Is the Korean housing market following Gangnam style?

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Highlights

- This paper examines housing sales and rental market spillovers in Korean regional markets from 1991 to 2016.
- We employ the spillover index of Diebold and Yilmaz (2014) and the quantile regression approach.
- The 1997-1998 Asian currency crisis intensified regional spillovers in the Korean housing market.
- Gangnam region is a hub of connectedness, implying that it is the most influential shock transmitter among the regional housing markets.
- Macroeconomic factors impact the spillovers across regional housing sales and rental markets under different degree of spillovers.

Is the Korean housing market following Gangnam style?

Abstract

Gangnam is the prime district in Korea which is known for expensive real estate market because of the convenient transportation, shopping and business, and the elite schools and academies in the area. This paper examines spillovers and network connectedness in Korean regional markets, using the spillover index of Diebold and Yilmaz (2014). We use the quantile regression approach to investigate the macroeconomic factors driving total spillover effects under low, normal, and high spillovers. We find that the 1997–1998 Asian currency crisis intensified regional spillovers in the Korean housing market. Moreover, we show that Gangnam is the largest transmitter of spillovers across the regional housing markets in Korea. Our visual network illustrates that Gangnam is a hub of connectedness, implying that it is the most influential shock transmitter among the regional housing markets. Finally, our study has implications for investors: Macroeconomic factors impact spillovers across regional housing sales and rental markets under different degrees of spillover.

Keywords: Korean regional housing market; dynamic spillover; network connectedness; quantile regression approach; spillover index.

JEL classification: C58; F37; G14; G15; Q3

1. Introduction

Since the outbreak of the 2007 US subprime crisis, most central banks have adopted quantitative easing (QE) measures to recover from the economic recession. QE lowers interest rates and increases money supply, resulting in price bubbles in global housing markets. This dramatic house price movement has attracted global attention because of its extensive links to and consequent effects on the world economy (Yang et al., 2018). Specifically, the Korean housing market has been overvalued for the last 10 years, owing to the redevelopment of urbanization resulting from a low interest rate regime (Korea Real Estate Market Report, 2017). It is worth noting that according to the Korean Statistical Information Service, the national housing purchase price index increased by 0.79 percent in 2016.[1] The South Korea Housing Index attained an all-time high of 103.70 points in June 2018, compared to a record low of 35.50 points in March 1987.[2]

In particular, housing prices in the Gangnam region have triggered bubbles and co-movements in other regional housing markets (Hyun and Milcheva, 2018; Lee and Lee, 2014; Lee and Lee, 2015). Gangnam is famous for its wealth and high standard of living. The neighborhood boasts large businesses, modern buildings, fancy nightclubs, upscale restaurants, expensive brand names stores, and multinational businesses like Google, Toyota and IBM have their South Korean head offices. In addition, there are elite schools that are rated the best in the country. Due to PSY's 'Gangnam Style' (K-pop) and the introduction of 'Medical Tourism', Gangnam has become a brand in itself and thus real estate prices have skyrocketed over the last decade. The real estate market in Gangnam is for people who are willing to spend the $10,000-per-square-metre cost of real estate. Many empirical and theoretical studies presented evidence that the rise in housing prices in Korea has been triggered by Gangnam housing market (Lee

[1] For more details, see also https://www.globalpropertyguide.com/Asia/South-Korea/Price-History and http://kosis.kr/eng/.
[2] https://tradingeconomics.com/south-korea/housing-index.

and Lee, 2004; Cheon and Kim, 2006; Kim and Park, 2006; Kim et al., 2011; Chang, 2014; Lee and Lee, 2014).

A large body of literature has examined the extent of housing market co-movements in developed, emerging, and developing countries (e.g., Baur and Heaney, 2017; Damianov and Elsayed, 2018; Montagnoli and Nagayasu, 2015; Tsai, 2015). Nevertheless, little is known about the spillover (linkage, connectedness, and interdependence) effects among regional housing markets in Korea. Such issues have important implications for a variety of market players such as investors, regulators, and others (Cotter et al., 2015; Gong et al., 2016; Miao et al., 2011). To regulate the housing market, including the response to housing price bubbles, a highly integrated regional housing market requires a nationwide housing policy; otherwise, different and locally oriented policies would be required (Yang et al., 2018).

The high house prices have become a serious issue in many countries, especially South Korea. The fluctuation of housing prices is not isolated but correlated across region area and then spread out across the economy (Zhang, et al., 2017). Many studies have discussed a similar phenomenon, referred to as the ripple effect (Pollakowski and Ray, 1997; Vansteenkiste and Hiebert, 2011; Gupta and Miller, 2012; Apergis and Payne, 2012; Tsai, 2014; Cook and Watson, 2015; Liao et al., 2015). In addition, macroeconomic news has influence on house price behaviors and correlations between regional housing markets (Meen, 1999; Cook, 2005; Hang and Quigley, 2006; Beltratti and Morana, 2010; Antonakakis and Floros, 2016; Tsai, 2018).

The above studies do not elaborate on the forces shaping spillover effects among Korean regional housing markets. Do spillovers modify magnitude and direction during an economic slowdown or expansion? How are they connected to each other in the network system? Which regional markets are the net-transmitters and net-recipients in the Korean housing market? Which factors drive spillover effects in the Korean housing market? Is the relationship between driving factors and spillover asymmetric? These questions have theoretical and practical implications for a variety of market players, including investors, policymakers, market regulators, homeowners, and potential buyers (Damianov and Elsayed, 2018).

This study explores the spillovers in the regional sales and rental housing markets in Korea by focusing on the intensity and direction of spillovers from 1991 to 2016. Policy adjustment in one market can induce a ripple effect in the remaining regional markets. This study, thus, contributes to the existing literature, along with four directions. First, we used the spillover index of Diebold and Yilmaz [thereafter, DY] (2012, 2014), which is based on a generalized decomposition of the forecast-error variance of a VAR model. An advantage of this method is that it allows us to measure directional spillovers and net spillovers across regional housing markets. Although a few studies have covered spillover effects in the Korean housing market, this paper analyzes more recent sample periods, including global and domestic market events, that is, the 1997–1998 Asian currency crisis, the 2007–2009 global financial crisis (GFC), and the 2010–2012 European debt crisis (EDC). Second, we use a rolling window approach to detect the time-evolution of spillover indexes and the extent to which the above financial crises altered the direction and intensity of connectedness across regional housing markets. The dynamics of the spillover index allow for differentiation between the impacts of tranquil/stable and volatile/crisis periods, including trends and busts across regional housing markets. Third, we determine the pure "transmitters" or "recipients" of spillovers in the Korean housing market. The adopted connectedness network helps us identify the degree and direction of spillover effects across regional housing markets. More interestingly, macroeconomic factor changes can affect the magnitude and directions of the spillover of housing prices (Duan et al., 2018). For this aim, we investigated the impacts of macroeconomic variables, such as the 91-day maturity certificate of deposit (CD) rate, the consumer price index (CPI), the Korean stock market index (KOSPI), the KRW-USD exchange rate, the Korean economic policy uncertainty (KEPU), and money supply (M2) on the spillovers index by accounting for them in the GVAR model. Kearl (1979), Follain (1981), and Feldstein (1992) showed that inflation reduces housing investment. Nielsen and Sorensen (1994) argue that an increase in inflation stimulates investment in the housing sector. The money supply affects housing prices, according to the quantity theory of money. The economic uncertainty index increases the turbulence and volatility of housing markets. Finally, we use the quantile regression approach (QRA) of Koenker (2005) to identify the determinant factors of spillover effects, using macroeconomic variables under different spillover circumstances. An advantage of the QRA is that it is more flexible than the ordinary least squares (OLS) model. It offers fresh insights into the impact of the macroeconomic variables on the total spillovers of housing markets under different situations, including low (lower quantiles) and high (upper quantiles) spillovers. This approach provides useful information on the asymmetric and non-linear effects of conditional variables on dependent variables (Baur, 2013).

Our results show that the magnitude of the spillover effects of rentals is higher than that of sales. We also find that Gangnam has the most influence on other regional sales and rental markets in Korea. Furthermore, we show that there are more net-pairwise links in the rental market than in the sales market; this indicates that the rental market has a more complex connectedness among regional markets. Gangnam has the highest net-pairwise connectedness with Incheon (sales) and Busan (rentals). A time-varying analysis shows that the spillover index results were affected by major regional and global events, especially the Asian currency crisis in 1997–1998 and the 2007–2009 GFC. Finally, we find that the CD rate has a negative impact on the Korean housing market under low spillovers. The CPI has a negative impact on the spillover effects of housing sales (rentals) under normal (low and high) spillovers. In contrast, KOSPI and M2 positively impact spillovers in housing sales in normal spillovers and rentals in low and normal spillovers. The relationship is symmetric, since the sign of the coefficient is not sensitive to quantiles. In addition, KEPU affects spillovers in housing sales under low spillovers, whereas KRW-USD has an insignificant relationship across all quantiles.

The paper is structured as follows. Section 2 presents a concise literature review, Section 3 explains the empirical method, Section 4 describes the data and provides descriptive statistics, Section 5 discusses the empirical results, and Section 6 concludes the paper.

2. Literature review

The debate of interlinkages and ripple effects of regional real estate markets began with the pioneering studies of Giussani and Hadjimatheou (1991) and MacDonald and Taylor (1993) where they have addressed the long-run relationship between movements in regional house markets. Alexander and Barrow (1994) show evidence of northward causal flow in the UK real estate markets, suggesting that south East first influence the neighboring East Midlands, before eventually affecting the North. Using VAR model, Pollakowski and Ray (1997) investigate the spillovers in US regional stock markets and show evidence that diffusion patterns attributed to demographics and political jurisdictions. Miao et al. (2011) examine the return and volatility spillovers among 16 metropolitan markets. In terms of return transmission, New York, San Francisco and Miami are the most influential markets while for the volatility transmission, the results show significant volatility spillovers in the East between New York, Boston and Washington, DC, and innovations in the housing markets of Miami, Los Angeles and San Francisco play an influential role within their respective regions. Central and Mountain regions are independent to the external influences.

Many empirical studies have addressed interactions and spillovers, using the Granger causality test and correlation analysis (Shih et al., 2014). Although causality and correlation-based measurements remain universal in empirical works, they test only static pairwise interdependence. To analyze the nature and direction of spillovers, investors may be interested in measuring the time-varying evolution of spillovers in housing markets. Damianov and Elsayed (2018) applied the spillover index to investigate return spillovers across housing markets, the mortgage and equity real estate investment trust (REIT) markets, and stock markets. According to their results, all markets play a dual role (net receiver and net receipt). Moreover, the housing market appears to have been a receiver of spillovers from the mortgage and equity REIT markets during the 2007 mortgage crisis. The housing market is also a transmitter of spillovers during a state of economic downturn. Yang et al. (2018) applied a high-dimensional VAR analysis to compute the spillover index of DY (2012), to examine housing price spillovers among 69 medium and large-sized cities in China. The authors found significant spillovers across Chinese city housing prices. They show high positive net spillovers in five economic rims, in several regional plans of the Chinese government. Moreover, these authors suggest that government policy is an important factor that determines price spillovers in an inter-city network.

