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Korean Housing Cycle: Implications for Risk Management (Factor-augmented VAR Approach)†

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This paper proposes an integrated risk-management framework that includes 1) measuring the risk of credit portfolios, 2) implementing a (macro) stress test, and 3) setting risk limits using the estimated systematic latent factor specific to capture the housing market cycle. To this end, we extract information from a set of real-estate market variables based on the FAVAR methodology proposed by Bernanke, Boivin and Eliasz (2005). Then, we show the method by which the estimated systematic factor is applied to risk management in the housing market in an integrated manner within the Vasicek one-factor credit model. The proposed methodology is well fitted to analyze the risk of slow-moving and low-defaultable forms of capital, such as alternative investments.

Key Word: Housing Cycle, FAVAR, Risk Management
JEL Code: R3, E17, G32

I. Introduction

South Korea's housing market has been highlighted for its contribution to the overall economy, which has been suffered from feeble consumer spending and sagging industrial output. South Korea's brisk property market with housing transactions and pre-sales of new apartments soaring across the nation, due to record-low interest rates and inexpensive household mortgages, is touching the boundary of a speculative bubble.[1] At present, an oversupply of new houses and tighter lending rules may signal a property market bubble within the coming years.

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[1] "Apartment prices have soared to 300 million won ($272,000) over the past three months on the news of rebuilding aged flat houses" citing a realtor's interview with The Korea Times.

The importance of risk management in the real-estate market is growing rapidly.[2]

However, identifying the risk profile is a Herculean task with regard to the real-estate market. Practitioners have relied on a rather ad-hoc approach to calculating the default probability of housing and construction firms. To be specific, employing loan-specific predictors such as delinquencies, interest in arrears, or loan-to-value (or debt- equity) ratios and other idiosyncratic drivers have been the norm after controlling for macroeconomic variables. In terms of holding portfolios, however, these idiosyncratic drivers should be diversified away.[3] Empirically, Duffie *et al*. (2009) find strong evidence of the presence of common latent factors, and Aron and Muellbauer (2016) emphasize the role of latent factors in the modeling and forecasting of mortgage delinquencies and foreclosures.

In this paper, we ask relevant but nuanced questions: what is the systematic (latent) factor within the housing market and its role in the risk management? What are the policy implications? To study these issues, we utilize the Vasicek one-factor credit model as our baseline model, which has served as the basis of the internal ratings-based approach in Basel II (see Vasicek, 1987, 1991, 2002). We illustrate the Vasicek one-factor model, where defaults are determined by a latent common factor. Borrower i's asset value A_i is assumed to depend on systematic factor Z and idiosyncratic component ε_i. Then,

$$A_i = \omega_i Z + \sqrt{1-\omega_i^2}\varepsilon_i ,$$

where Z and ε_i are independent standard normal variables and the default event is triggered if $A_i < \Phi^{-1}\left(\overline{PD_i}\right)$. Here, PD_i is the unconditional default probability. The parameter ω_i is an asset value correlation between A_i and A_j. When $\omega_i = \omega$ for all i, the parameter ω is known as the common asset correlation, and we assume that ω_i is a constant for the same credit grade i.[4] Then, the conditional default probability (PD) is given as follows:

$$\begin{aligned} PD_i\left(Z\right) &= Prob(A_i \le \Phi^{-1}\left(\overline{PDi}\right) \mid Z) \\ &= Prob\left(\omega_i Z + \sqrt{1-\omega_i^2}\varepsilon_i \le \Phi^{-1}\left(\overline{PD_i}\right)\right) \\ &= \Phi\left[\varepsilon_i \le \frac{\Phi^{-1}\left(\overline{PD_i}\right) - \omega_i Z}{\sqrt{1-\omega_i^2}}\right] \end{aligned}$$

[2]We will use the terms "housing" and "real-estate" market interchangeably.

[3]The model is very similar to the traditional CAPM in that each asset has idiosyncratic and systematic risk components. In a large portfolio of homogenous assets, the only systematic risk matters as the idiosyncratic risk is diversified away. However, as Chen *et al*. (2006) point out, because the bank's aggregate terminal payoff is significantly fat-tailed, this skewness remains even when the holding of an infinitely large number of loans in its portfolio does not disappear. We assume no remaining fat tails in the payoffs of housing market firms for illustration purposes.

