Q3 2021.

model_T-1/volume; rental-price model_T-1/probability; and rental-price model_T-1/volume. The integrated supply model_T is also classified into the integrated supply model_T/probability and integrated supply model_T/volume depending on the transaction-price model used as inputs. This is based on the downpayment model. Stein (1995), Zhou (1997), and Clayton et al. (2010) have shown that the price of a house can affect housing transactions. The integrated supply model_T analyses not only the sale price but also the rental price. Korea has two distinct rental systems; Chosei and typical monthly rent. We use Chonsei deposit (initial one-time lumpsum payment and no rent, dominant in Korean rental market) as rental price. Government agency (Real Estate Board) provides both formula and data for the conversion. The same house can be traded in both the sale and rental markets, and in a market with such a supply type shift, it is necessary to simultaneously analyse the two. A tabular representation of these models is shown below in Table 1. The input variables in Table 1. show the main variables that were used in addition to the owner characteristics for the supply model and the property characteristics for the price model respectively. These variables are derived from the results of either supply model_T-1 or price model_T-1.

3.1.1. Supply models

The supply model_T-1 and integrated supply model_T in our study are panel multinomial logistic models with random effects. The dependent variable is 1 for no transaction, 2 for the occurrence of a sale transaction, and 3 for the occurrence of a lease transaction. The panel multinomial logistic models must satisfy the independent and irrelevant alternatives (IIA) assumption. This assumes that all choices are independent of each other, which is usually difficult to satisfy in the social sciences. Therefore, in our study, we relaxed this assumption and conducted a panel multinomial logit model to account for random effects (Rabe-Hesketh & Skrondal, 2012).

There are three choices available to a homeowner at time t in each quarter. The homeowner can choose to stay at home (j = 1) doing nothing, which may be a strategic choice due to loss aversion (Waltl & Lepinteur, 2023) and increasing search costs (Clauretie & Wolverton, 2006). The owner of the house can also choose to sell the house (j = 2) or rent it out (j = 3).

Given homeowner i's choice to supply (or not supply) housing in the form of j at time t, the indirect utility function, V_{ijt}, is given by Equation (1) below. Each quarter, the homeowner chooses the alternative with the highest utility. a_j is a constant term for each choice type of the housing unit, and W_{ij} is the vector of observed socio-economic characteristics of homeowner i, given the choice of choice type j. β_j is the vector of the estimated coefficients of this vector of socio-economic characteristics, and ε_{ijt} is an error term that assumes a first-order extreme-value distribution. Finally, u_{ij} is a term that accounts for individual homeowners' heterogeneous characteristics that are not observed in the data. According to Hausman and Taylor (1981), panel data may be subject to heterogeneous individual effects that are unobserved in the data.

The probability that homeowner i supplies housing in the form of j at time t can be represented by Equation (2). This should be based on the IIA assumption, where individual homeowners' heterogeneous characteristics not observed in the data are treated as fixed effects. Moreover, if we assume that homeowner heterogeneity, u_{ij}, does not exist, the model becomes a generalised multinomial logistic model. The generalized multinomial logistic model assumes that homeowners' choices and the alternatives chosen over time are independent. However, in the real world, homeowners often make choices over time that are the same as their previous choices.

Assuming u_{ij} as a multivariate normal distribution with random effects and correlation between the random-effects terms, the covariance between the random-effects terms of supply types j and k can be estimated (cov_{jk}), and the estimation will be performed under a relaxed IIA assumption. That is, the choice probabilities of the repeated choices made by homeowner i share the unobserved heterogeneous characteristics of the individual subject, u_{ij}.

Consider the base housing-supply type as no transaction (j = 1); u_{i1} and coefficient vector β_j are normalised to zero. The distribution of the random-effect term is given by Equation (3) (Rabe-Hesketh & Skrondal, 2012).

$$V_{ijt} = \alpha_j + u_{ij} + W_{it}\beta_j + \varepsilon_{ijt}; \quad (1)$$

$$P_{ijt} = \frac{\exp\left(\alpha_j + u_{ij} + W_{it}\beta_j\right)}{\sum_{k=1}^{3}\exp\left(\alpha_k + u_{ik} + W_{it}\beta_k\right)}; \quad (2)$$

$$\begin{bmatrix} u_{i2} \\ u_{i3} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_2^2 & cov_{23} \\ cov_{32} & \sigma_3^2 \end{bmatrix}\right). \quad (3)$$

Hausman and McFadden (1984) presented the Hausman test for testing the IIA assumption. In our study, we tested the IIA assumption using the suest-based Hausman test, which is an improvement on the traditional Hausman test. As is common in the social sciences, the results show that the alternatives are not independent of each other. Therefore, we relax the IIA assumption by using a panel multinomial logit model with random effects, as proposed by Rabe-Hesketh and Skrondal (2012).

Table 2. Suest-based test for IIA

Excluded transaction type	Chi^2	d.f.	*P*-value
No transaction	79.183	30	0.00
Sales transaction	55.823	30	0.00
Lease transaction	88.669	30	0.00

Table 2 shows the results of the tests. The test statistic for whether the estimate with no transaction choice is the same as that with transaction choice is 79.183, which rejects the null hypothesis at the 1% significance level, i.e. the odds between sales and leases are not independent of no transaction. The test for independence with sales and lease transactions excluded is also rejected at the 1% significance level, with statistics of 55.823 and 88.669, respectively.

The input variables considered in the supply type model are owners' characteristics. The variables are as follows: holding period and its square term; owner's age and its square term; current mortgage balance; owner's address (dummy); number of owners (dummy); owner's legal status (dummy); and time dummy. In the integrated supply model_T, we add the estimated sale and rental prices and their respective squared terms. The sale and lease prices are estimated using the pricing model (T-1).

3.1.2. Price models

On average, the number of sales and lease transactions are 1.4 sales and 2.2 rentals per quarter over a 46-quarter period. This means that, on average, there were 1.4 sales transactions and 2.2 rental transactions in each quarter during the study period; thus, we use pooled OLS rather than panel analysis and include time dummies. The most independent variables in the pricing model are house characteristics. They include the floor level, number of rooms, number of bathrooms, interior area, total number of units of an apartment complex, age of a complex and its square term, number of car parking spaces per unit, and proportion of newly developed apartment units at the town level.

Town sub-market level relative transaction (sale and lease) volume, referred to as the ratio of sales volume or ratio of lease volume (at town scale), is estimated as a transaction occurrence when the probability of sale and lease estimated in the supply model_T-1 exceeds a certain cut-off value, and the number of expected transactional housing units is summed by town, which is then divided by the sample number of apartments in each town. Thus, the proportion of tradable housing units per quarter and per town was calculated and entered as an input.

In this case, the cut-off value that divides the transaction into transaction or not was calculated using Youden's J. The Youden's J value represents the classification performance at a certain threshold point as a single value; thus, the classification performance can be compared for different cut-off values. In our study, the cut-off value that maximises Youden's J was calculated to classify the calculated probability values into no transaction, sale transaction, and rental transaction. We also included the proportion of newly developed housing units in Gangdong district as an input, which was calculated for each quarter and town and entered as a ratio. The price models were analysed by dividing them into sale-price and rental-price models, with 2,703 sales and 3,684 rentals for 46 quarters and for 4,037 units.