Differently to the above studies, Ji et al. (2018) explored the spillover between international real estate investment trusts (REITs) in the United States, Australia, France, Netherlands, New Zealand, and Singapore markets. For this aim, they used an entropy-based network method to account for the nature and extent of spillover between several components of the housing network. They found that the US market is the greatest transmitter in the connectedness network and highlight the declining incidence of contagion in global housing markets. Duan et al. (2018) analyzed the impact of macroeconomic variables on the spillover effects of housing markets by using a dynamic spatial panel model and found that the exclusion of spatial spillover effects may give rise to an overestimation bias in housing markets.

Moreover, some empirical studies have analyzed dependence and the spillover effect in Korean regional housing markets. For example, Lee and Lee (2014) examined spillover effects of apartment housing prices across seven large cities in Korea using the spillover index method of Diebold and Yilmaz (2009). They found that housing prices in the Seoul region have had a strong interconnectedness with those in other major cities since 2000. By employing the same method, Jeon and Hyung (2018) examined the spillover effect of the Gangnam housing and rental price indices to other regional housing markets in Korea. They suggested that the rise/fall in Korean housing market prices was attributable to Gangnam housing prices in 1997–2008. However, Chang (2014) supported evidence of the regional independence of housing price spillovers among regions (Seoul, Gyeonggi, 5-metropolitan city, and small-medium city) in 2014–2013. Tsai (2015) has analyzed the risk spillovers between US housing and stock markets, using DY (2012) methodology. The author fails to find a long-term equilibrium between both markets because of time-varying linkages between real estate and stock markets. In addition, the spillover index between markets is time-varying and intensifies during the crisis periods (dot-com bubble in 2000, Lehman Brothers collapse in September 2008, and GFC). Finally, the author shows a bidirectional causality between the money supply and the spillover index and the fact that the spillovers cause the variabilities of the treasury bill rate. Shi (2017) shows a time-varying causality between Chinese stock and housing markets (first-, second-, and third-tier cities) during bull market and financial crisis episodes. More recently, Tsai (2018) used Markov-switching models to investigate housing affordability in UK regional housing markets. He showed that the levels of housing burden among regions are interrelated, suggesting that a high cost of housing burden in one region may result in residents buying houses in other regions, and that house prices tend to converge with income levels.

Other strand of literature has examined the relationship between real estate markets and global factors. Chen and Liow (2006) examine the mean and volatility transmission between stock markets and real estate markets using multivariate GARCH model. The authors show that the volatility spillovers are more pronounced with Asian economies than across the world. Similarly, Zhu et al. (2013) explore dynamic linkages in returns, idiosyncratic risks and volatilities across U.S. regional housing markets and show that geographic closeness, economic proximity is a source of influence of interconnections across real estate markets. Miller and Peng (2006) examine the relationship between housing volatilities and economic conditions in MSAs and find that the volatility series is Granger-caused by the home appreciation rate and the growth in gross metropolitan product.

Although many studies have carried out fruitful studies on the spillover effect in housing markets, most researchers focus on static spillover effects rather than dynamic spillover effects. To analyze the time-varying spillover effect, we investigate the directional spillover, net pairwise spillover, and network connectedness in Korean housing markets. We further examine whether the impact of the driving forces on the spillover effects under various quantiles are different. It is necessary to identify the dominant macroeconomic variables on the spillover effects on the Korean housing markets.

3. Methodology

3.1 Spillover index method

To analyze spillovers across regional housing markets, we use a generalized VAR (GVAR) approach and incorporate the variance decomposition matrix created by the spillover index methodology of Diebold and Yilmaz (2012, 2014). This approach provides estimates of total, net, and directional spillover influence among regional housing markets. The evolution of the first order differences of housing index returns follows a covariance stationary VAR(p) of the form:

$$y_t = \sum_{k=1}^{p} \psi_k \, y_{t-k} + \varepsilon_t. \quad (1)$$

The variable y_t is an $(N+M) \times 1$ vector of including *N* housing index returns and *M* macroeconomic drivers, and ψ_k is an $(N+M) \times (N+M)$ matrix of autoregressive coefficients, indicating the effect of past housing index returns on the evolution of y_t. The term

ε_t accounts for the effect of the excluded variables in the evolution process and is assumed to be serially uncorrelated. The VAR model accounts for possible linear mean causality effects originated from macroeconomic drivers and impacting on the real estate variables. Moreover, the model includes possible feedback effects from the real estate movements to the real side of the Korean economy. A moving average representation of Eq (1) is $y_t = \sum_{l=0}^{\infty} \Theta_l \, \varepsilon_{t-l}$, where $\Theta_l = \psi_1 \Theta_{l-1} + \psi_2 \Theta_{l-2} + \cdots + \psi_p \Theta_{l-p}$. In implementing the GVAR, the effects of variable j on the H-step-ahead generalized forecast error variance of variable i are accounted for through the following relationship:

$$c_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' \Theta_h \Sigma \, e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' \Theta_h \Sigma \, \Theta_h' e_i\right)}, \qquad (2)$$

where the term Σ is a non-orthogonalized covariance matrix of errors corresponding to the VAR system. The term σ_{jj} is a vector of the standard deviations of the error term for the j^{th} equation, and e_i is an $(N + M) \times 1$ vector, which has 1 as the i^{th} element and zero as the other elements. The term Θ_h accounts for the coefficients that scale the h-lagged error in the infinite moving-average representation of VAR.

Pairwise directional spillovers from the regional housing market j to regional housing market i are estimated as follows:

$$C_{i \leftarrow j}^{H} = c_{ij}^{g}(H). \qquad (3)$$

The total directional spillovers from all other regional housing markets to the regional housing market i are calculated as the sum of off-diagonal values from the resulting connectedness matrix:

$$C_{i \leftarrow \cdot}^{H} = \sum_{\substack{j=1 \\ j \neq i}}^{N} c_{ij}^{g}(H). \qquad (4)$$

The total and off-diagonal sums of columns represent the total directional connectedness to other from j as:

$$C^H_{\cdot\leftarrow i} = \sum_{\substack{i,j=1\\ j\neq i}}^{N} c^g_{ij}(H). \tag{5}$$

We can also define net total directional connectedness as:

$$C^H_i = C^H_{\cdot\leftarrow i} - C^H_{i\leftarrow\cdot} \tag{6}$$

Finally, the total connectedness (system-wide connectedness) is the ratio of the sum of the “to-others” (from-others) elements of the variance decompositions matrix to the sum of all elements:

$$C^H = \frac{1}{N}\sum_{\substack{i,j=1\\ j\neq i}}^{N} c^g_{ij}(H) \tag{7}$$

To build the network topology of the connectedness of all markets, Diebold and Yilmaz (2014) used the variance decomposition matrix as the adjacency matrix of a weighted directed network (Mensi et al., 2018).

Note that, in computing the previous quantities, we focus only on the spillover generated within the real estate indexes, while the GVAR model also includes *K* macroeconomic drivers. We thus consider a subset of the generalized forecast error variance decomposition, namely the upper left $N \times \mathrm{N}$ block, properly scaled. While the spillover existing within the macroeconomic drivers is of limited interest, we consider as a further insightful element, the evaluation of the connectedness associated with the impact coming from macroeconomic drivers and impacting on the real estate variables, namely

$$C^H_{i\leftarrow \mathrm{macro}} = \sum_{\mathrm{j=N+1}}^{N+M} c^g_{ij}(H). \tag{8}$$

This quantity will monitor the impact of the mean spillover to the real estate variables coming from macroeconomic variables.

3.2 Quantile regression analysis

To first explore the structure and degree of dependence between total spillover and macro variables, we employ the quantile regression (QR) analysis, which allows us to analyze potential asymmetric dependence (i.e., upper and lower dependence). Compared with OLS, QR analysis is a useful tool to estimate the marginal effect for different quantiles of the dependent variable distribution, and it is less sensitive to the outliers (Koenker and Bassett, 1978). Therefore, the QR analysis can reveal information about the asymmetric and nonlinear effects of the independent variables on the dependent variable to provide the dynamic distributional change results. Thanks to this merit, QR analysis is widely used to model the dependence of financial variables and to examine the structure and degree of dependence (Chung et al., 2009; Lee and Li, 2012; Baur, 2013), Value at Risk (Engle and Manganelli, 2004; Shahzad, et al., 2018), and CoVaR (Adrian and Brunnermier, 2011). This technique has also been applied to investigate the impact of the driving factors on different quantiles (or different spillover situations) in equity markets (Mensi, et al., 2014; Gatfaoui, 2017; Lee and Cho, 2017; Peng et al., 2018), energy market (Zhu et al., 2016; Roth and Rajagopal, 2018), and housing markets (Kang and Liu, 2014; Al-Bahrani and Su, 2015).

Generally, the QR analysis specifies the conditional quantile as a linear function of explanatory variables and is given by:

$$y_i = x_i'\beta_\tau + \xi_{\tau,i},\ 0 < \tau < 1 \tag{9}$$

$$Q_\tau(y_i|x_i) \equiv \inf\{y: F_i(y|x) \geq \tau\} = x_i\beta_\tau\ , \tag{10}$$

where $Q_\tau(y_i|x_i)$ is the τ th conditional quantile of y_i given x_i, β_i is the vector of parameters to be estimated for different values of $\tau \in (0,1)$, $\xi_{\tau,i}$ is the error term, and $F_i(y|x)$ is the conditional distribution function of y given x. Thus, the values of coefficient β_τ is estimated by minimizing the weighted sum of absolute errors, as follows:

$$\hat{\beta}_\tau = \arg\min \textstyle\sum_{t=1}^{T} \left(\tau - 1_{\{y_t < x_t'\beta_t\}}\right) |y_t - x_t'\beta_\tau|, \tag{11}$$

Following prior literature (Koenker and Bassett, 1978; Koenker and Hallock, 2001), we employ the linear programming algorithm to develop a solution to the resulting minimization problem.

We explore the asymmetric and nonlinear relationship between the total spillover (TS) index and key macroeconomic variables such as the 91-day maturity CD rate, CPI, KOSPI, KRW-USD exchange rate, and money supply (M2). To examine the impact of the intervention of government economic policy, we also include the Korean economic policy uncertainty (KEPU) from Baker et al. (2015) that measures policy-related economic uncertainty in Korea.[3] Other macroeconomic variables are obtained from the Bank of Korea. The choice of these variables is motivated by their strong links to the housing market in Korea.