[4]An important implication is that asset value and defaults are independent, conditional on the realization of the systematic factor Z.

In the context of the Vasicek single-factor model, a certain type of difficulty arises regarding how the systematic factor (Z) is defined in the housing market. An economic interpretation of the latent factor is by nature the state of the economy, as the loans and leases are directly related to the ups and downs of business cycles.[5] In this regard, we postulate that the systematic factor is the housing business cycle. That is, conditional PDs of housing and construction firms are a function of the housing cycle, in which conditional PDs decrease during the housing bubble periods and increase during the housing bust times.

This paper aims to deliver an integrated risk-management methodology to include 1) measuring the risk of credit portfolios, 2) implementing a (macro) stress test, and 3) calculating the risk limits for resource allocation using an estimated systematic factor specifically designed to capture the housing market cycle. Using proprietary parameters from the Korea Housing & Urban Guarantee Corporation (KHUG), whose main business includes a guarantee business, we propose a new integrated means of risk management with empirical results.[6]

We take a direct approach to capture the systematic factor dynamics by building a representative housing market index. Following common practices in constructing indices, we use factor methods. To this end, we infer information from a set of real-estate market variables by applying the FAVAR methodology proposed by Bernanke *et al*. (2005). Then, we show how to apply the estimated systematic latent factor to risk management specific to the housing market in an integrated manner.

Managing risk at KHUG is particularly challenging because the guarantee exposures are listed as off-balance-sheet items and its exposures are closely related to most durable goods, especially houses; thus, the risk profiles between houses and financial products such as stocks and bonds are significantly different in terms of the distributions of the default probability and liquidity. Therefore, applying the traditional risk-management scheme would be naive and misleading when attempting to measure precise risk amounts. In this regard, the idea of constructing a housing market index is particularly useful for two reasons. First, the amount of the "surety" claim by the "obligee" varies greatly depending on the business cycle, as the risk is highly interdependent among guarantee exposures because the scale of damage is closely related to economic fluctuations.[7] Secondly, there are considerable limitations to risk diversification among guarantee exposures due to the strong positive correlation; thus, guarantee insurance has a special characteristic closely related to the systemic risks existing in the overall economy. We believe that our proposed methodology is very well fitted to analyze the risks associated with slow-moving and low-defaultable forms of capital such as alternative investments.

Because the housing market accounts for a large proportion of the Korean economy, and given that more than 80% of the asset value possessed by individuals is skewed to real estate, it is undoubtedly important to understand housing market

[5]Figure 1 in Bruche and Gonzlez-Aguado (2010) exhibits clearly that a systematic factor related to the business cycle appears to dance between the default probability and the loss given default measure.

[6]See Appendix for details.

[7]A guarantee business appears to be financially sound with high profits during economic booms, but it suffers large losses and is likely to become insolvent during economic depressions.

fluctuations and their impact on actual business cycles. Considering the statement that the main policy goal in the housing market is to achieve stability in various dimensions, such as rents, property prices, supply and demand, and credit amounts, the Korean government has been known to use colorful policy measures. In this regard, we propose an integrated risk-management framework which captures the Korean housing cycle based on the FAVAR approach. Based on this cycle, we provide several policy implications for the Korean housing market in a timely and ex-ante manner.

The remainder of this article is organized as follows: Section II describes how we construct the systematic factor. Section III describes our choice of real-estate variables. Section IV presents the estimated latent factor and its power to capture the Korean housing cycle, and Section V proposes three risk-management applications. Section VI provides several housing policy implications. Section VII offers concluding remarks and discusses limitations.

II. Model Specification

This section describes our modeling approach to extract the systematic factor. Vector Autoregression (VAR) models have been an important tool in applied macroeconomics since Sims (1980). Many contemporaneous studies indicate that large VARs can be quite competitive with regard to forecasting.[8] Factor-augmented Vector autoregressive (FAVAR) models have enjoyed increasing levels of popularity for forecasting macroeconomic variables (see Abbate *et al*., 2016; D'Agostino *et al*., 2013). In a similar vein, we base our modeling approach on the FAVAR model, originally proposed by Bernanke *et al*. (2005).[9] Following the recent trend in macroeconomic modeling, we start with time-varying-parameter FAVARs in which the coefficients and loadings change (see Primiceri, 2005; Koop and Korobilis, 2014). To be precise, we use extensions of factor-augmented VARs which jointly model a large number of real-estate variables used to construct the systematic latent factor with key macroeconomic variables. We describe our modeling approach briefly below.