3.2. Data and variables

Gangdong District is one of 25 districts on the southeastern side of Seoul, the capital city of South Korea (Figure 2). It occupied an area of 25 km^2 with a population of 464,037 (18,871 people/km^2) as of 2022. In terms of population, it is similar to the City of Miami in the U.S. and larger than the population of Ljubljana, the capital of Slovenia in Eastern Europe (272,000 as of 2023). This district comprises nine towns. Gangdong became South Korea's first district with a population of more than 1 million in 1987 and was subsequently divided. Located at the eastern end of Seoul, it is an area that has been able to experiment with the impact of large-scale apartment developments (tens of thousands of units), increased demand for migration to surrounding areas and increased supply with new residents in the new cities of neighbouring Gyeonggi province (the cities of Hanam, Guri, and Namyangju). In addition, 65% of Gangdong district's housing units are apartments (Statistics Korea, 2022), making it a suitable study site with moderate apartment prices and sufficient transaction volume among Seoul's 25 districts.

This study seeks to understand homeowners' supply type choices by compiling more than 10 years of housing-market data for an apartment, from 2011 to 2022, on a quarterly basis. In South Korea, the property-registration

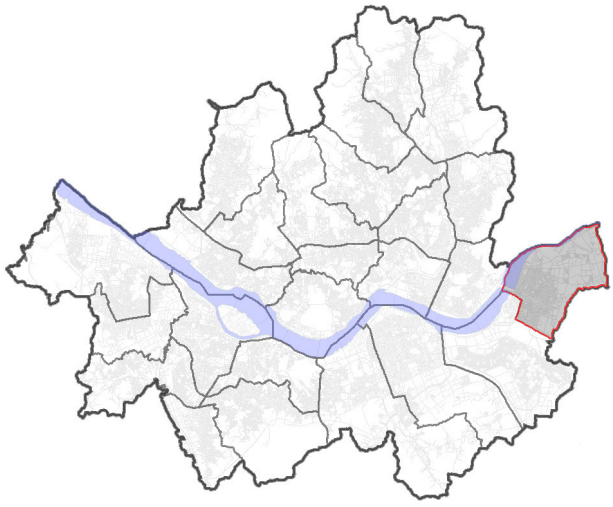

Figure 2. Research area: Gangdong district in Seoul Korea; the blue line in the middle is a Han river

book contains information on ownership changes and the name, age, and address of the owner. Mortgage information is also recorded therein. Lease-transaction information is publicly available through the government (Ministry of Land, Infrastructure, Transport, and Tourism); however, as of 2023, information on apartment buildings and suite numbers is not publicly available for privacy-protection reasons. We matched the publicly available transaction information with the property-registration book and public announcement of apartment-price information to identify an apartment. Finally, we identified 4,037 units of 314 complexes, 4.2% of all apartments in Gangdong. For all of these identified cases, we could build a historical transaction history for individual units by merging property-registration book and lease-transaction information. The combined data included information about the homeowner, including the homeowner's age, address, and holding period, as well as any mortgages on the home. In addition, the data contained information about the house, including the age of the house, interior area, floor level, number of rooms, and total number of units in the complex. Ironically, personal information (age, gender, address, and mortgage loan amount) on the identified apartment owners is not protected.

Because the transaction-price data for apartment sales in Korea have been collected and published since January 2007, and the transaction-price data for apartment leases have been collected and published since January 2011, the observation period is set from January 2011 to June 2022 (46 quarters), when both data are available. Since the supply type decision model recognises the status quo as a decision, the research data in the supply model have the form of a strongly balanced panel differing from those in the pricing models. We modelled the data according to the following assumptions: If a sale and a rental transaction occurred together in the same quarter (281 buy-to-rent cases), we assumed that the sale transaction occurred first

Table 3. Descriptive statistics for owner's supply decision

Transaction types	Number of cases	Proportion (%)
No transaction	179,315	96.56
Sales transaction	2,703	1.46
Lease transaction	3,684	1.98
Total	185,702 (4,037 unit * 46 Qtrs.)	100.00

in the quarter immediately preceding the rental transaction. Thus, the 185,702 (4,037 units * 46 quarters) data points comprise 2,703 sale transactions, 3,684 rental transactions, and 179,596 status quo, as shown in Table 3. Sale transactions occurred in only 1,959 apartments (1.35 transactions/apartment&46 quarters) and rental transactions occurred in even fewer apartments (1,566) (2.17 transactions/apartment&46 quarters). Among them, 1,473 units (36.48%) that did not have any transactions, while 584 units (14.46%) only had lease transaction.

Appendix Figure A1 shows an example of how the study data are organised. A total of 4,037 houses in the study have house id numbers, and each house has 46 quarters of transaction information from Q1 2011 to Q2 2022. Therefore, the total number of observations in this dataset is 185,702. Tables 4 and 5 summarise the descriptive statistics of housing characteristics and other variables for 4,037 units in the 314 apartment complexes in our study. The average interior area is 85.297 m^2, the average number of storeys is 6.278, and the average age of a complex (thus a unit) is 18.76 years. We categorised the houses into three sizes: small houses as 83 m^2 or less, medium houses as 83 m^2 to 150 m^2, and large houses as more than 150 m^2.

The ratio between Chonsei deposit and sales price (constant prices at 2020) is roughly 73% and average contracted mortgage LTV is 26.5%, assuming a unit with average interior area as shown in Table 4. 51% of units does not have any debt as of 2022. Homeowner characteristics were collected regarding the age of the principal owner, "geun mortgage" (120% of contracted mortgage amount by following Korean practice), number of owners, legal-person status, and address. The average holding period is 32.46 quarters, with a standard deviation of 21.29, and thus flipping behaviour is not confirmed. The average age of the principal owner is 54 years. The average "geun mortgage" amount is KRW133.76 million. Only 1.79% of the units in the study are owned by corporations, with most being owned by individuals. In addition, 84.33% of the units were owned by a single person, while 14.92% were owned by two people, and only 0.75% were owned by three or more people. The most common address of the owner was in Gangdong district (74.28% of the total), followed by 8.89% in neighbouring areas and 16.83% in other areas. In cases in which the homeowner is not an individual (such as a corporation), the address and age of the owner were calculated based on the location of the corporation and date of establishment, respectively.

Table 4. Descriptive statistics of the research variables (continuous variables)

Variable	Unit	Obs.	Avg.	Std.	Min.	Max.
Sales price	1,000 USD[§]/3.3 m^2	185,702	18.52	5.93	11.11	46.69
Rent price (Chonsei deposit)	1,000 USD[§]/3.3 m^2	185,702	13.59	3.43	5.51	27.05
Current geun mortgage balance	1,000 USD[§]/unit	185,702	148.70	340.20	0	9,662[§§]
Interior area	m^2	4,037	85.297	28.822	22.14	295.17
Floor level	level	4,037	6.278	3.966	1.00	26.00
Number of rooms	counts	4,037	3.064	0.598	1.00	6.00
Number of bathrooms	counts	4,037	1.805	0.432	1.00	3.00
Age of building	years	314	19.280	3.084	13.00	35.00
Total number of units of a complex	counts	314	71.048	129.972	6.00	987.00
Parking lot per household	counts	314	1.270	0.465	0.263	4.368
Holding period	quarters	185,702	32.46	21.29	0	138
Age of household head	age	185,702	54.17	13.10	0	101
Sales turnover rate (Town)	%	185,702	1.459	0.872	0	15
Lease turnover rate (Town)	%	185,702	1.984	1.00	0	16

Note: § The exchange rate is 1,000 KRW/USD. §§ It is a cross collateralized mortgage, one big mortgage amount with jointly collateralized multiple units.