To determine the driver factor of total spillover, we estimate a QRA model specified as follows:

$$Q_{\tau}(rTS_t) = c(\tau) + \beta_{1\tau} rCD_t + \beta_{2\tau} rCPI_t + \beta_{3\tau} rKOSPI + \beta_{4\tau} rKRW + \beta_{5\tau} rM2_t + \beta_{6\tau} rEPU_t + \xi_t, \quad (12)$$

where $c(\tau)$ denotes a constant term, and Q_{τ} indicates the τ^{th} quantile in the explained variables of total spillover index (rTS). Moreover, the $\beta_{k\tau}$ parameter monitors the impact at the τ^{th} quantile of the dependent variable of the explanatory variables (rCD, $rCPI$, $rKOSPI$, $rKRW$, $rM2$, and $rKEPU$). Note that we use as explanatory variables the innovations obtained from the GVAR model. Therefore, while the VAR model accounts for the linear mean impact of the macroeconomic variables on the real estate variables, with QRA we evaluate the linear impact of macroeconomic variables on the quantiles of the spillover index. Consequently, our analysis will shed light on the role of macroeconomic variables going beyond what could be captured by a linear mean model (i.e. the VAR).

4. Sample data and descriptive statistics

[3] This index is based on the number of news articles published in six Korean national newspapers that contained terms related to economic policy uncertainty (see Baker et al. (2015) for more details).

This study uses both the monthly housing sales and *chonsei* (the rental housing price index in Korea) indexes from January 1991 to October 2016; this period spans 307 observations. Under the *chonsei* system, the tenant deposits a large sum of money—which can be up to 70% of the value of the house—with the owner (Kim, 2013), and after this lump sum is paid, no further monthly rent is required. At the end of the lease period (usually two years), the owner returns the key money deposit to the tenant. Data from the Kookmin Bank are used in this study. To examine cross-regional spillover and connectedness, we examine eight regional housing markets, that is, two districts in Seoul (Gangnam and Gangbuk) and six metropolitan cities (Busan, Deagu, Incheon, Gwangju, Daejeon, and Ulsan) in Korea.[4]

All housing sales and rental data were converted to returns by taking log percent differences. Table 1 summarizes the descriptive statistics and unit root tests of eight housing indexes in both housing sales (in Panel A) and rentals (in Panel B) markets. We find similarities in the sales and rental return series; however, the regional rental return series are more volatile than the corresponding sales return series. The distributions for all regional sales and rental returns do not satisfy the skewness and kurtosis criteria for normality. The high significance of the Jarque-Bera test statistics for normality confirms these results. In addition, two-unit root tests—the Augmented Dickey-Fuller (ADF) and Phillips-Perrron (PP) tests—show that all return series are stationary. Thus, the use of the VAR model is appropriate.

[Insert Table 1 here]

5. Empirical results

5.1. Total regional-spillovers index and pairwise connectedness

Table 2 reports the total time-invariant spillover index among regional housing sales

[4] We divided Seoul into the two sub-markets of Gangnam and Gangbuk; this is because the Korean government's housing policy tends to focus on the Gangnam housing market.

and rental markets and divides this into transmitters and receivers of return spillovers. In addition, it determines the amplitude to which assets are net transmitters or net recipients. The results show that the magnitude of the total spillover for sales (53.7% in Panel A) is lower than that for rentals (63.2% in Panel B).

Panel A in Table 2 shows that Gangnam is the largest contributor to other regional sales markets, contributing an average of 100.6% to other markets, while receiving 52.2% from other regional sales markets. Gangnam contributes 48.4% more in net terms to the remaining return markets than it receives from them. This Gangnam district (or South Korea's Beverly Hills) characterized by its exorbitant real-estate prices and wealthy residents. The second-largest contributor is Daegu, with a net contribution estimated at 40.2%; the gross directional return spillovers from Daegu to others are 86.5%, while the gross directional return spillovers of other regional sales markets to it are 46.3%. The other regional markets (Gangbuk, Busan, Incheon, Gwangju, Daejeon, and Ulsan) are net recipients because the sum of their contributions to the other markets is less than what they receive from them. More specifically, Daejeon and Gwangju are the largest net recipients due to the lack of industrial infrastructures and small populations relatively compared with other regional markets.

As in the housing sales market, the rental market in Panel B shows that Gangnam is the largest average contributor of spillovers to others (143%), followed by Gangbuk (106.6%). Ulsan is the largest recipient of spillovers, with the average contribution of all remaining regional housing markets estimated at 15.5%. Hence, Gangnam is the largest net transmitter of spillovers, with a net contribution of 81.4%, followed by Gangbuk (38.7%), Incheon (6.4%), and Deagu (2.2%). Ulsan, Busan, Daejeon, and Gwangju are net recipients of spillovers, with values of -45.7%, -35.7, -32.3, and -15%, respectively. As shown in Table 2, Gangnam has the highest net-pairwise connectedness, implying that Gangnam housing prices are the most influential transmitters in both housing markets.

Using the total spillover table, we can construct a matrix containing "net-pairwise directional connectedness" for all pairs in both housing sales and rental markets. The connectedness among variables can be shown on a network topology graph. Figs. 1(a) and 1(b) show "net" pairwise directional connectedness (network) among eight regional housing sales and rental markets, respectively. Note that the arrows between any two nodes are only one-way, and their color denotes the magnitude of the net-pairwise directional connectedness between the two nodes.

From Figs. 1(a) and 1(b), we can see that there are more net-pairwise links in the rental market than in the sales market, suggesting that the rental market has a more complex network connectedness. More importantly, we find Gangnam as a hub of connectedness, implying that Gangnam is the most influential transmitter of shocks across both types of regional housing markets. In particular, Gangnam has the highest net-pairwise connectedness with, and therefore the most direct influence on, Incheon (sales) and Busan (rentals). It is worth noting that Gangnam transmits risk to both Incheon and Gangbuk for both rental and sales markets. More interestingly, Gangbuk transmits risk to Incheon, indicating the presence of indirect effect. The indirect effect is present for the case of Gangnam, Gwangju and Busan housing markets. More precisely Gangnam is a transmitter of risk to both Gwangju and Busan and Gwangju receives risk from Busan. According to the Korean Statistical Information Service (KOSIS), the accumulated rate of nominal increase in house price in Seoul was 49.7%, which is almost double of the 28.5% increase in the other 6 large cities during 2006Q4-2007Q4. In addition, housing speculators purchased apartments in Gangnam of Seoul that are especially attractive to the middle and upper classes and as a result, housing prices soared at extraordinary rates. Thus, the housing prices of Gangnam have a strong influence on other regional housing markets in Korea.

Most of the net-transmitter regional markets (Gangbuk, Deagu, and Incheon) have a bidirectional connectedness with other regional housing markets. Including Gangnam, Gyeonggi province includes two nearby cities (Gangbuk and Incheon) which connect by Seoul metropolitan train system. Traditionally, Daegu is the old city of Conservative politics and elite schools in which people preferred this city for their successful life. They exchange shocks with one another. Conversely, all net-recipient regional markets (Busan, Gwangju, Daejeon, and Ulsan) are peripheral markets in net-pairwise connectedness, indicating that they receive shocks primarily from the hub market. Interestingly, two neighbor cities (Busan and Ulsan) more connected than two distant regions (Gwangju and Daejeon) in the rental markets. Gwangju is the six biggest city and has the second highest house price rise. It shows an increase of 3.9 per cent end 2018 followed by Daegu (3.6 per cent), Daejeon (2.5 per cent) and Incheon (0.7 per cent). Uslan is the seven largest city where the price dropped by 6.9 per cent in the same period followed by Busan (1.5 per cent). Busan is the second populous city followed by Incheon, Daegou. Daejeon, Gwangju. We note that the supply in the provinces is not symmetric as some provinces show over-supply, according to the Ministry of Land, Infrastructure and Transport.

[Insert Table 2 here]

[Insert Figure 1 here]

5.2. Rolling window analysis

Fig. 2 shows the dynamic total sales and rental spillover indexes across the eight regional housing markets by using a rolling window approach. They are in line with the results summarized in Table 2 and confirm that the magnitude of sales spillovers is lower than that of rental spillovers. Both spillover indexes show similar cyclical movements and magnitudes over the sample period. We observe that both spillover indexes reached their maximum levels (above 80%) during the 1997–1998 Asian currency crisis. However, relatively smaller changes in the spillover indexes occurred during the recent crises (the 2007–2009 GFC and 2010–2012 EDC). It is evident that the Asian currency crisis had a greater impact on the Korean regional housing markets than the recent financial crises.

[Insert Figure 2 here]

To deepen our analysis of the time-varying behavior of spillover indexes, we examine net spillovers, which uncover information on the direction of spillovers across the eight regional housing sales and rental markets. Positive (negative) values indicate a transmitter (recipient) of shocks to (from) other markets. Figs. 3 and 4 illustrate the net spillovers over time of sales and rental markets, respectively. In both sales and rental markets, Gangnam emerges as the largest transmitter, followed by Daegu and Gangbuk; the other markets (Busan, Incheon, Gwangju, Daejeon, and Ulsan) are net recipients of spillovers. This finding confirms that Gangnam has the greatest influence on the other regional housing markets in Korea.

[Insert Figures 3-4 here]

Macroeconomic factors play a significant role in the intensity and directions of the volatility spillovers. We follow Damianov and Elsayed (2018) to analyze the spillovers and network connectedness in Korean regional markets, using the spillover index of Diebold and Yilmaz (2014), after accounting for macro variables.[5] Tables 3 and 4 present the spillover matrix in regional housing sales and rent markets by accounting for macro variables.

The results reported in Tables 3 and 4 show that the Gangnam regional market is still the highest transmitter of risk to the other regional markets. Looking at the housing sales markets after accounting for macro variables, we show that Deagu is a net transmitter of risk while the other markets are net receipts of risk. This is principally because of the influence of the Korean stock market returns, the certificate of deposit rate, and the foreign exchange market. More interestingly, the risk from other markets for all Korean housing and regional markets has increased, indicating the crucial role of the macro variables in understanding the magnitude and

[5] The authors are grateful to an anonymous reviewer for suggesting adding the macro variables in the GVAR model.

the direction of risk spillovers.