Let Y_t be a M x 1 vector of observable economic variables and F_t be vector of unobserved factors whose joint dynamics of $\Gamma_t = \left(Y_t', F_t'\right)$ are given by the following two equations,

(1) $$\Gamma_t = c_t + \sum_{i=1}^{p} B_{t,i} \times \Gamma_{t-i} + \upsilon_t ,$$

[8]See Bańbura *et al.* (2010), Carriero *et al.* (2009), Carriero *et al.* (2011) Carriero *et al.* (2012), Koop and Korobilis (2014).

[9]The FAVAR model has several advantages. Employing the factor model is a way to mitigate omitted variable bias, and research has demonstrated that the FAVAR model has superior long-term predictability useful for stress-testing.

$$X_t = \Lambda_t^z Z_t + \Lambda_t^y Y_t + \varepsilon_t \quad (2)$$

where the Y vector consists of a set of three endogenous macroeconomic variables, $Y_t = [real\ GDP_t,\ inflation_t,\ policy\ rate_t]$. These variables constitute the general equilibrium of the Korean economy. F_t is the latent factor, which we interpret as the housing cycle. The error terms υ_t and ε_t are assumed to follow a normal distribution with a zero mean and covariance matrixes Q_t and V_t, respectively. Additionally, time-varying coefficients are assumed to evolve as follows:

$$\begin{bmatrix} \Lambda_t^z \\ \Lambda_t^y \\ B_{t,i} \end{bmatrix} = \begin{bmatrix} \Lambda_{t-1}^z \\ \Lambda_{t-1}^y \\ B_{t-1,i} \end{bmatrix} + \begin{bmatrix} \nu_t \\ \varphi_t \\ \eta_t \end{bmatrix}, \ where \begin{bmatrix} \nu_t \\ \varphi_t \\ \eta_t \end{bmatrix} \sim N\left(\begin{bmatrix} w_t & 0 & 0 \\ 0 & N_t & 0 \\ 0 & 0 & R_t \end{bmatrix}\right)$$

All errors in equation (1) are correlated over time and with each other and all elements in the coefficient matrix $B_{t,i}$ are properly vectorized to match the dimension of Γ_t. All variance-covariance matrices are modeled to evolve with the EWMA (exponentially weighted moving average) process with the same decay parameters used in Koop and Korobilis (2014). Equation (1) is employed to model the dynamic interactions of the index with the macroeconomic variable Y_t, and equation (2) is used to extract the latent housing market index from various real-estate variables X_t.

This econometric specification is important for two reasons. First, the multivariate model with all variables in the system equation can better characterize their comovement and interdependence. Second, purging the effect of macroeconomic conditions from the housing market cycle is done so that the estimated factor reflects information solely associated with the real-estate sector. That is, including Y_t on the right-hand side of equation (2) is intended to ensure that the systematic factor reflects only housing market information. By doing this, we purge housing information from the effects of current macroeconomic conditions.[10] 10 In this regard, employing $\Lambda_t^y Y_t$ makes a significant difference.[11]

III. Data Description

In this section, we describe our choice variables and sample data. Instead of aggregating all possible real-estate variables, we carefully choose candidate

[10]There may be a type of post-crisis bias which states that some housing market cycles would be estimated using financial crisis data at the time of the financial crisis, leading to the bias. Because we focus on risk-management applications, and given that the financial crisis in Korea was known to be relatively mild compared to those in developed countries, we presume that the post-crisis bias would be negligible here.

[11]Hatzius *et al.* (2010) employ a similar approach for the same reason.