Table 5. Descriptive statistics of the owners' characteristics (categorical variables)

Variable	Total obs.	Categories	Obs.	Proportion
Legal person	185,702	Individual	182,377	98.21
		Corporation, etc.	3,325	1.79
Number of owners	185,702	Single	156,603	84.33
		Two persons	27,705	14.92
		Three or more	1,394	0.75
Owner's address	185,702	Gangdong district	137,935	74.28
		Bordering region	16,517	8.89
		Other region	31,250	16.83

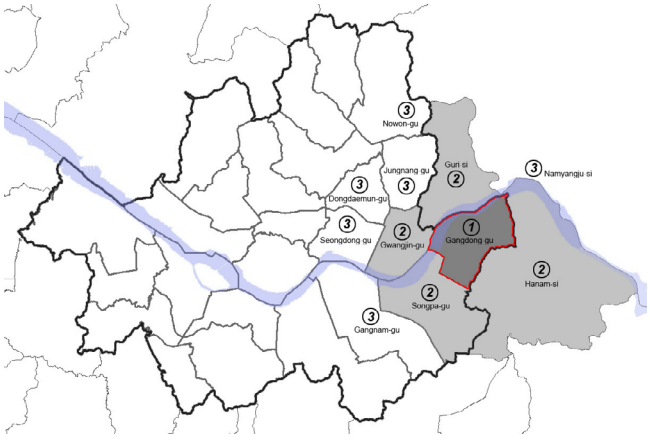

Figure 3. Neighbourhood classification; ③ are illustrative and include all other regions

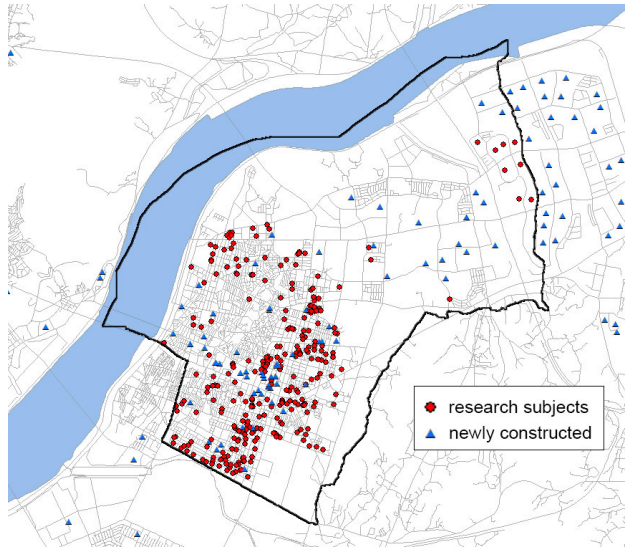

Figure 4. Distribution of the apartment complexes (red dot) and new developments (blue triangle); Gangdong district is inside solid line under Han river in blue

The owner's address was classified as follows: If it was located in Gangdong district, it was operationally coded as 1 to reduce number of dummies. Gwangjin district, Songpa district in Seoul and the cities of Guri, Namyangju, and Hanam in Gyeonggi-province, which border Gangdong district, were coded as 2. The remaining addresses were coded as 3 (other region). Figure 3 shows the map of Gangdong district and its neighbourhoods.

Figure 4 shows the geographical distribution of the apartment complexes in Sungrae town (37.9%), while only one complex is in Sangil town. In addition, we consider the volume of newly entered units to identify their impact. During the research period, 33,240 new units (65 complexes) were introduced. The towns of Godeok and Sangil had the highest number of new units (10,515 and 11,215, respectively), while those of Dunchon and Amsa had the lowest number of new units (less than 1,000).

The rental market in South Korea is regulated by the Lease Protection Act. The Act stipulates a minimum lease term of two years for tenants (Article 4) and allows a right to renew the contract up to four years (Article 6.3). However, generally, both the owner and the renter tend to rely on a lease relationship through a two-year lease-transaction agreement. For these legal and institutional reasons, the Korean housing market is characterised by a two-year cycle of sales and leases. Therefore, in our study, we hypothesise that a new sale or lease transaction is more likely to occur at the end of the two-year lease period. Accordingly, we create a "lease + 2 years" dummy variable and include it in both supply type models. The lease + 2 years dummy was coded as one if it was eight quarters (two years) after the initial lease and zero otherwise.

4. Empirical results and discussions

4.1. Empirical results

4.1.1. Supply model_T-1

Table 6 shows the estimation results of the supply model_T-1 using a panel multinomial logit analysis with random effects. The estimation was performed using xtmlogit in STATA 17, with standard errors clustered by apartment complex. The random-effects term is significant at the 1% level, with *t*-values of 3.00 and 8.69 for the estimated coefficients of σ_1^2 and σ_2^2, respectively, and the estimated coefficient of cov_{12} is also statistically significant at 1%, with a *t*-value of 5.51. This suggests that households' unobserved heterogeneous characteristics affect the choice of sale- and lease-supply types, respectively, which are common to both choices and are correlated with each other.

The estimation results show that both the term and squared value of the holding period show statistically significant effect for the probabilities of sale and lease choices, but in opposite directions. In the case of a sale, the longer the holding period, the higher the probability of choosing a sale transaction. These results may reflect the intentions of homeowners based on the purpose of ownership. It reflects the fact that some houses are purchased for investment purposes and are more likely to be rented initially, while others are purchased to live and are less likely to be sold in the short-term. However, the squared term of the holding-period variable is opposite, indicating that the probability of choosing a sale transaction (lease transaction) decreases (increases) beyond a certain critical holding period. Indicating that the probability of choosing a sale (lease) transaction decreases (increases) again above a certain critical value (Non-linear effect).

Owner age is statistically significant in both the term and its squared value for the sale choice, again non-linear effect. As the age of the household head increases, the probability of choosing a sale transaction decreases and then increases again above a certain critical age, which is consistent with the lock-in effect found in Ferreira et al. (2010) for sale transactions, where the probability of a sale decreases continuously with age and then increases again above a certain age. Meanwhile, for renting, the household-head age variable was not statistically significant.

For the current mortgage balance, there was no statistical significance for sale choice but a negative correlation for lease choice, indicating that the lower the current mortgage balance, the higher the probability of a lease choice, which is statistically significant at the 1% significance level. The renters should not prefer a house with higher LTV. The owner's address is statistically significant at the 1% level for both sale and lease choices, increasing the probability of a transaction if the owner lives in a nearby area or other region rather than Gangdong. The probability of leasing is approximately 1.851 times higher for owners living in a nearby area and 2.296 times higher for those living in other regions.

The number of owners was not statistically significantly negative for the sale choice. In the case of the rental choice, the probability of renting was statistically significant at the 1% level when the number of owners was two rather than one. This can be interpreted as a decrease in the probability of choosing a lease when there are two owners (e.g. married couple). The owner's legal-person status was not statistically significant.