Both tables show similar results between the Korean regional housing markets and macroeconomic variables. The most important sources of net spillovers are the CD rates, Korean exchange rate, and stock return among macroeconomic variables. It is well known that the changes in the bank interest rate (CD) influence housing markets because housing assets can be used as collateral for borrowing funds, especially for residential investments (Chu, 2018; Franjo, 2018; Vergara-Alert, 2018, among others). In addition, the KRW-USD exchange rate is the largest contributor to regional housing markets, followed by stock returns. Regional housing markets are affected by economic cycles. In particular, the Korean economy has suffered severe financial crises (i.e., the 1997 Asian currency crisis and 2008 global financial crisis), which led to the money tightness of the Korean currency and stock markets (Cho and Yoo, 2011; Kim and Kim, 2013; Meng, 2016; Kang and Suh, 2017). Thus, the financial crisis may cause an increase in the bank interest rate in the domestic housing debt market and then lead to a shortage of funds in the regional housing markets.

Furthermore, inflation and money supply are net receivers of spillover, indicating that changes in housing prices influence inflation and money supply. This is consistent with the study of Antonakakis et al. (2016), which finds spillovers from the housing market to the wider economy, especially through the pressure of inflation. Fig. 5 plots the time-varying spillovers across Korean housing markets and major macroeconomic variables. The graphical evidence exhibits period of upside trend particularly in 1997-1998 corresponding to the Asian crisis following the Asian crisis, the spillovers shows a constant trajectory followed by a sudden break in 2002. Thereafter, the spillovers ranges between 55% to 60% for the period 2004-2014. We note that the spillovers level of rents exceeds those of sales for almost all periods. This result shows that rental market is more volatile and more sensitive to the macro announcements. Figs 6 and 7 illustrate respectively the role of macro variables on Korean regional sale and rental markets. The results show that the regional housing markets exhibit period of net receipt altered by period of net transmitter. This results can be explained by whether the information transmitted to the housing market is good or bad.

[Insert Tables 3-4 here]

[Insert Figures 5-7 here]

5.3. What drives regional spillovers in the Korean housing market?

To determine the drivers of regional spillovers in the Korean regional housing markets, we use the QRA[6] of Koenker and Bassett (1978) and the traditional linear OLS regression for a comparison purpose. QRA provides a deeper insight into the dependence between two random variables. It explores the conditional dependence of a specific quantile of the spillovers index, with respect to the conditioning control variables (Mensi et al. 2014).[7] Compared with OLS, the QRA method is able to effectively estimate the marginal effect of the different quantiles of the distribution of the dependent variable (Tan and Yang, 2017). In fact, the impacts of the driving forces on housing market spillover effects under various quantiles are different. Practically, the QRA method is less sensitive to outliers to robust to departure from normality. Thus, the QRA provides robust information on the asymmetric and nonlinear effects of the independent (macroeconomic) variables on the dependent (spillover index) variable under the non-normality distribution (Mata and Machado, 1996; Fattouh et al., 2005; Lee and Cho, 2017). It is worth noting that the spillover index experiences significant changes that lead to a variability in the intensity of the effects of macro variables across quantiles.

The motivation behind using the QRA is to determine the nonlinear relationship between the potential determinant macroeconomic variables and regional spillovers under

[6] For more details on QRA, see Koenker (2005), Koenker and Bassett (1978), and Koenker and Hallock (2001).
[7] QRA is a popular method and is applied in different topics, including systematic risk and bankruptcy forecasting, among others (Bassett and Chen, 2001; Baur et al., 2012; Chuang et al., 2009; Engle and Manganelli, 2004; Li and Miu, 2010).

different degrees of spillover (from low to high). Table 5 presents the QRA estimates of the housing sales and rental markets, in the seven quantiles from 0.05 to 0.95.

The results show that the effects of macroeconomic variables depend on the Korean housing situation (low, normal, and high spillovers). More precisely, we show that the CD rate positively impacts housing sales under lower spillover (quantiles: $q = 0.05$ to $q = 0.25$) and negatively the rent market for lowest quantiles. Moreover, we find a negative and insignificant relationship between the CPI and housing sales regardless quantiles while the relationship is negative and significant for upper quantiles for rent market. The KOSPI positively impacts total spillovers in housing sales in high spillovers level. The KRW-USD exchange rate has a significant effect on housing sales spillovers for upper quantiles and for rent markets for lowest quantiles. The results are similar for M2 macro variable. This result is in line with the findings of Tsai (2015). The KEPU affects total spillovers in housing sales in low and high spillover, but for the housing rental market, we find a significant relationship for lowest quantile and for $q = 0.75$.

Fig. 8 displays the trajectories for all the quantiles and conditioning variables for sales and rental housing markets in Korea. The graphical evidence is in line with the results reported in Table 5. To conclude, the relationship between the factors driving spillovers in the regional housing markets is symmetric, and the magnitude depends on the degree of housing spillovers.

[Insert Table 5 here]

[Insert Figures 8 here]

Checking whether the coefficients of the QR results are homogeneous or heterogeneous is important. More specifically, we test if the slopes are constant over quantiles. To do this, we use the Wald test (Koenker and Bassett, 1982) to test the null hypothesis of equality of slopes across quantiles against the alternative hypothesis of heterogeneity of slopes. Table 6 reports the results of the Wald test for the equality of slopes for the quantile $q = 0.05$ against quantiles

$q = 0.5$ and $q = 0.95$ (results for the remaining cases are available upon request). Except for the case of the CPI and M2 variables for sales (CPI, KOPSI, KRW-USD index for rent market), the results strongly reject the null of homogeneity slopes when we compare that quantile against medium quantiles. This result indicates that the coefficient varies across quantiles. The result also indicates that the effect of macroeconomic variables on risk spillovers depends on the level of risk spillovers. The result is less pronounced for quantiles against $q = 0.95$.

[Insert Table 6 here]

6. Conclusions

This paper examines the spillover effects and connectedness among regional housing markets in Korea. We used the spillover indexes of Diebold and Yilmaz (2014). We emphasize the importance of net pairwise network connectedness in regional housing markets as a measure of how shocks are transmitted across these markets. The major finding shows that the Gangnam region has been the most influential regional housing market, followed by Gangbuk region. This finding reinforces the importance of Gangnam within the region and provides significant policy implications for housing investors. We also find that the financial crises, i.e., the 1997 Asian currency crisis, 2007–2009 GFC, and 2010–2012 EDC, intensify the spillover effects across the Korean regional housing market. Although Gangnam remains at the hub of the Korean housing market, neighboring regions have become increasingly influential in affecting other regional markets in the connectedness network, which should be considered by real-estate policies. These results may have important implications for policymakers as well as managers of REITs.

In addition, we used the QRA to explore the macroeconomic determinant factors (91-day maturity CD rate, CPI, KOSPI, KRW-USD exchange rate, M2, and KEPU) on the spillovers of housing markets. The QRA results reveal that macroeconomic factors have symmetric impacts on different degrees of spillover (low, normal, and high). To reduce the risk of housing spillovers, policymakers should apply customized policies according to different housing market situations. For example, changes in interest rates have a negative impact on the Korean housing market under high spillover. In contrast, changes in money supply positively impact total housing spillovers in low and normal spillovers. In addition, economic uncertainty affects spillovers in low spillover, while changes in the exchange rate have an insignificant relationship across all quantiles.

These findings appeal to both real estate investors and policymakers in two ways. First, the network of housing spillovers helps investors understand the mechanism of housing risk transmission, minimize exposed spillover risk, and construct optimal housing portfolios across regional markets. Second, housing market conditions are directly related to national economics. To stabilize the housing market, policymakers must understand the relationship between macroeconomic factors and housing spillovers under different market conditions.

Inflation negatively responds to Korean housing spillovers. This negative dependence indicates that an increase in inflation reduces interaction in Korean regional housing. This recoupling hypothesis reveals that housing purchases can play the role of an effective hedge for inflation. The positive relationship between M2 and the spillovers index indicates that a larger money supply lowers market long-term interest rates, which decreases the yield of fixed income financial assets (bonds) relative to the return of housing. The bank of Korea can thus act on monetary policy (interest rates or monetary price) and money supply (monetary quantity) to stabilize inflation and reduce the housing market connectedness. This policy shifts the investment from bonds to real estate. The Korean stock exchange market returns significantly influence regional housing spillovers.

This study can be generalized to the other tiger countries (Taiwan, Hong Kong, and Singapore) by analyzing the returns and volatility spillovers in housing sales and rental markets under different time horizons (short, medium, and long term).

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Table 1. Descriptive statistics and unit root tests.

	Mean	Max.	Min.	Std. dev.	Skew.	Kurt.	Jarque-Bera	ADF	PP
Panel A: Sales									
Gangnam	0.354	5.533	-4.292	1.1262	0.578	6.874	252.05***	-7.947***	-7.939***
Gangbuk	0.196	3.918	-3.504	0.7826	0.883	8.992	601.81***	-6.638***	-9.336***
Busan	0.270	7.019	-2.391	0.8966	2.287	13.42	3101.5***	-5.477***	-11.12***
Deagu	0.250	7.755	-5.573	0.9841	1.627	15.42	3830.8***	-6.101***	-9.599***
Incheon	0.251	4.461	-2.746	0.8636	0.930	6.073	199.04***	-6.389***	-7.952***
Gwangju	0.166	9.761	-7.107	0.8927	2.321	47.26	34766. ***	-5.273***	-14.94***
Daejeon	0.203	5.072	-3.041	0.7463	1.450	11.82	1330.4***	-9.987***	-10.38***
Ulsan	0.338	4.772	-5.706	0.8856	-0.567	11.21	1960.2 ***	-3.926***	-13.97***
Panel B: Rent									
Gangnam	0.499	13.21	-10.29	1.7806	0.353	14.88	2184.5***	-5.618***	-9.151***
Gangbuk	0.439	14.08	-10.24	1.5557	1.064	24.99	7526.6***	-3.587***	-10.21***
Busan	0.405	14.01	-4.343	1.1933	4.405	49.95	35193. ***	-14.26***	-8.054***
Deagu	0.411	12.76	-6.242	1.3942	2.518	26.35	8799.4***	-5.594***	-11.45***
Incheon	0.549	6.272	-5.681	1.3373	0.908	7.520	365.92***	-4.144***	-9.227***
Gwangju	0.340	10.46	-8.585	1.0921	1.276	35.57	16458.***	-5.155***	-12.64***
Daejeon	0.407	9.942	-5.645	1.4246	1.481	14.92	2327.0 ***	-13.07***	-12.85***
Ulsan	0.452	5.934	-13.24	1.3078	-3.270	43.19	25561. ***	-7.811***	-16.76***

Note: ADF and PP denote the augmented Dickey Fuller test and the Phillip-Perron unit root test, respectively. ** and *** indicate significance at the 5% and 1% levels, respectively.

Table 2. Cross-regional spillovers in the Korean housing market.