TABLE 1—16 CANDIDATE REAL-ESTATE VARIABLES (X_t)

Factor Dimension	Variable Name
Price	Transaction-based Sales Price Index for Apartments
	House Price Index
	Jeonse Price Index
	Ratio of Jeonse to Purchase Price for Apartments
	Construction Cost Index
Quantity: (Construction)	Number of Households Approved for Sales
	Value of Construction Completed at Current Prices
	Amount of Order Received for Housing Construction
	Ratio of Sold Units to Total Units of New Apartments
	Number of Guaranteed Housing Units
Quantity: (Stock)	Apartment Transaction Volume
	Number of Unsold New Apartment Housing Units after Completion
	Unsold New Apartment Housing Units
Others	KB's Buyer's Market Response Index
	Amount of Mortgage Loan
	Mortgage Spread

variables based on the DiPasquale and William's (1996) four-quadrant model of the real-estate market. The four factor dimensions of the four-quadrant model are rent, price, construction, and stock. In addition to these factors, we consider three more factor dimensions. First, we take the dynamic (transaction amount) factor dimension into account because the four-quadrant model has been criticized for its static nature. Next, we consider the credit factor dimension to include price and quantity of the mortgage. Our last factor dimension of interest is a unique real-estate contract called 'Jeonse', which contains cross-market information on rents, Jeonse, and the property market.[12]

For practical purposes in the policy and economic analysis, we have four factor dimensions after regrouping the seven abovementioned factors (rent, price, construction, and stock, transaction, credit, and Jeonse). In sum, we consider a total of 16 real-estate variables from the four factor dimensions (price, construction, stocks & transactions, and others). Note that we separate the quantities of housing into two physical components: the number of houses being produced and the number of houses on the market at a given point (stock) or for some period of time (transaction).[13]

These factor dimensions contain information about several types of price indices, new residential constructions, housing starts, apartment transaction volumes and mortgage amounts, among others. We also include cross-market information such as the ratio of the Jeonse amount to the purchase price for the apartment. We access monthly frequency data spanning from the beginning of 2006 to the end of 2016, and all non-stationary data are properly transformed to ensure stationarity. In total, 16 variables are described in Table A1.[14]

[12]Jeonse, or a full rent deposit, is a real-estate term unique to South Korea, referring to the way apartments or other types of the house are leased. The Korean Jeonse system is an intermediate form of the lease and home sales markets both in a legal and economic sense. See Appendix for details.

[13]Note that the final variables of our choice are not precisely aligned with those in DiPasquale and Williams's four-quadrant model to include a set of information specific to the Korean housing market.

[14]Refer to Appendix for a detailed description. Here, KB represents Kookmin Bank.

IV. Korean Housing Cycle

This section contains our estimated systematic factor describing the Korean housing cycle. Figure 1 captures a time series of the estimated systematic factor. The estimated systematic factor exhibits several intriguing observations. First, the estimated factor coincides with major real-estate market fluctuations, including the 2008 financial crisis, 2011's DTI regulation and 2014's relaxed LTV & DTI regulation. To be specific, the factor reached its lowest level four months after Lehman Brothers collapsed in September of 2008, and the estimated factor appears to conform to major real-estate policies effectively.

After 2008, the Lee Myung-Bak administration (17th term for 2008-2012) announced approximately 18 real-estate measures and after its inauguration in 2013, the Park Geun-Hye administration (18th term for 2013-2017) announced 14 real-estate policy packages. Many housing policies have exhibited different and possibly paradoxical effects on real-estate market, thus displaying the phenomenon of 'the fool in the shower'.[15]

The bottom line is that Korean housing cycles are strongly steered by the government. To be a good proxy for the housing cycle, therefore, it is imperative to capture the effects of housing policies effectively. We show that our estimated factor meets this requirement well by describing how well the systematic factor responds to several representative policy events.

FIGURE 1. ESTIMATED SYSTEMATIC FACTOR

Note: Time series of the estimated systematic factor.

[15]Before the Lee's regime, the government implemented a comprehensive real-estate tax, a transfer tax system, and other measures to curb demand. The housing policies during the Lee's presidency were largely attributable to the expansion of supply in the public sector, the revitalization of transactions focusing on unsold pre-sale units, and the stabilization of the pre-sale and rental market. However, the effects of the counter-measures were limited. The policy packages during the Park's regime except for the latest one released on Nov. 3 in 2016 focused on deregulation and boosting the market. The policy packages during the Park's regime except for the latest one released on Nov. 3 in 2016 focused on deregulation and boosting the market.

The 2011 DTI regulation had several adverse effects on the housing market. The greatest impact was the sharp drop in the transaction volume. In February of 2012, the number of apartment transactions across the country decreased by 20% compared to that in February of 2011, when no DTI regulations were in effect. The impact of the DTI regulation on housing prices was even greater. As of the end of February of 2012, the housing market in the Seoul metropolitan area fell 0.2% in the previous year, while the apartment market fell 0.4%. Our estimated factor continued to decrease after the 2011 DTI regulation. It was in fact a turning point to observe how the DTI regulation was affecting the market.