The lease + 2 years dummies, which is used to analyse the possible two-year transaction cycle in the Korean housing market, have coefficients of 3.372 for sales and 9.100 for leases, both of which are statistically significant at the 1% level. The probability of a sale transaction is approximately 3.4 times higher and that of a lease transaction is 9.1 times higher after two years of lease, indicating a clear institutional structure of the two-year lease term in the formation of the sale-lease choice.

Table 7 summarises the estimated probabilities of each transaction from Q1 2011 to Q2 2021. On average, the estimated probability of no transaction is the highest at 96.60%, followed by the probability of a lease choice at 1.88% and that of a sale choice at 1.52%. The standard deviation is the lowest for the sale choice at 0.79%, with

Table 6. Results of the panel multinomial logit analysis on the supply type decision of the owner: 2011Q1~2021Q2

Supply model_T-1 (Base category: Status quo)		Sale		Lease	
		Odds ratio	*t*-value	Odds ratio	*t*-value
Constant		0.014***	–4.12	0.029***	–9.61
Owner characteristics	Holding period	1.026***	5.54	0.973***	–7.88
	Squared holding period	0.999***	–4.93	1.000***	7.26
	Age of household head	0.946***	–3.21	1.012	0.99
	Squared age of household head	1.000**	2.26	0.999*	–1.65
	Current mortgage balance	1.000	0.15	0.985***	–4.39
	Lease + 2yrs dummy	3.372***	12.04	9.100***	28.62
	Owner's address: Nearby area	1.229***	2.95	1.851***	8.34
	Owner's address: Other regions	1.458***	6.49	2.296***	14.38
	Number of owners: 2 persons	0.919	–1.26	0.731***	–3.01
	Number of owners: 3 or more	1.236	0.85	1.547**	1.96
	Legal person: Corporation	0.537	–1.46	0.679	–1.57
Time dummy (base: 2011)	2012	0.713***	–3.09	0.886	–1.31
	2013	0.906	–0.91	0.879*	–1.74
	2014	1.058	0.53	0.817**	–2.15
	2015	1.503***	4.27	0.956	–0.52
	2016	0.884	–1.05	0.825**	–2.23
	2017	1.486***	3.76	0.783***	–2.63
	2018	1.077	0.65	0.803**	–2.32
	2019	0.831	–1.43	0.790***	–2.71
	2020	1.392***	3.01	0.739***	–3.30
	2021	0.662***	–3.40	0.724***	–3.53
Regional dummy (base: Gangil-town)	Gil-town	4.732*	1.78	0.605**	–2.23
	Dunchon-town	4.372*	1.70	0.671*	–1.72
	Myeongil-town	4.571*	1.75	0.552**	–2.50
	Sangil-town	4.283*	1.67	0.456***	–3.54
	Sungrae-town	4.166*	1.64	0.721	–1.49
	Amsa-town	3.785	1.53	0.782	–0.99
	Cheonho-town	5.114*	1.88	1.019	0.08
σ_1^2		0.048*** (*t*-value = 3.00)			
σ_2^2		0.569*** (*t*-value = 8.69)			
cov_{12}		0.136*** (*t*-value = 5.51)			
Log-pseudolikelihood		–27,857.556			
Wald $Chi^2(56)$		5,286.37			
Number of observations		169,554 (2011Q1 to 2021Q2)			

Note: Variable names in parentheses indicate the base category. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.
(Standard error adjusted for 314 clusters in apartment complexes)

Table 7. Summary of the estimated choice probabilities for each supply type

Variable (2011Q1~2021Q2)	Obs.	Sample avg.	Estimated avg.	Std.	Min.	Max.
No transaction probability	169,554	96.56	96.60	2.64	56.49	99.81
Sale probability	169,554	1.46	1.52	0.79	0.03	20.01
Lease probability	169,554	1.98	1.88	2.17	0.00	39.30

the probability of a sale choice estimated up to 20.01% and that of a lease choice estimated up to 39.30%. Overall, our model produces a higher sale probability and lower lease probability than the sample averages.

4.1.2. Price model_T-1

Table 8 presents the estimation results for the sales-price model_T-1 and rental-price model_T-1. In this context, the probability of sales is defined as the value of the

probability of sales transactions calculated from the supply model_T-1. Furthermore, the ratio of sales volume and ratio of lease volume variables have been calculated for each town. These ratios have been obtained by coding the number of apartments that have been assigned as transaction occurring (sales or lease), based on the probability of sales and lease transactions calculated in the supply model_T-1. This has been done by exceeding a pre-defined threshold, and then summing the number of apartments identified as occurring a transaction by town. This figure has then been divided by the sample number of apartments in each town.

The F-values for the models are 232.71 and 101.63, respectively, indicating that the models are statistically significant, and the adjusted R^2 values are 67.41% and 40.69% (model_T-1/probability) and 68.88% and 43.29%

Table 8. Estimation results of the price model incorporating estimated supply type: 2011Q1~2021Q2

Variables		Price model_T-1/probability				Price model_T-1/volume			
		Sales price		Lease price		Sales price		Lease price	
		Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
Constant		7.227***	67.71	7.247***	51.56	7.394***	69.45	7.389***	52.98
Sale probability		–1.557***	–3.62	2.971***	6.95				
Lease probability		0.139	1.05	–0.801***	–7.96				
Ratio of sales volume (by Town)						–0.347***	–11.81	0.221***	6.33
Ratio of lease volume (by Town)						0.021	0.91	–0.391***	–13.74
Ratio of new development volume (by Town)		–0.205	–1.32	–0.572**	–2.02	–0.197	–1.29	–0.694**	–2.50
Housing characteristics	Floor level	0.008***	9.98	0.010***	8.35	0.008***	10.68	0.008***	7.31
	Number of rooms	–0.001	–0.09	–0.079***	–8.22	–0.012*	–1.80	–0.087***	–9.00
	Number of bathrooms	–0.029***	–3.24	–0.026*	–1.95	–0.031***	–3.54	–0.018	–1.32
	Total number of units (by complex)	0.084***	24.07	–0.001	–0.13	0.079***	22.73	0.022***	4.48
	Age of building	–0.006*	–1.95	0.014***	3.45	–0.008**	–2.32	0.000	0.04
	Squared age of building	0.000	1.17	0.000*	–1.89	0.000	1.52	0.000	0.05
	Parking lot per household	0.027***	3.34	0.040***	3.28	0.031***	3.92	0.036***	3.01
	Interior area: Medium	–0.060***	–8.46	–0.018*	–1.73	–0.059***	–8.50	–0.032***	–3.15
	Interior area: Large	–0.124***	–5.15	–0.353***	–9.18	–0.113***	–4.76	–0.306***	–8.10
Mortgage rate		–0.033	–1.62	–0.066**	–2.41	–0.036*	–1.80	–0.062**	–2.35
Time dummy (2011)	2012	–0.028*	–1.79	0.080***	3.69	–0.113***	–6.59	0.103***	4.43
	2013	–0.036	–1.45	0.052	1.51	–0.070***	–2.84	0.043	1.30
	2014	–0.026	–0.84	0.088**	2.15	–0.005	–0.16	0.049	1.22
	2015	0.036	0.90	0.104*	1.89	0.190***	4.56	0.027	0.49
	2016	0.042	0.94	0.212***	3.61	–0.014	–0.32	0.221***	3.84
	2017	0.142***	3.67	0.238***	4.54	0.283***	7.09	0.141***	2.66
	2018	0.242***	6.95	0.301***	6.35	0.238***	6.98	0.287***	6.18
	2019	0.284***	5.94	0.235***	3.83	0.204***	4.33	0.266***	4.41
	2020	0.388***	7.33	0.280***	3.93	0.481***	9.16	0.224***	3.19
	2021	0.581***	11.51	0.380***	5.73	0.477***	9.51	0.432***	6.58
Number of observations (Number of apartment units)		2,577 (1,959)		3,374 (1,566)		2,577 (1,959)		3,374 (1,566)	
F-value – Sale (23, 2553), Lease (23,3350)		232.71***		101.63***		248.88***		112.95***	
Adj. R^2		67.41		40.69		68.88		43.29	