	Gangnam	Gangbuk	Busan	Deagu	Incheon	Gwangju	Daejeon	Ulsan	**From others**	**Net**	**Conclusions**
Panel A: Housing Sales											
Gangnam	47.8	16.48	6.17	8.05	10.44	0.75	4.21	6.09	52.2	48.4	Net-transmitter
Gangbuk	29.81	34.58	6.33	6.57	10.53	2.82	2.65	6.72	65.4	-0.2	Neutral
Busan	9.54	9.73	39.17	19.28	4.42	2.54	4.02	11.3	60.8	-12	Net-recipient
Deagu	7.96	5.95	10.29	53.7	5.7	4.97	2.58	8.85	46.3	40.2	Net-transmitter
Incheon	28.52	19.02	7.08	6.98	31.23	0.5	0.65	6.03	68.8	-26.3	Net-recipient
Gwangju	2.98	3.41	4.73	22.76	3.45	53.14	1.59	7.94	46.9	-27.6	Net-recipient
Daejeon	11.59	5.58	8.99	3.36	4.86	2.22	61.09	2.32	38.9	-21.3	Net-recipient
Ulsan	10.2	5	5.22	19.54	3.1	5.47	1.87	49.61	50.4	-1.2	Net-recipient
To others	100.6	65.2	48.8	86.5	42.5	19.3	17.6	49.2	429.7		
All	148.4	99.7	88	140.2	73.7	72.4	78.7	98.8	**Total**: 53.70%		
Panel B: Housing Rent											
Gangnam	38.43	24.95	5.46	6.44	13.76	3.9	5.69	1.37	61.6	81.4	Net-transmitter
Gangbuk	29.29	32.11	7.31	6.85	14.38	3.64	5.49	0.92	67.9	38.7	Net-transmitter
Busan	21.79	16.51	25.57	14.84	6.61	4.39	6.78	3.51	74.4	-35.7	Net-recipient
Deagu	16.37	10.41	9.35	38.88	10.31	7.31	3.37	4	61.1	2.2	Net-transmitter
Incheon	25.97	20.6	4.14	5.45	35.48	3.33	3.48	1.55	64.5	6.4	Net-transmitter
Gwangju	12.7	8.46	3.09	13.87	8.37	47.74	3.04	2.74	52.3	-15	Net-recipient
Daejeon	21.09	14.16	4.85	4.91	10.52	5.86	37.25	1.37	62.7	-32.3	Net-recipient
Ulsan	15.77	11.51	4.54	10.98	6.94	8.86	2.56	38.84	61.2	-45.7	Net-recipient
To	143	106.6	38.7	63.3	70.9	37.3	30.4	15.5	505.7		
All	181.4	138.7	64.3	102.2	106.4	85	67.7	54.3	**Total**: 63.20%		

Note: This table presents the estimated contribution to the variance of the 48-month forecast variance error.

Table 3. Cross-regional spillovers in the Korean rent markets with macroeconomic variables.

	Gangnam	Gangbuk	Busan	Deagu	Incheon	Gwangju	Daejeon	Ulsan	CD	CPI	KRW	KOSPI	M2	KEPU	From
Gangnam	33	23.94	3.88	5.4	15.67	3.69	10.07	0.48	0.3	1.23	0.8	1.09	0.06	0.39	67
Gangbuk	26.61	27.79	5.34	5.1	17.51	4.7	9.42	0.22	0.19	1.79	0.54	0.43	0.05	0.3	72.2
Busan	20.7	18.73	19.06	6.49	12.75	6.39	11.86	0.17	0.11	2.02	0.46	0.44	0.41	0.43	80.9
Deagu	18.73	13.34	2.52	26.93	15.59	9.16	7.02	0.42	0.36	0.73	2.34	1.52	0.24	1.1	73.1
Incheon	26.09	22.42	2.71	3.29	30.93	1.76	8.01	0.3	0.16	2.07	0.61	0.93	0.1	0.62	69.1
Gwangju	12.07	10.06	3.33	12.98	8.76	40.21	6.98	0.6	0.5	1.38	1.03	0.73	1.12	0.24	59.8
Daejeon	16.9	14.91	6.11	5.51	12.28	5.63	35.26	0.29	0.19	1.67	0.14	0.29	0.57	0.26	64.7
Ulsan	13.46	12.12	5.17	4.05	6.6	5.58	2.83	41.31	2.72	1.95	1.54	1.05	1.29	0.33	58.7
CD	2.29	2.33	1.31	3.43	1.48	1.55	1.04	3.19	56.64	3.1	16.87	4.2	0.78	1.78	43.4
CPI	3.34	2.37	0.93	1.73	3.1	2.25	3.05	0.64	4.95	60.1	13.34	2.44	0.87	0.9	39.9
KRW	0.31	0.96	0.2	2.12	1.62	0.83	0.82	1.08	8.13	3.48	58.63	17.1	1.01	3.71	41.4
KOSPI	0.75	0.59	0.37	1.35	0.73	0.49	0.65	1.1	2.59	1.29	13.32	68.38	2.66	5.73	31.6
M2	2.37	1.63	1.16	0.95	1.29	3.63	1.28	1.84	1.74	2.93	3.93	0.96	75.68	0.61	24.3
KEPU	0.74	0.33	0.1	0.45	0.47	0.09	1.45	0.1	1.19	0.6	4.4	5.48	0.14	84.46	15.5
To	144.4	123.7	33.1	52.8	97.8	45.7	64.5	10.4	23.1	24.2	59.3	36.7	9.3	16.4	741.6
All	177.4	151.5	52.2	79.8	128.8	86	99.7	51.7	79.8	84.3	117.9	105	85	100.9	53.00%
Net	77.4	51.5	-47.8	-20.3	28.7	-14.1	-0.2	-48.3	-20.3	-15.7	17.9	5.1	-15	0.9	

Note: See the notes in Table 2.

Table 4. Cross-regional spillovers in the Korean housing sales markets with macroeconomic variables.

	Gangnam	Gangbuk	Busan	Deagu	Incheon	Gwangju	Daejeon	Ulsan	CD	CPI	KRW	KOSPI	M2	KEPU	From
Gangnam	43.69	15.23	4.4	9.35	12.46	0.29	3.36	1.24	1.52	0.69	5.09	1.19	0.86	0.61	56.3
Gangbuk	30.01	31.14	4.03	5.86	15.32	0.45	1.5	1.32	1.62	0.37	5.53	1.4	0.74	0.7	68.9
Busan	9.23	5.42	41.43	13.64	8.8	1.23	8.61	0.63	1.14	0.3	5.88	1.48	1.93	0.27	58.6
Deagu	6.65	1.16	5.37	45.31	5.7	4.32	3.37	1.37	3.15	1.8	11.55	7.35	2.22	0.7	54.7
Incheon	28.59	20.76	5.34	5.6	32.01	0.14	1.08	1.18	1.42	0.26	2.27	0.56	0.33	0.45	68
Gwangju	2.16	0.65	8.26	17.71	1.97	36.17	1.93	5.07	1.57	0.97	14.11	5.53	2.87	1.04	63.8
Daejeon	9.08	3.88	15.4	7.15	6.34	1.14	49.37	0.25	0.88	0.44	5	0.33	0.53	0.2	50.6
Ulsan	12.54	3.94	8	11.85	4.56	5	1.43	41.95	1.13	1.16	4.04	1.65	2.25	0.48	58
CD	0.36	0.2	0.28	2.42	0.69	5.14	0.8	2.61	61.55	1.96	17.07	3.88	1.39	1.66	38.5
CPI	0.89	0.79	0.19	3.62	0.66	0.25	0.19	0.98	3.42	70.43	13.75	2.63	1.55	0.64	29.6
KRW	0.77	0.09	0.4	2.83	0.18	1.04	0.21	0.24	7.18	3.23	62.18	16.6	1.41	3.64	37.8
KOSPI	2.45	1.06	1	2.02	0.44	0.35	0.29	0.77	2.53	1.25	13.6	66.47	2.48	5.29	33.5
M2	1.14	0.11	3.31	7.61	0.59	2.88	0.69	0.71	1.94	2.7	3.63	1.11	73.42	0.17	26.6
KEPU	0.04	0.08	0.07	0.18	0.09	0.37	0.51	0.28	1.07	0.61	4.39	5.29	0.06	86.97	13
To	103.9	53.4	56.1	89.8	57.8	22.6	24	16.7	28.6	15.7	105.9	49	18.6	15.8	657.9
All	147.6	84.5	97.5	135.2	89.8	58.8	73.3	58.6	90.1	86.2	168.1	115.5	92	102.8	47.00%
Net	47.6	-15.5	-2.5	35.1	-10.2	-41.2	-26.6	-41.3	-9.9	-13.9	68.1	15.5	-8	2.8	

Note: See the notes of Table 2.

Table 5. Quantile regression estimates for the Korean housing sales market.