The relaxed LTV & DTI regulations of 2014 were one aspect of the massive government policy package called "Choinomics."[16] With the potential of flat-lining economic growth, the finance minister implemented a US$39 billion fiscal stimulus package and the Bank of Korea cut interest rates twice by an accumulated 50 basis points to 2 percent. In addition, to counter stagnating property prices during 2013 and early 2014, mortgage-lending rules were also eased. These measures led to a 2.4% increase in apartment prices during 2014, whilst mortgage lending and borrowing for long-term rents increased significantly.

The relaxed LTV & DTI regulation of 2014 contributed to the recovery, though it lost its contributional power for late 2015 and 2016. After this deregulation, our estimated factor continued to increase until early 2015 and then reversed, decreasing until early 2016 due to supply-side shocks.

Based on the anecdotal interpretations, we verify that the estimated systematic factor captures the effects of the Korean housing policies, thus represents the Korean housing cycle well. Interestingly, we verified that the estimated factor dynamics conforms to a time-series of the auction price in the apartment auction market. The auction price is generally known to reflect housing market dynamics very well due to the existence of marginal traders and their trading activities.[17]

V. Risk-Management Applications

This section proposes three practical risk-management applications: 1) measuring the risk of credit portfolios by credit ratings, 2) stress-testing, and 3) setting the credit risk limit using the estimated factor in an integrated framework.

A. *Risk Measurement*

The first practical application is to measure the risk of holding credit assets and portfolios. Measuring credit risk requires risk components such as exposure, conditional default probabilities, and loss given default. Marginal default

[16]The term Choinomics represents a series of expansionary policies the government pursued under Finance Minister Choi Kyung Hwan. Under him, the government has sought to stimulate the economy through a set of expansionary measures. For instance, it eased regulations on mortgages and expanded fiscal spending by unleashing a US$39 billion fiscal stimulus package.

[17]Chun (2013) and Seo and Jeong (2013) report a positive correlation between the apartment price index and auction prices.

probabilities can be calculated based on different methodologies, such as a structural model or a reduced-form model, or from rating agencies related to default probabilities. We calculate the conditional default probabilities of Vasicek model, $PD_i(F)$, based on the estimated systematic factor (F_t) from equation (2). Here, i denotes credit ratings ranging from AAA to D for a total of 15 classifications.[18] We set $\Phi^{-1}(PD_i)$ to be the i grade's long-term unconditional default probability, μ_i. Subsequently, we have the following equation:

$$(3) \qquad PD_i(F_t)=\Phi\left[\varepsilon_i \le \frac{\mu_i - \omega_i F_t}{\sqrt{1-\omega_i^2}}\right]$$

We borrow the empirical parameters for exposure, the LGDs and the CCFs from KHUG. Regarding the loss given default measures, the convention is to use historical data depending on the seniority of the claims analyzed and to assume that they are constant across time and across seniority levels.

The two panels in Figure 2 display the time series of the conditional PDs of portfolios with a credit grade of A^+ and the relationship between the conditional PDs and the realization of F depending upon the parameter ω, respectively.[19] The risk dynamics of the two conditional PDs is plotted in the first panel, in which several empirical anecdotes mentioned in section IV appear to be well captured.