Note: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

(model_T1/volume), respectively. The results of the four pricing-model estimations show that the estimated probability of a sale (unit level) and proportion of volume (town level) with a sale and rent are statistically significant in both the sale-price and rent-price models. The increase in the probability of a sale and proportion of volume for a sale affected not only the decrease in the sale price, illustrating the economic causality between volume and price in a short-term with fixed market demand, but also the increase in the rental price, which was significant at the 1% level. Meanwhile, an increase in the probability of renting and proportion of volume negatively impacted rental prices but not sales prices. These findings regarding the link between the sales and rental markets indicate that, contrary to Loewenstein and Willen's (2023) hypothesis, the Korean housing market may be affected by the transition between owner-occupied and renter-occupied housing in the existing housing market. However, the occurrence of a lease choice did not significantly affect sale prices. This result may imply that sale and lease decisions respond to different shocks differently. The positive shock affecting a lease choice might not be sufficient enough for a sale-decision choice and resultant sale price.

The floor level was positively and statistically significant for both sales and rental prices in all models. The number of rooms was negatively correlated and statistically significant in all models, except for the sales-price model_T-1/probability. These results suggest that the value of a home can be increased by designing it with larger rooms (or living room) rather than multiple smaller rooms in the same square footage, reflecting a structural change from big to nuclear families in Korea. In the case of the interior area, we find a negative correlation in both the sale- and rental-price models for all size categories. This also reflects current social change: the nuclear family. The total number of units in a complex and the number of car parking spaces per unit are positively correlated in all the models for both sale and rental, except for rental in the price model_T-1/probability. The higher the total number of units, the higher the sale price and the higher the rental price due to the increased frequency of transaction discovery, lower management costs, and increased community-amenity factors.

The square term of the age of a unit is positive, indicating that the sale price decreases up to a certain age and then increases again as the age of the apartment increases. This result can be interpreted as a depreciation in building value as the unit ages, and the fact that the price increases after a certain number of years can be interpreted as the expected effect of re-development being reflected in house prices, as in Chung's (2002) study. In the case of mortgage interest rates, except for the case of sales in the price model_T-1/probability, all the models show a statistically significant negative effect of mortgage rates in all cases. This can be interpreted as a decrease in market demand due to an increase in interest rates, which is reflected in a decrease in market prices. Meanwhile, an increase in newly developed units, measured by town, does not significantly impact sales prices; however, it significantly and negatively impacts rental prices. The lack of a significant effect on sales prices may be due to government regulation on the pre-sale price of new development units. The pre-sale price of new development units should also depend on nearby existing apartment unit prices, in practice. However, we do not include town dummies in the pricing model because the newly developed unit variable certainly has collinearity with the town dummy.

4.1.3. Integrated supply model_T

The integrated model was estimated by adding the estimated sale and rental prices from four price models (Table 8) and their respective squared terms as inputs. Table 9 shows the results of the estimation of the integrated supply model_T. The estimated sale and lease prices significantly impact the respective transaction volumes. The relationship between the sale price and the probability of a sale is non-linear, with a positive effect on the probability of a sale and a negative effect above a certain critical level. However, the squared term of rental price has no significant impact on lease choice.

Our research applies behavioural economics perspectives (loss aversion and search model) to analyse homeowners' decision-making. Loss aversion refers to the tendency of homeowners to be reluctant to sell when prices fall in order to avoid losses. According to the loss aversion model (Genesove & Mayer, 2001), homeowners are reluctant to sell at lower prices, which may lead to a decrease in transaction volume. This study empirically analyses the effect of loss aversion on the volume of home sales transactions by finding a positive relationship between the sale price and the occurrence of sales transactions.

On the other hand, when the price changes more than a certain critical level, a wait-and-see effect may occur, as shown by the search model (Berkovec & Goodman, 1996). The search model explains the process by which homeowners explore market conditions before making a transaction decision, and the wait-and-see effect refers to the tendency of homeowners to wait for a more favourable price during their search process. The results of our study empirically analyse this tendency and find a non-linear relationship in which the selling price negatively affects the transaction volume above a certain critical level.

Meanwhile, we find no significant relationship between estimated sales prices and rental transaction volumes and vice versa. These results suggest that the effect of rental(sale) prices on the choice of sale(rental) activity is limited. A gradual adjustment may apply here, as in the search model (Berkovec & Goodman, 1996). The results for the other variables are similar in magnitude and direction to those for the supply model_T-1 in Table 6 and are not significantly different.

Table 9. Results of the panel multinomial logit analysis on the owner's supply type decision: 2011Q2~2021Q3