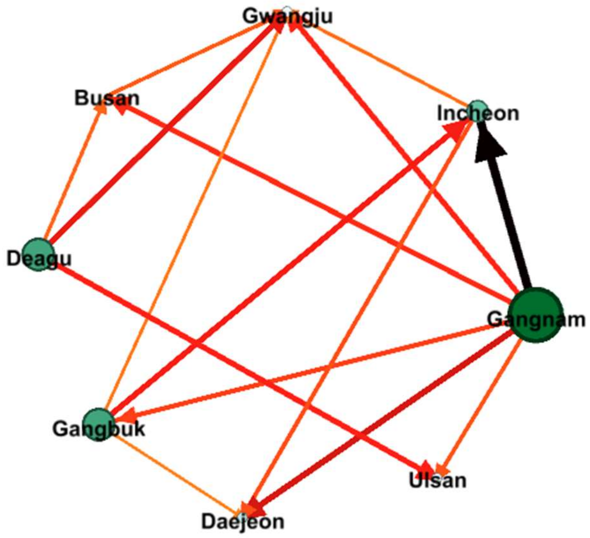
	Q(0.05)	Q(0.10)	Q(0.25)	Q(0.50)	Q(0.75)	Q(0.90)	Q(0.95)
Panel A: Korean housing sales market							
$\beta_1 rCD$	0.0273*** (0.0076)	0.0105* (0.0058)	0.0045* (0.0025)	0.0006 (0.0017)	0.0027 (0.0020)	0.0042 (0.0050)	0.0049 (0.0068)
$\beta_2 rCPI$	0.0061 (0.0047)	-0.0022 (0.0051)	-0.0006 (0.0012)	0.00015 (0.0010)	-0.0007 (0.0015)	-0.0017 (0.0031)	-0.0008 (0.0086)
$\beta_3 rKOSPI$	0.0143*** (0.0048)	0.0035 (0.0049)	-0.0002 (0.0014)	-0.00006 (0.0011)	-0.0017 (0.0017)	-0.00021 (0.0035)	-0.0007 (0.0055)
$\beta_4 rKRW$	0.0181 (0.0039)	0.0069 (0.0064)	0.0010 (0.0018)	0.0005 (0.0015)	0.0037* (0.0022)	0.0123*** (0.0046)	0.0185*** (0.0052)
$\beta_5 rM2$	-0.0057 (0.0053)	-0.0017 (0.0033)	0.00008 (0.0011)	0.0005 (0.0010)	0.0028 (0.0019)	0.0079** (0.0036)	0.0082 (0.0054)
$\beta_6 rKEPU$	-0.0088** (0.0041)	-0.0014 (0.0046)	0.0003 (0.0012)	-0.0009 (0.0011)	-0.0038*** (0.0011)	-0.0062*** (0.0022)	-0.0046*** (0.0053)
Pseudo R^2	0.12411	0.04219	0.01493	0.00455	0.03430	0.08413	0.15589
Panel B: Korean housing rent market							
$\beta_1 rCD$	-0.009*** (0.0029)	-0.0003 (0.0055)	0.0010 (0.0009)	-0.0005 (0.0008)	-0.0021* (0.0012)	-0.0031 (0.0026)	-0.0042* (0.0023)
$\beta_2 rCPI$	-0.0019 (0.0034)	-0.0013 (0.0044)	-0.0006 (0.0009)	-0.0003 (0.0007)	-0.0005 (0.0009)	-0.0046* (0.0025)	-0.0095*** (0.0031)
$\beta_3 rKOSPI$	0.0017 (0.0018)	0.0009 (0.0030)	-0.0004 (0.0009)	-0.0003 (0.0008)	-0.0005 (0.0014)	-0.0015 (0.0031)	-0.0027 (0.0043)
$\beta_4 rKRW$	-0.0103** (0.0045)	-0.0029 (0.0105)	-0.0005 (0.0009)	-0.0002 (0.0007)	-0.0002 (0.0008)	0.0012 (0.0017)	0.0028 (0.0018)
$\beta_5 rM2$	-0.011*** (0.0022)	-0.00003 (0.0069)	-0.0003 (0.0008)	-0.0004 (0.0008)	-0.0002 (0.0011)	-0.0017 (0.0018)	-0.0047** (0.0020)
$\beta_6 rKEPU$	0.0091*** (0.0016)	0.0037 (0.0053)	0.00003 (0.0008)	-0.00005 (0.0010)	0.0027*** (0.0008)	-0.00009 (0.0016)	-0.0009 (0.0046)
Pseudo R^2	0.11308	0.02215	0.00144	0.00432	0.02176	0.05733	0.14222

Notes: Standard errors are in parentheses. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

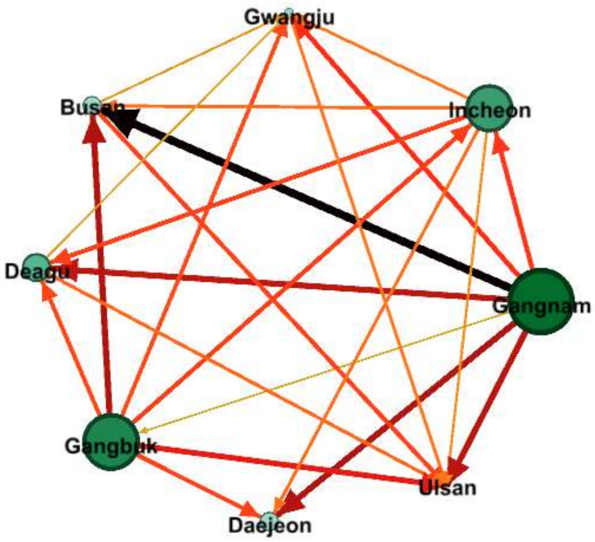
Table 6. Wald tests for the equality of slopes (0.05 against 0.5 and 0.95 quantiles).

	Against the 0.5 quantile		Against the 0.95 quantile	
	Test-statistic	p-value	Test-statistic	p-value
Panel A: Sales				
$\beta_1 rCD$	0.0266***	0.0004	-0.0042	0.5307
$\beta_2 rCPI$	0.0060	0.1971	0.0009	0.9080
$\beta_3 rKOSPI$	0.0144***	0.0026	0.0006	0.9014
$\beta_4 rKRW$	0.0176***	0.0000	-0.0179***	0.0007
$\beta_5 rM2$	-0.0062	0.2336	-0.0077	0.1484
$\beta_6 rKEPU$	-0.0078*	0.0537	0.0037	0.4764
Panel B: Rent				
$\beta_1 rCD$	-0.0086***	0.0033	-0.0048	0.1892
$\beta_2 rCPI$	-0.0016	0.6276	0.0076*	0.0936
$\beta_3 rKOSPI$	0.0020	0.2898	0.0044	0.3392
$\beta_4 rKRW$	-0.0101	0.0232	-0.0131**	0.0066
$\beta_5 rM2$	-0.0109***	0.0000	-0.0065*	0.0576
$\beta_6 rKEPU$	0.0092***	0.0000	0.0101**	0.0369

Notes: This table presents the estimated results of the Wald test for equality of slopes (0.05 against each of 0.5 and 0.95 quantiles). The asterisks *, ** and *** denote statistical significance at the 0%, 5%, and 1% levels, respectively.



(a) Sales



(b) Rentals

Fig. 1. Net-pairwise network connectedness: (a) Sales and (b) Rentals

Notes: This chart displays the directional connectedness among the 56 pairs of housing markets. Black, red, and orange links (black, gray, and light gray when viewed in grayscale) correspond to the tenth, twentieth, and thirtieth percentile of all net-pairwise directional connectedness. The node size shows the magnitude of net-pairwise directional connectedness, the colors of the nodes range from green (strongest) to light blue to white (weakest), and the arrows show the direction of the net-pairwise connectedness.

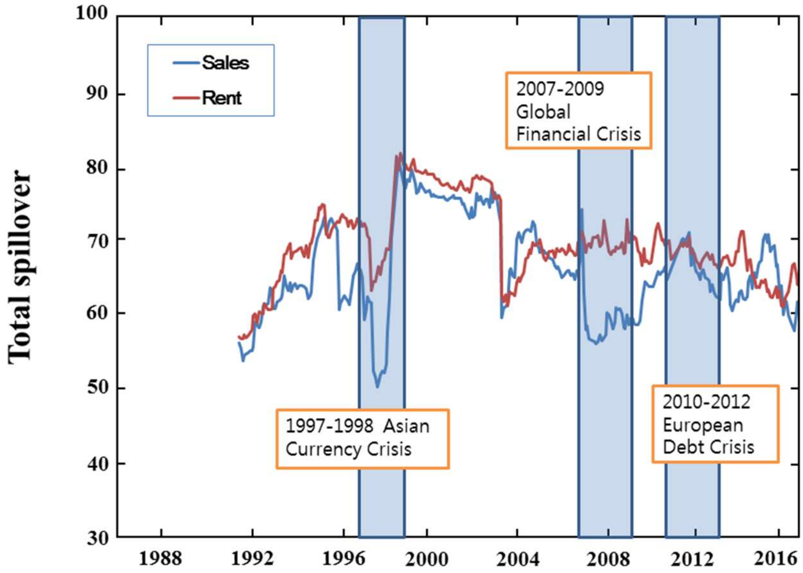
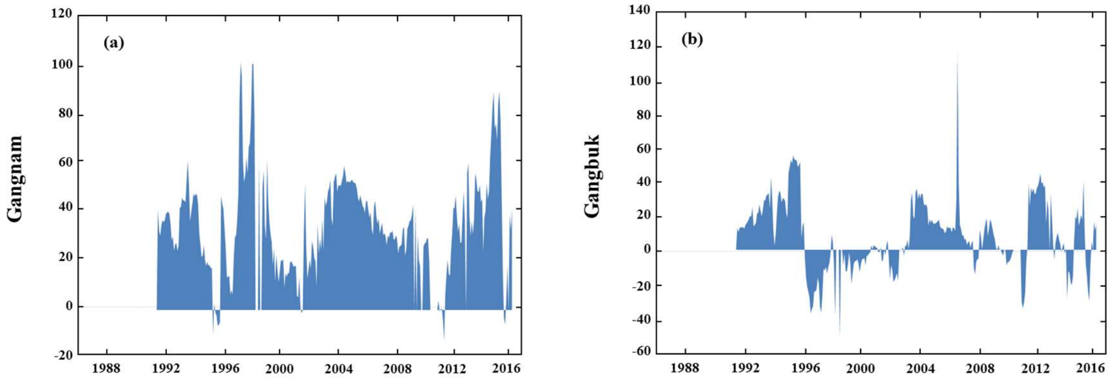