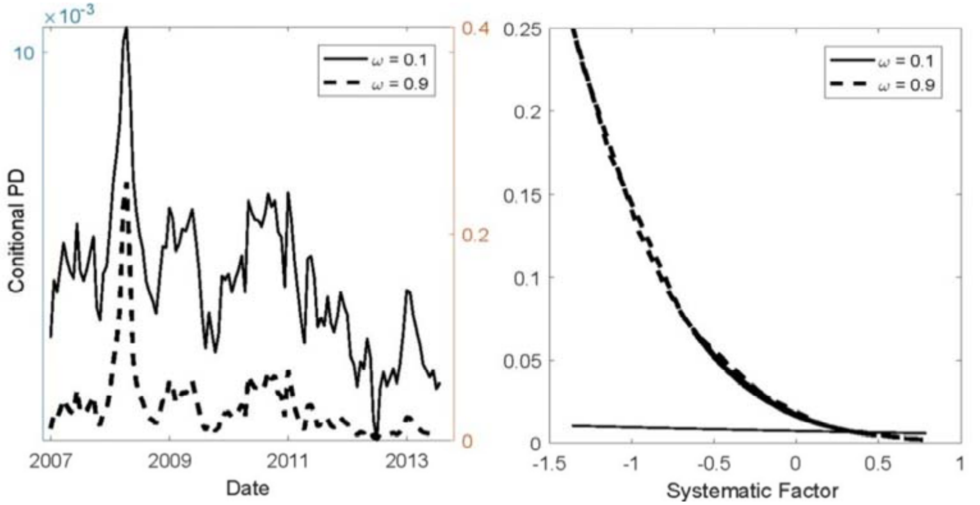

FIGURE 2. RISK DYNAMICS FOR THE A^+ CREDIT GRADE

Note: Time series of conditional PDs for two given values of ω and the relationship between the realization of Z and the conditional PDs. The A credit grade ranging from AAA to A^- is assigned to more than 83% of total credit risk exposure in housing sales guarantee products.

[18]The credit conversion factor (CCF) is an additional risk component of the guarantee product.

[19]The A credit grade, ranging from AAA to A^-, accounts for more than 83% of all credit risk exposure in housing sales guarantee products. Our choice of the A^+ credit grade is for illustrative purposes.

The conditional PDs spiked during the financial crisis given the two ω values, in this case 0.1 and 0.9. When the housing policies favorable to the housing market were announced, the conditional PD decreased correspondingly, and increased otherwise. The relationship between the conditional PDs and the realization of the systematic factor is given in the second panel. For a given housing market shock F, we have the conditional probability of default on assets within the same credit grade. The ratio of conditional PDs for the two ω values varies, ranging from a minimum value of 0.3190 to a maximum value of 24.3071. The roles of ω in calculating the conditional PDs are larger in the realm of a lower realization of F and are smaller otherwise; thus, there exists an asymmetric effect.

B. *Forecasting and Stress Test*

This section presents the method by which a recursive forecast is combined with (macro) stress-testing. Unlike the stress-testing practice in the banking sector, it is difficult to implement stress-testing properly in the housing market, mainly because the credit risk of holding housing-related claims and portfolios is difficult to model, as is simulating the conditional PDs, because housing portfolios are collateralized by the physical houses. Therefore, there is little relevant historical default data information. For safe assets, calculations based on historical data may not be sufficiently reliable to determine the default estimate probability, as few defaults are observed. These low-default assets pose an estimation problem and present some difficulty when attempting to simulate expected default rates (Basel Committee on Banking Supervision, 2005).

The proposed methodology utilizes the estimated systematic factor. Because the latent factor is purged from the effect of macroeconomic conditions forming the simplest DSGE (dynamic stochastic general equilibrium), our final estimated factor reflects information solely associated with the real-estate sector. This approach enables us to forecast and simulate the default rates based on the Vasicek one-factor model in a structural framework.

Figure 3 displays the time series of three macroeconomic variables and the estimated latent factor. The shaded area in Figure 3 exhibits the predicted paths of four variables for the one-year period spanning from November of 2016 to November of 2017. The two panels in the first row show the time series of the predicted real GDP and inflation, whilst the two panels in the second row exhibit the predicted policy rate and estimated factor. We observe that the conditional mean prediction of the housing cycle exhibits a sharp fall for three consecutive months and then shows stable dynamics for the remaining period.

Along with the predicted path of the systematic factor, we consider three simulated shock paths under the assumption that unit standard deviation, two standard deviations, and three standard deviations are imposed on the systematic latent factor.[20] The size of a shock applied to structural VAR systems is traditionally measured as either the one-unit or the one-standard-deviation shock of the structural error. Note that the conditional mean forecast is implemented under a

[20]In statistics, the 68-95-99.7 rule refers to when 68.27%, 95.45% and 99.73% of the values lie within one, two and three standard deviations of the mean, respectively.