Base variable: Status quo		Integrated supply model_T/probability				Integrated supply model_T/volume			
		Sale		Lease		Sale		Lease	
		Odds ratio	*t*-value	Odds ratio	*t*-value	Odds ratio	*t*-value	Odds ratio	*t*-value
Constant		0.007***	–3.73	0.011***	–6.07	0.009***	–3.88	0.017***	–5.69
Estimated sales price (T-1)		1.001*	1.69	0.999	–0.80	1.001*	1.94	0.999	–0.99
Estimated sales price (T-1) squared		0.999*	–1.76	1.000	0.94	0.999**	–2.28	1.000	0.88
Estimated lease price (T-1)		0.999	–0.56	1.002**	2.02	0.999	-0.84	1.002**	2.35
Estimated lease price (T-1) squared		1.000	1.00	0.999	–1.50	1.000	1.45	0.999	–1.44
Owner characteristics	Holding period	1.025***	5.28	0.971***	–7.84	1.027***	5.49	0.972***	–7.97
	Squared holding period	0.999***	–4.69	1.000***	7.17	0.999***	–4.92	1.000***	7.34
	Age of household head	0.951***	–3.04	1.015	1.25	0.948***	–3.06	1.012	1.00
	Squared age of household head	1.000**	2.10	0.999*	–1.80	1.000**	2.15	0.999	–1.61
	Current mortgage balance	1.000	0.38	0.985***	–4.12	1.000	0.37	0.986***	–3.95
	Lease + 2yrs dummy	3.402***	12.03	9.300***	28.97	3.374***	12.07	9.095***	28.59
	Owner's address: Nearby area	1.233***	3.02	1.867***	8.43	1.228***	2.98	1.857***	8.39
	Owner's address: Other regions	1.441***	6.29	2.295***	14.27	1.443***	6.23	2.290***	14.15
	Number of owners: 2 persons	0.928	–1.11	0.736***	–2.95	0.928	–1.12	0.741***	–2.88
	Number of owners: 3 or more	1.305	1.07	1.629**	2.21	1.310	1.09	1.644**	2.25
	Legal person: Corporation	0.588	–1.24	0.706	–1.36	0.568	–1.32	0.691	–1.44
Time dummy (base: 2011)	2012	0.705***	–2.94	0.808**	–2.15	0.709***	–2.96	0.800**	–2.19
	2013	0.882	–1.04	0.771***	–2.87	0.892	–0.95	0.764***	–3.11
	2014	0.997	–0.02	0.663***	–3.51	1.013	0.09	0.647***	–3.51
	2015	1.333**	2.10	0.727**	–2.38	1.353**	2.20	0.711***	–2.74
	2016	0.732*	–1.79	0.576***	–3.94	0.751*	–1.67	0.553***	–4.13
	2017	1.165	0.93	0.528***	–4.26	1.190	1.05	0.511***	–4.64
	2018	0.806	–1.24	0.532***	–4.00	0.826	–1.11	0.520***	–4.20
	2019	0.645**	–2.44	0.546***	–4.33	0.660**	–2.41	0.549***	–4.53
	2020	0.985	–0.08	0.468***	–4.51	1.012	0.06	0.473***	–4.60
	2021	0.484***	–2.84	0.429***	–3.99	0.505***	–2.98	0.455***	–3.89
Regional dummy (base: Gangil-town)	Gil-town	4.470*	1.65	0.522**	–2.33	3.797	1.52	0.362***	–3.00
	Dunchon-town	4.183	1.59	0.587*	–1.82	3.649	1.49	0.426**	–2.53
	Myeongil-town	4.369	1.63	0.475**	–2.45	3.751	1.51	0.331***	–3.09
	Sangil-town	3.876	1.51	0.382***	–3.50	3.394	1.41	0.285***	–4.03
	Sungrae-town	4.014	1.54	0.639	–1.61	3.552	1.46	0.481**	–2.31
	Amsa-town	3.639	1.44	0.690	–1.35	3.222	1.35	0.535**	–2.16
	Cheonho-town	4.752*	1.72	0.869	–0.50	4.403*	1.70	0.683	–1.16
σ_1^2		0.047*** (*t*-value = 2.93)				0.046*** (*t*-value = 2.88)			
σ_2^2		0.566*** (*t*-value = 8.72)				0.571*** (*t*-value = 8.75)			
cov_{12}		0.133*** (*t*-value = 5.38)				0.132*** (*t*-value = 5.30)			
Log-pseudolikelihood		–27,843.847				–27,841.601			
Wald $Chi^2(64)$		5,669.37***				5,661.15***			
Number of observations		169,554				169,554			

Note: Variable names in parentheses indicate the base category. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

Table 10. Prediction power comparison: 2020Q1 to 2020Q4

MAPE (%)				
Model	Gangdong district		Three towns: Gil, Sungrae, and Dunchon	
	Sale	Lease	Sale	Lease
Integrated supply model_T/probability (calibrated)	14.7	23.2	11.4	16.3
Integrated supply model_T/volume (not calibrated)	3,101	1,400	2,987	1,294
Previous year volume	49.3	14.6	46.5	4.5

4.2. Application

Table 10 compares the forecasting performance of the integrated supply model_T/probability and integrated supply model_T/volume for the four quarters of 2020. Since 2021, there have been few transactions due to COVID-19, the Modified Housing Lease Protection Act (2021), which recognises renters' right to extend their leases up to two more years, and recent interest-rate hikes. The spatial scope of the forecast covers both the whole of Gangdong district and three towns (Gil, Sungrae, and Dunchon), with tractable transaction volumes (>9 transactions per quarter on average).

The benchmark model assumes a real transaction volume of the same quarter of the previous year, reflecting the seasonality and lease term structure. We also estimated two alternative models: the integrated supply model_T/volume, which modelled the volume of transactions, and integrated supply model_T/probability (calibrated), which was calibrated to actual transaction volumes. The performance-comparison metric is the mean absolute percentage error (MAPE) (see Appendix Table A1 for model calibration).

In reality, the occurrence of sale and lease transactions is extremely rare. To solve this problem, the model/volume was calculated using Youden's J, and the model/probability was calibrated to the actual transaction volume. The comparison results show that the integrated supply model_T/probability (calibrated) is the best for sales-volume forecasting, whereas the year-ago benchmark model is the best for rental volume. This suggests institutional influences in the Korean housing-rental market.

5. Conclusions

Despite its importance, determining an owner's supply choice has been under-researched due to data-acquisition limitations. Our study is based on a dataset of 4,037 individual apartments in Gangdong district, Seoul, Korea over a 46-quarter period (2011Q1–2022Q2), which combines the data from the property-registration book and actual transaction information. The merged information comprises physical housing characteristics (complex and individual housing information), price variables (sale- and lease-transaction prices), owner characteristics (owners' age, mortgage loan amount, etc.), and market variables (mortgage interest rate, newly developed unit, etc.).

Our study simultaneously analyses the occurrence of housing transactions and their prices. In analysing the relationship between the volume and price of sales transactions, we construct a micro-level model to capture owner and housing characteristics and integrate the volume and price of rental transactions to analyse both the sales and rental markets. The main contributions are that we (1) study homeowners' choice between selling and renting decisions in a systematic manner, which have not been studied in detail in the existing literature, (2) consider the interaction between the sales and renting markets, and (3) construct micro-level panel data to explain the behavior of housing markets (selling and renting markets simultaneously) in dynamic and structural ways. Since housing stock is limited in the short run, both sales and rental markets need to be simultaneously considered to fully analyse the housing market. Our study provides a new framework for explaining housing sales and rental transactions and transaction prices, and confirms that both markets are linked through housing stock. While the quantity of new housing supply significantly impacts the stability of the rental housing market, in the case of Korea, which relies heavily on private rental housing, it is necessary to examine the existing housing market.

The key findings of our study are two. We find that the housing sales and rental markets interact and co-move together. We also demonstrate that the institution of the two-year lease contract period influences the transaction probabilities in both the sales and rental markets. In the supply-type choice model, a lock-in effect exists of transaction occurrence on owners' age, with the probability of sale increasing and then decreasing as owners' age increases, and the probability of renting decreasing and then increasing. In terms of holding period, some dwellings are purchased initially as an investment and are more likely to be rented initially, while others are purchased as a place to live and are less likely to be sold in the short-term.