Fig. 2. The dynamics of regional spillovers across Korean housing markets



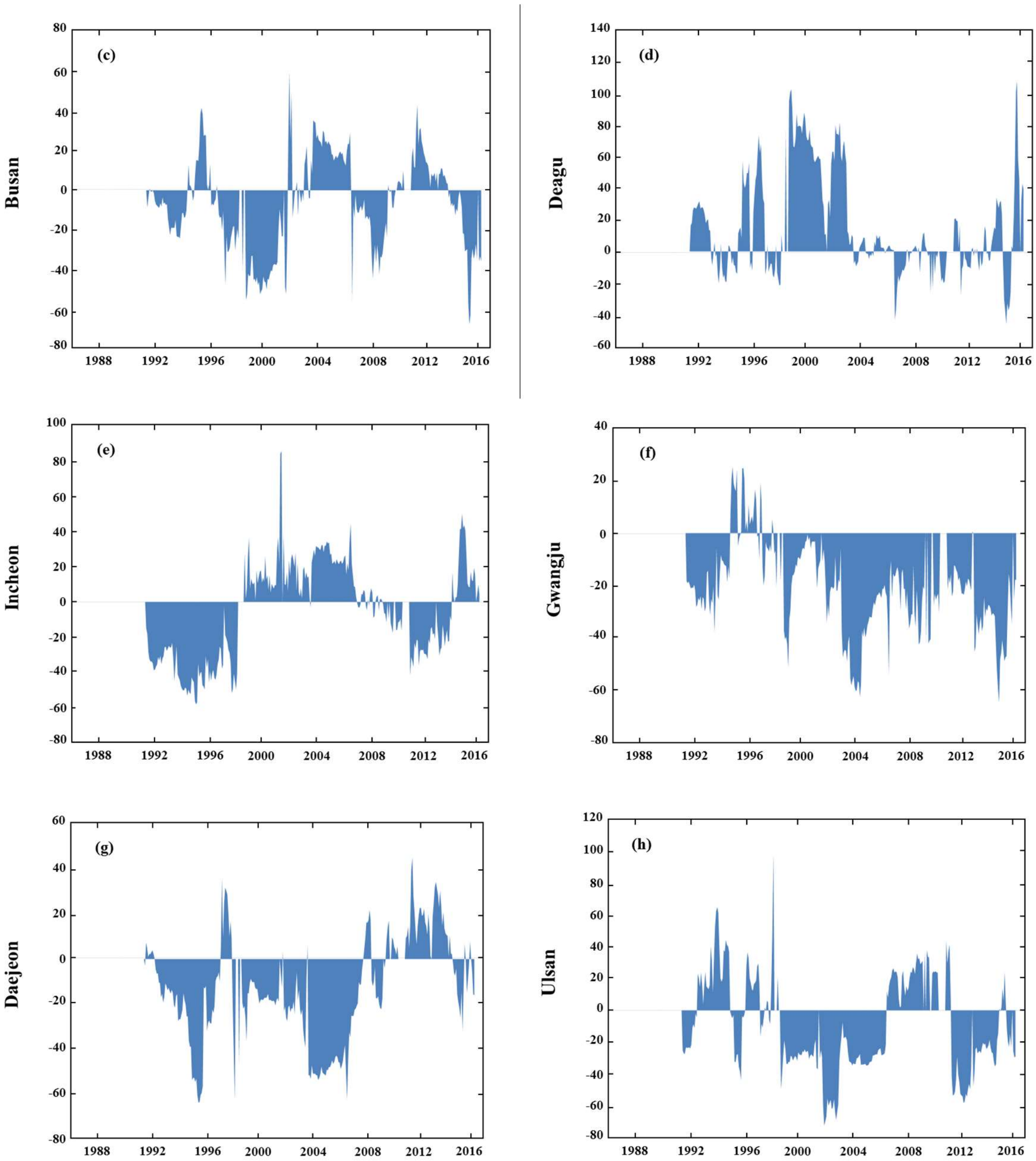
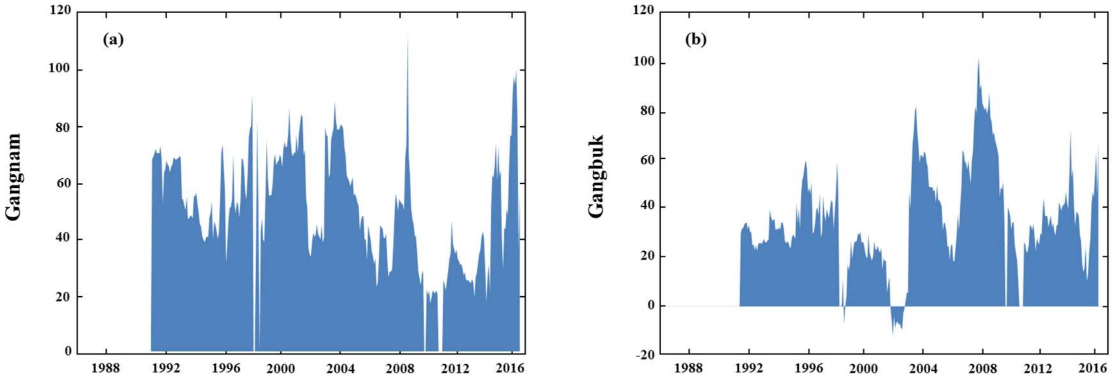


Fig. 3. The dynamics of regional spillovers across Korean housing sales markets



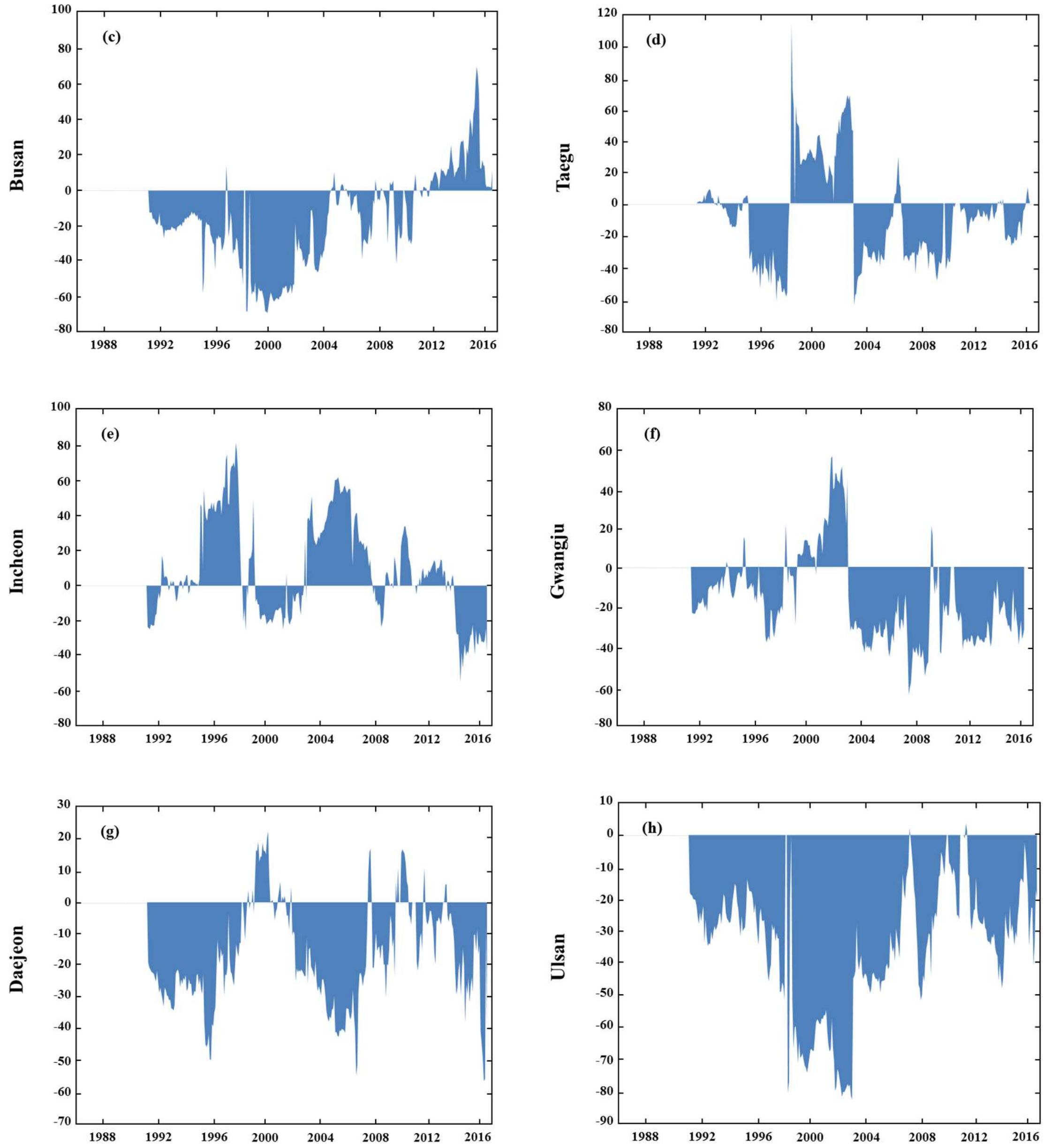


Fig. 4. The dynamics of regional spillovers across Korean housing rental markets

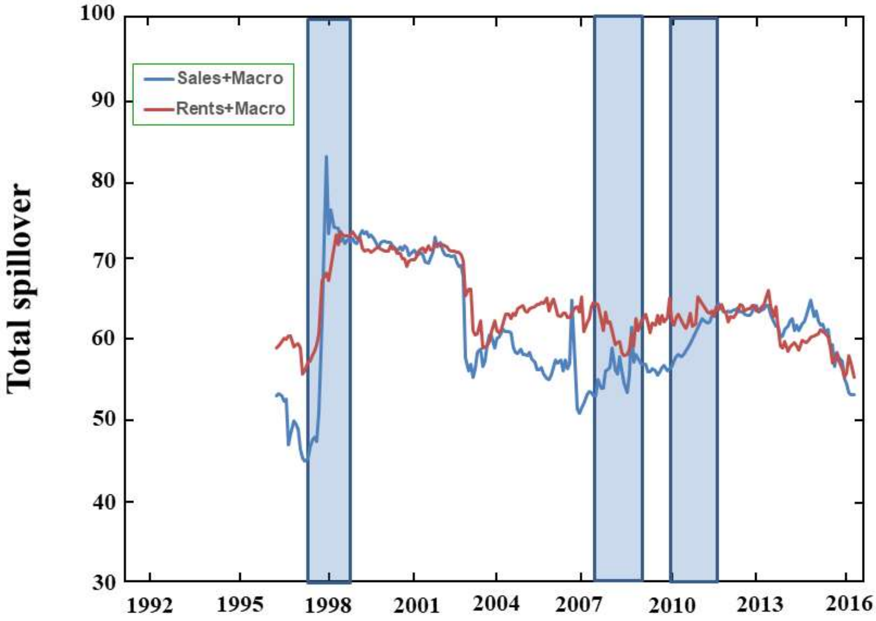


Fig. 5. The dynamics of total spillovers across Korean regional housing markets and macro-economic variables.