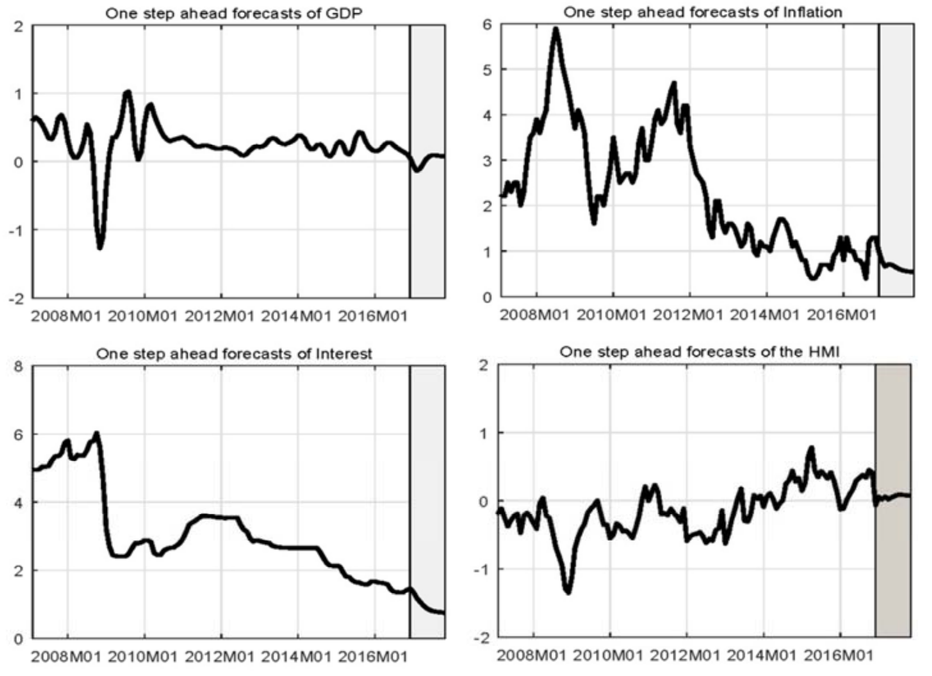

FIGURE 3. THE SYSTEMATIC FACTOR FORECAST UNDER THE DSGE FRAMEWORK

Note: A set of three endogenous economic variables, the real GDP_t, $inflation_t$, $policy\ rate_t$ is given along with the systematic factor (F_t). These endogenous variables constitute the general equilibrium of the Korean economy together with the housing market.

structural VAR framework whose identification strategy with regard to the structural shocks in the transition equation is uses the lower-triangular Cholesky decomposition to analyze the effects of endogenous economic variables on the housing cycle.

The left panel in Figure 4 captures the simulated paths when negative one, two and three standard deviation shocks are imposed on the systematic factor, that is, on the housing market cycle. The panel on the right displays the corresponding conditionally stressed PDs for claims and portfolios with the A^+ credit grade based on equation (3). Any stress test, whether micro or macro, has key elements such as the set of risk exposures subjected to stress, a scenario that defines (exogenous) shocks that stress those exposures, and a measure of the outcome. In this regard, based on the various predicted paths of the latent factor, we calculate the VaR amounts given the parameter values of different risk components, including the exposures, LGDs, and CCFs. The risk horizon for the predicted risk components is set as one year, from November of 2016 to November of 2017. Total exposure for the A^+ credit grade is approximately 27.7 trillion won.

Table 2 contains risk measures as VaR (value at risk) amounts for the A^+ credit grade. The two panels in Table 2 exhibit the VaR amounts for hypothetical values of $\omega = 0.1$ and $\omega = 0.5$, respectively. We observe the important role of the