Meanwhile, the probability of sale and lease transactions increases significantly every two years after a lease contract is signed. During the lease period, only the buy-to-rent investors are interested in the unit (No eviction allowed). In other words, it is difficult to sell efficiently to maximise the homeowner's utility during the lease period,

and thus the probability of new transactions seems to be low. The results of the forecasting-performance comparison show that the integrated supply model_T/probability (calibrated) is the best for sales volume, whereas the benchmark two-year lagged model is the best for rental volume. This suggests an institutional effect in the Korean housing market (or in any market where there is an active transition between owner-occupied and tenant-occupied housing). The existence of a relationship between the sales and rental markets has significant policy implications. As the probability of transaction volume changes, the supply and demand mechanism of the existing housing market may change, and prices may change accordingly. The goal of housing policy should not only be the stability of the housing price but also the systemic stability and affordability of the housing market for seamless transactions in terms of residential mobility. In addition, governments and housing investors should think more carefully about the impact of rental-related policies (such as renter protection laws) on the sales market and the impact of sales-related policies (such as heavy property taxes) on the rental market. For example, policies like Berlin's rent freeze and Korea's tenant protection laws demonstrate the unintended effects of neglecting the interaction between sales and rental markets. To achieve these policy objectives, further analysis of and research on the existing housing stock is essential. The study has limitations. First, it does not incorporate information on whether a home has been renovated. For existing housing, the presence or absence of interior repairs may have had a significant impact on both the prices and probabilities of a transaction. Homeowners may increase the supply of quality housing by improving the quality of their homes through renovations in order to rent or sell them (DiPasquale, 1999). A more important data limitation is that the study does not incorporate more detailed owner information, such as homeowners' assets (financial and real), property taxes, or total debt amounts and contracted interest rates. A homeowner's financial situation and property taxes can significantly impact their choice to sell or rent. Although we analysed long-term panel data for more than 10 years, the geographical scope is limited to a district, in Seoul, so future studies should expand data for broader generalization of findings.

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Author contributions

Seongwon LEE and Seungwoo SHIN conceived the study and were responsible for the design and development of the data analysis. Seongwon LEE and Yeonjae LEE were responsible for data collection and analysis. Seongwon LEE and Seungwoo SHIN were responsible for data interpretation. Seongwon LEE and Yeonjae LEE wrote the first draft of the article.

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References

Berkovec, J. A., & Goodman, J. L., Jr. (1996). Turnover as a measure of demand for existing homes. *Real Estate Economics*, *24*(4), 421–440. https://doi.org/10.1111/1540-6229.00698

Bogdon, A. S. (1992). *The determinants of homeowner expenditures for renovation, alteration and repair* [Thesis, Harvard University]. ProQuest Dissertations & Theses Global. https://www.proquest.com/openview/c6ec5853a073734a4255f12066023579/1?pq-origsite=gscholar&cbl=18750&diss=y

Chau, K. W., Wong, S. K., & Yiu, E. C. Y. (2003). Price discovery function of forward contracts in the real estate market: An empirical test. *Journal of Financial Management of Property and Construction*, *8*(3), 129–137.

Chung, E. (2002). Redevelopment and house prices: Expectations and realizations. *Korea Real Estate Review*, *12*(2), 143–155.

Clapp, J. M., & Salavei, K. (2010). Hedonic pricing with redevelopment options: A new approach to estimating depreciation effects. *Journal of Urban Economics*, *67*(3), 362–377. https://doi.org/10.1016/j.jue.2009.11.003

Clark, S., & Lomax, N. (2020). Rent/price ratio for English housing sub-markets using matched sales and rental data. *Area*, *52*(1), 136–147. https://doi.org/10.1111/area.12555

Clauretie, T., & Wolverton, M. (2006). Leave vacant or rent: The optimal decision for absentee home sellers. *Journal of Real Estate Research*, *28*(1), 25–38. https://doi.org/10.1080/10835547.2006.12091172

Clayton, J., Miller, N., & Peng, L. (2010). Price-volume correlation in the housing market: Causality and co-movements. *The Journal of Real Estate Finance and Economics*, *40*, 14–40. https://doi.org/10.1007/s11146-008-9128-0

Colwell, P. F. (2002). Tweaking the DiPasquale-wheaton model. *Journal of Housing Economics*, *11*(1), 24–39. https://doi.org/10.1006/jhec.2001.0301

de Wit, E. R., Englund, P., & Francke, M. K. (2013). Price and transaction volume in the Dutch housing market. *Regional Science and Urban Economics*, *43*(2), 220–241. https://doi.org/10.1016/j.regsciurbeco.2012.07.002

Depken, C. A., Hollans, H., & Swidler, S. (2009). An empirical analysis of residential property flipping. *The Journal of Real Estate Finance and Economics*, *39*, 248–263. https://doi.org/10.1007/s11146-009-9181-3

DiPasquale, D. (1999). Why don't we know more about housing supply? *The Journal of Real Estate Finance and Economics*, *18*(1), 9–23. https://doi.org/10.1023/A:1007729227419

DiPasquale, D., & Wheaton, W. C. (1992). The markets for real estate assets and space: A conceptual framework. *Real Estate*

Economics, *20*(2), 181–198. https://doi.org/10.1111/1540-6229.00579

Ferreira, F., Gyourko, J., & Tracy, J. (2010). Housing busts and household mobility. *Journal of Urban Economics*, *68*(1), 34–45. https://doi.org/10.1016/j.jue.2009.10.007

Follain, J. R., & Velz, O. T. (1995). Incorporating the number of existing home sales into a structural model of the market for owner-occupied housing. *Journal of Housing Economics*, *4*(2), 93–117. https://doi.org/10.1006/jhec.1995.1005

Genesove, D., & Mayer, C. (2001). Loss aversion and seller behavior: Evidence from the housing market. *The Quarterly Journal of Economics*, *116*(4), 1233–1260. https://doi.org/10.1162/003355301753265561

Genesove, D., & Mayer, C. J. (1994). *Equity and time to sale in the real estate market* (NBER Working Paper No. 4861). National Bureau of Economic Research. https://doi.org/10.3386/w4861

Hausman, J. A., & Taylor, W. E. (1981). Panel data and unobservable individual effects. *Econometrica*, *49*(6), 1377–1398. https://doi.org/10.2307/1911406

Hausman, J., & McFadden, D. (1984). Specification tests for the multinomial logit model. *Econometrica*, *52*(5), 1219–1240. https://doi.org/10.2307/1910997

Hort, K. (2000). Prices and turnover in the market for owner-occupied homes. *Regional Science and Urban Economics*, *30*(1), 99–119. https://doi.org/10.1016/S0166-0462(99)00028-9

Huang, Y., Lieske, S. N., & Liu, Y. (2023). Factors influencing vertical urban development at the parcel scale: The case in Brisbane, Australia. *Environment and Planning B: Urban Analytics and City Science*, *50*(3), 694–708. https://doi.org/10.1177/23998083221129283

LaCour-Little, M., & Yang, J. (2023). Seeking alpha in the housing market. *The Journal of Real Estate Finance and Economics*, *67*(3), 319–374. https://doi.org/10.1007/s11146-021-09853-1

Lan, C. I. C., & Lee, C. J. (2020). Property-led renewal, state-induced rent gap, and the sociospatial unevenness of sustainable regeneration in Taipei. *Housing Studies*, *36*(6), 843–866. https://doi.org/10.1080/02673037.2020.1720615

Lee, B. S., Chung, E. C., & Kim, Y. H. (2005). Dwelling age, redevelopment, and housing prices: The case of apartment complexes in Seoul. *The Journal of Real Estate Finance and Economics*, *30*, 55–80. https://doi.org/10.1007/s11146-004-4831-y