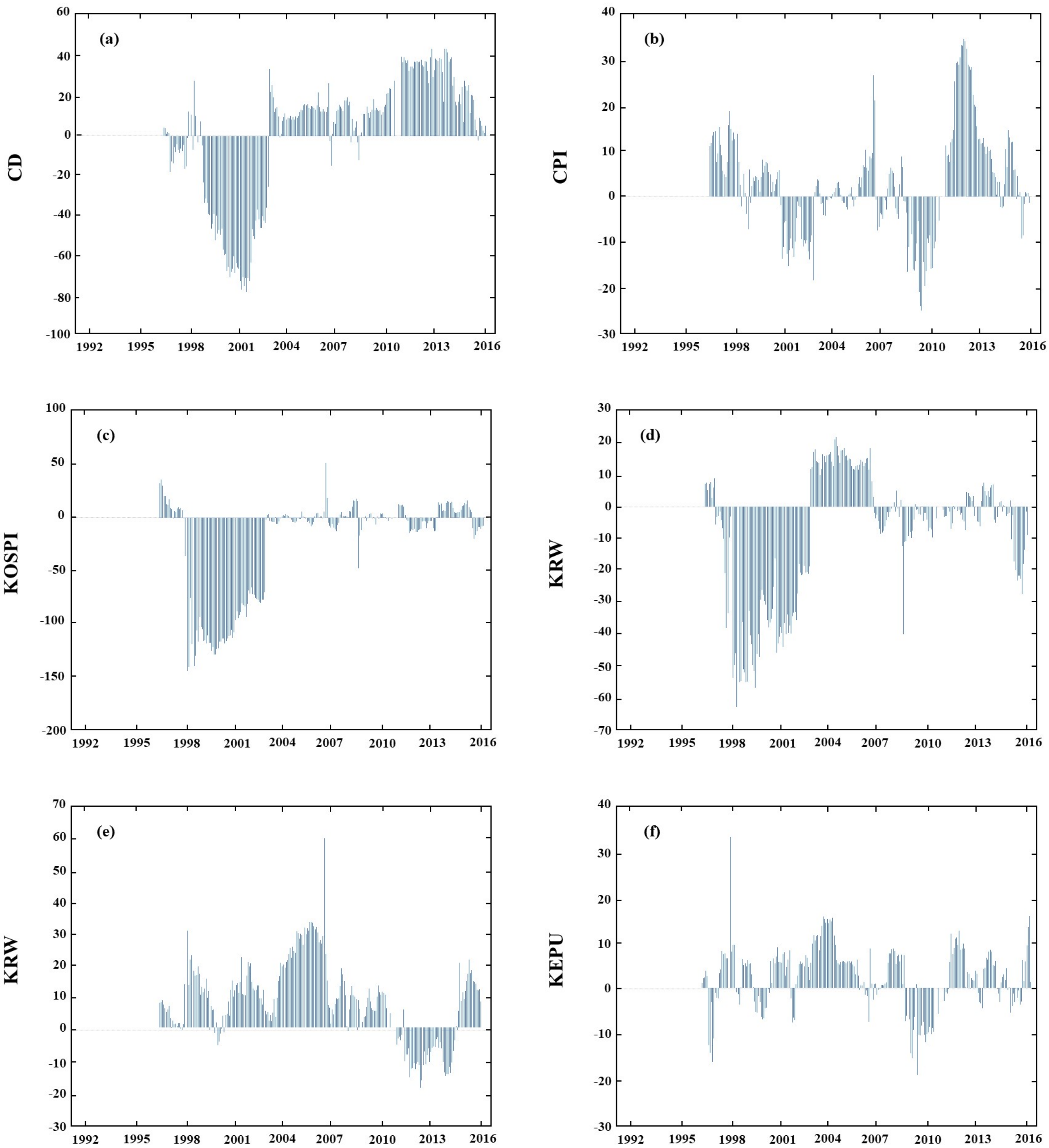


Fig. 6. The impact of macro-economic variables on the Korean regional sale markets.

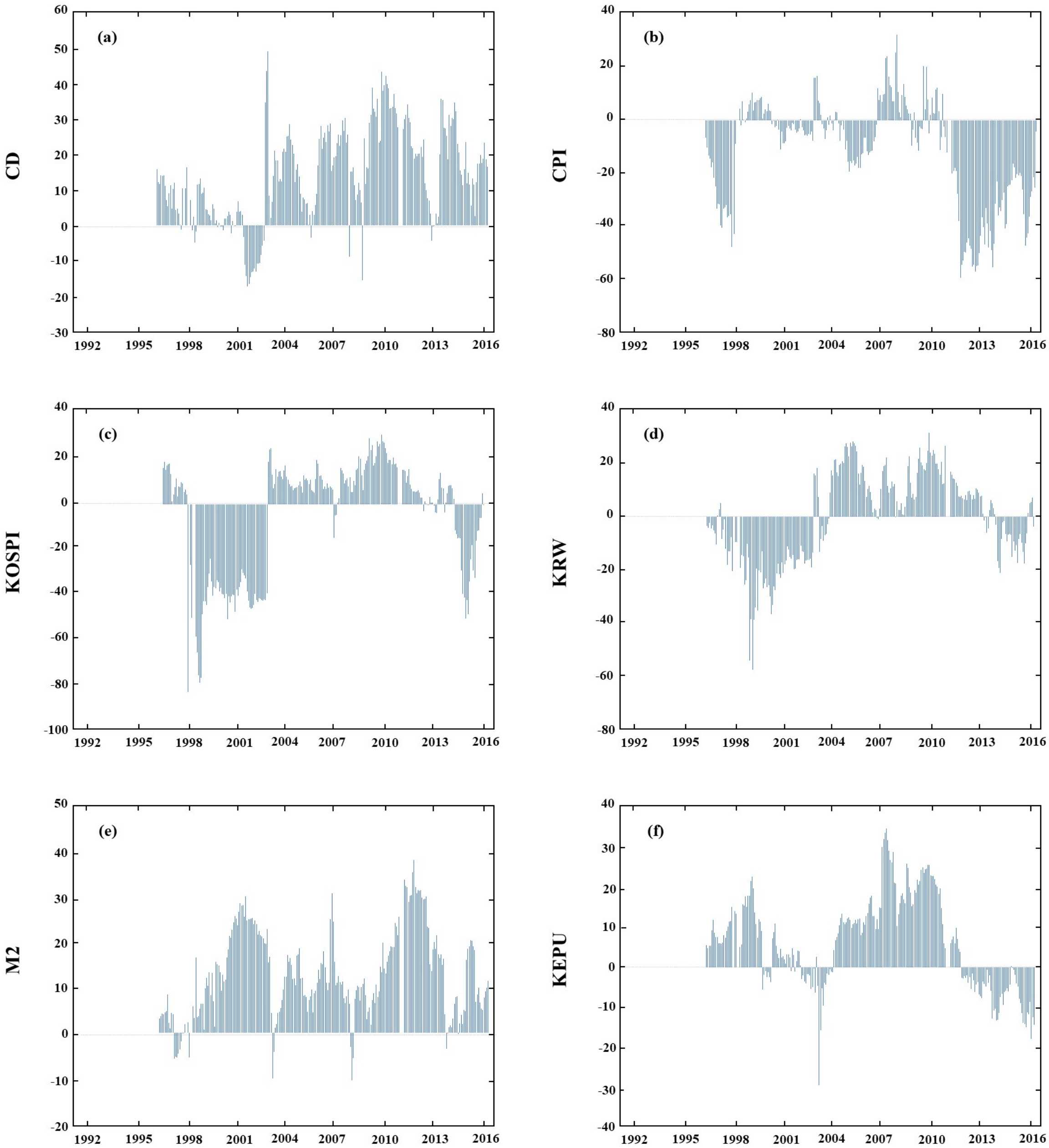
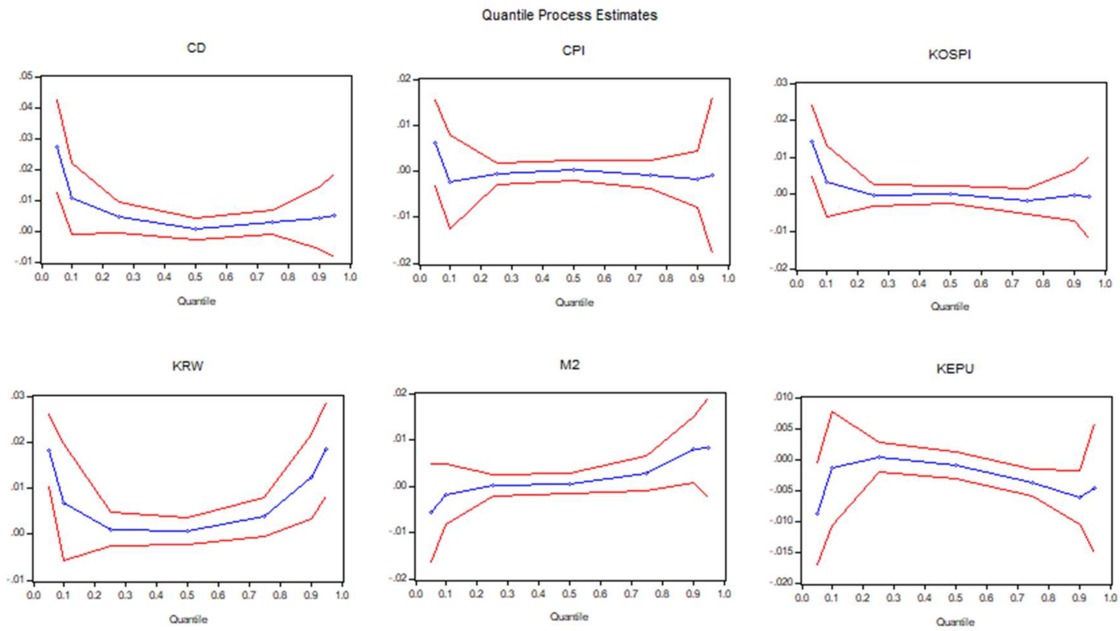


Fig. 7. The impact of macro-economic variables on the Korean regional rental markets.

A) Sales



B) Rentals

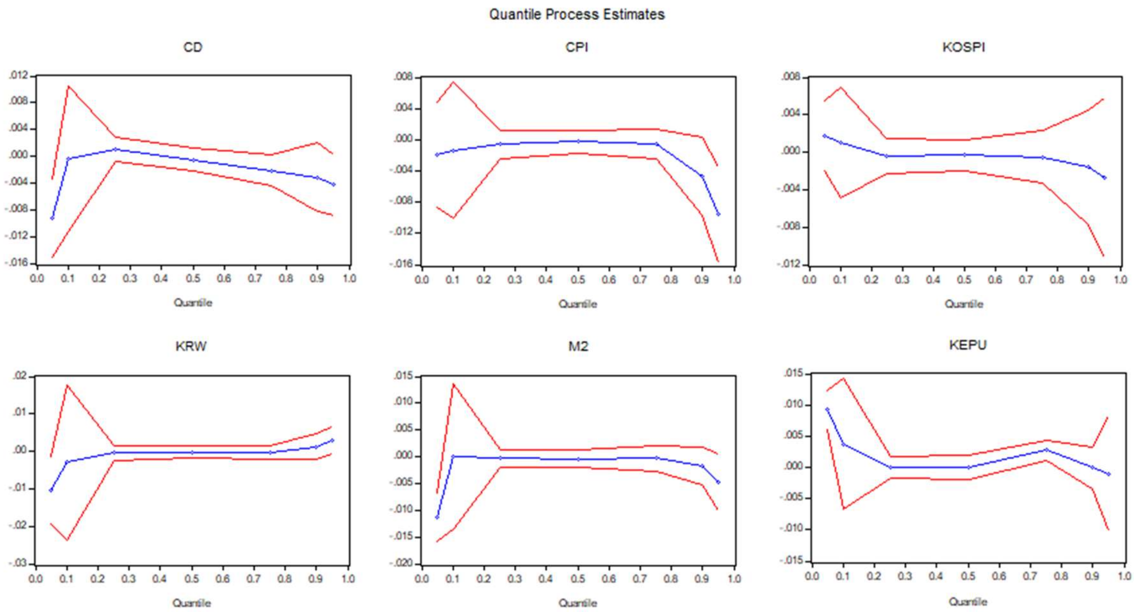


Fig. 8. Changes in the quantile regression coefficients

Notes: Red lines represent a 95% confidence band. The vertical axis denotes the regression coefficients of the explanatory variables at different quantile points.