Leung, C., Lau, G., & Leong, Y. (2002). Testing alternative theories of the property price-trading volume correlation. *Journal of Real Estate Research*, *23*(3), 253–264. https://doi.org/10.1080/10835547.2002.12091081

Li, X., Han, S. S., & Wu, H. (2019). Urban consolidation, power relations, and dilapidated residential redevelopment in Mutoulong, Shenzhen, China. *Urban Studies*, *56*(13), 2802–2819. https://doi.org/10.1177/0042098018799950

Loewenstein, L., & Willen, P. S. (2023). *House prices and rents in the 21st century* (No. w31013). National Bureau of Economic Research. https://doi.org/10.3386/w31013

Marlett, D. M. (1993). *Causes of anxiety for transfer students: Implications for teachers*. https://eric.ed.gov/?id=ED359162

Miceli, T. J., & Sirmans, C. F. (1999). Tenant turnover, rental contracts, and self-selection. *Journal of Housing Economics*, *8*(4), 301–311. https://doi.org/10.1006/jhec.1999.0253

Miller, N., & Sklarz, M. (1986). A note on leaning indicators of housing market price trends. *Journal of Real Estate Research*, *1*(1), 99–109. https://doi.org/10.1080/10835547.1986.12090516

Montgomery, C. (1992). Explaining home improvement in the context of household investment in residential housing. *Journal of Urban Economics*, *32*(3), 326–350. https://doi.org/10.1016/0094-1190(92)90022-D

Myers, D., Park, J., & Cho, S. (2023). Housing shortages and the new downturn of residential mobility in the US. *Housing Studies*, *38*(6), 1088–1109. https://doi.org/10.1080/02673037.2021.1929860

Ooi, J. T., & Le, T. T. (2012). New supply and price dynamics in the Singapore housing market. *Urban Studies*, *49*(7), 1435–1451. https://doi.org/10.1177/0042098011415718

Park, E. S. (2013). *Empirical analyses of price interactions between newly supplied and existing multi-family housing* [Doctoral dissertation, Seoul National University]. https://snu-primo.hosted.exlibrisgroup.com/permalink/f/1l6eo7m/82SNU_SSPACE210371/124907

Popkin, S. J., Levy, D. K., O'Brien, M., & Boshart, A. (2021). *An equitable strategy for public housing redevelopment*. Urban Institute.

Potepan, M. J. (1989). Interest rates, income, and home improvement decisions. *Journal of Urban Economics*, *25*(3), 282–294. https://doi.org/10.1016/0094-1190(89)90051-X

Rabe-Hesketh, S., & Skrondal, A. (2012). *Multilevel and longitudinal modeling using Stata* (Vol. II, 3rd ed.). Stata Press. https://www.stata-press.com/books/multilevel-longitudinal-modeling-stata/

Rothenberg, J. (1991). *The maze of urban housing markets: Theory, evidence, and policy*. University of Chicago Press. https://books.google.lt/books/about/The_Maze_of_Urban_Housing_Markets.html?id=BXWRLSFg51EC&redir_esc=y

Sagner, P., & Voigtländer, M. (2023). Supply side effects of the Berlin rent freeze. *International Journal of Housing Policy*, *23*(4), 692–711. https://doi.org/10.1080/19491247.2022.2059844

Shi, S., Young, M., & Hargreaves, B. (2010). House price–volume dynamics: Evidence from 12 cities in New Zealand. *Journal of Real Estate Research*, *32*(1), 75–100. https://doi.org/10.1080/10835547.2010.12091266

Statistics Korea. (2022). *Housing census, 2022, housing units by type of housing units*. https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1JU1501&conn_path=I2&language=en

Stein, J. C. (1995). Prices and trading volume in the housing market: A model with down-payment effects. *The Quarterly Journal of Economics*, *110*(2), 379–406. https://doi.org/10.2307/2118444

Supreme Court of Korea. (2021). *Housing transaction volumes by contract types*. https://www.scourt.go.kr/supreme/supreme.jsp

Tsai, I. C. (2019). Dynamic price–volume causality in the American housing market: A signal of market conditions. *The North American Journal of Economics and Finance*, *48*, 385–400. https://doi.org/10.1016/j.najef.2019.03.010

Tsai, I. C., & Peng, C. W. (2016). Linear and nonlinear dynamic relationships between housing prices and trading volumes. *The North American Journal of Economics and Finance*, *38*, 172–184. https://doi.org/10.1016/j.najef.2016.10.014

Waltl, S. R., & Lepinteur, A. (2023). Tracking home-owners' sentiments: Subjective indices and convergent validity. *The Journal of Real Estate Finance and Economics*, 1–29. https://doi.org/10.1007/s11146-023-09949-w

Wu, G., Li, C., Niu, X., Li, P., & Tao, L. (2021). Evolution of relationship between housing and rental prices and inter-urban differences in China under the context of the simultaneous rental and sales markets policy. *Real Estate Management and Valuation*, *29*(3), 29–38. https://doi.org/10.2478/remav-2021-0019

Zhou, Z. G. (1997). Forecasting sales and price for existing single-family homes: A VAR model with error correction. *Journal of Real Estate Research*, *14*(2), 155–167. https://doi.org/10.1080/10835547.1997.12090894

Appendix

Calibration

Calibration is performed by regression. The dependent variable is the actual sales and rental transaction volume of the targeted homes by quarter and by town. The independent variables are time (in quarters) and time squared, and the probability of selling or renting by quarter and town, and its square, and finally a quarter dummy to check for seasonality.

Table A1. Calibration result: (2011Q2~2021Q3)

Dependent variable: Actual trading volume of subject units		Sale volume		Lease volume	
		Coefficient	*t*-value	Coefficient	*t*-value
Constant		0.843***	12.54	–1.727***	–25.62
Time		–0.002	–0.53	0.141***	33.09
Time squared		0.000***	3.60	–0.002***	–23.23
Sales probability		1.346***	158.17	–0.111***	–12.99
Sales probability squared		–0.011***	–56.72	0.005***	23.87
Lease probability		–0.312***	–29.41	1.302***	122.54
Lease probability squared		0.008***	34.70	–0.007***	–29.84
Quarter dummy (base: Q1)	Q2	–0.335***	–10.90	–1.534***	–49.75
	Q3	–0.933***	–30.35	–0.239***	–7.76
	Q4	–2.042***	–64.99	–2.313***	–73.43
R^2 adj.		78.42		85.57	

Unit ID	*Time*	*Transaction*	*Holding Period*	*Owner's Age*	···
1	2011Q1	No Transaction(0)	30	56	···
1	2011Q2	Sale(1)	31	56	···
1	2011Q3	No Transaction(0)	1	33	···
1	2011Q4	No Transaction(0)	2	33	···
4036	2022Q2	Sale(1)	44	21	···
4037	2011Q1	No Transaction(0)	10	48	···
4037	2011Q2	No Transaction(0)	11	48	···
4037	2011Q3	No Transaction(0)	12	48	···
4037	2011Q4	No Transaction(0)	13	48	···
4037	2021Q3	No Transaction(0)	7	37	···
4037	2021Q4	Lease(2)	8	37	···
4037	2022Q1	Sale(1)	9	38	···
4037	2022Q2	No Transaction(0)	1	42	···

Figure A1. Data structure example