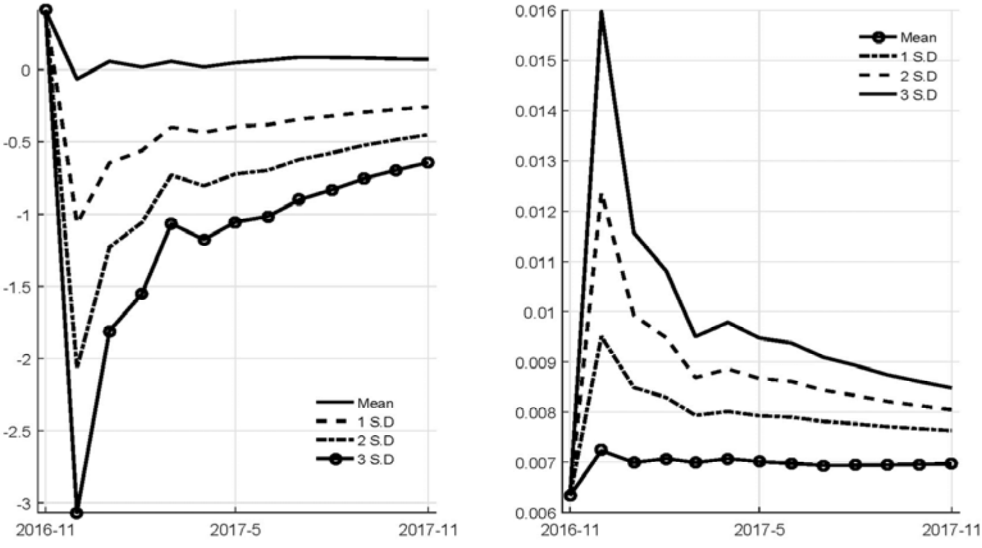

FIGURE 4. (MACRO) STRESS TEST

Note: The left panel captures the simulated shock paths for negative one, two and three standard deviations of the systematic factor and the right panel displays the corresponding conditional stressed PDs with a ω value of 0.1.

TABLE 2—VaR AMOUNTS FOR A$^+$ CREDIT GRADE

(UNIT: 0.1 BILLION WON)

Date	Panel A: ω = 0.1				Panel B: ω = 0.5			
	Mean	1 S.D.	2 S.D.	3 S.D.	Mean	1 S.D.	2 S.D.	3 S.D.
2016/12	1,370	1,757	2,219	2,759	539	2,426	6,592	11,701
2017/05	1,331	1,489	1,616	1,752	443	931	1,531	2,389
2017/11	1,323	1,439	1,510	1,585	424	746	1,016	1,361

parameter ω in the capturing of the degree of sensitivity to the systematic factor.

VaR amounts when ω is equal to 0.1 increase relatively at a mild pace from 175.7 billion won to 275.9 billion won in December of 2016, while VaR amounts with $\omega = 0.5$ increase rapidly from 242.6 billion won to 1170.1 billion won for the corresponding simulated shocks. An interesting observation is the time-series dynamics of the VaR amounts in Panel B when $\omega = 0.5$. The VaR amounts plummet as time passes. On the other hand, the VaR amounts in Panel A with $\omega = 0.1$ decrease moderately. A surprising result is that at the end of the risk horizon in November of 2017, the final VaR amounts in Panel B with $\omega = 0.5$ are far less than those in Panel A with $\omega = 0.1$.

C. *Credit Risk Limit*

Theoretically speaking, setting risk limits is a function of the risk policy, which includes the risk capacity and the appetite inside the organization.[21] We describe briefly how to set risk limits when the confidence interval (CI) is set to 95%.

[21]This risk appetite framework is consistent with current industry best practices and regulatory expectations.

Currently, KHUG calculates the credit risk limit (CRL) using the following formula,

$$\text{CRL}_t = min\left\{\text{Eligible Captial}_t,\ \alpha_{95\%} \times \text{Exposure}_t\right\}$$

where $a_t = \dfrac{UL_t}{Exposure_t}$ and the denominator UL_t is the unexpected loss amount. We estimate the value of $\alpha_{95\%}$ from its historical probability distribution with a 95% confidence interval. The economic meaning of alpha is the time series of internal risk perception and risk tolerance manifestation inside KHUG. This approach is vulnerable to the criticism that setting risk limits is done in a backward-looking manner. To mitigate this argument, we modify $\alpha_{95\%}$ to include the estimated latent factor, which captures the housing cycles through the time-varying confidence interval; that is, $\alpha_{95\%}$ becomes α_{Ft} through the $CI\left(F_t\right)$ conditioning of the size of the housing market shock.

In practice, a risk limit has three components: a risk metric, a risk measure that supports the risk metric, and a certain bound. Following the common practice, our approach to setting up the limit is described below: We start by fitting the historical data of the estimated systematic factor to a probability distribution, after which we calculate the area into which the predicted mean path of the systematic factor falls. For a normal distribution, for example, we verify whether the values of the predicted systematic factor are at 68%, 95%, or 99.73%. When the predicted systematic factor falls into the normal region, such as within 90%, we calculate area VaR amounts under the predetermined confidence interval. We then proceed to calculate $\alpha_{95\%}$ from its probability distribution. In contrast, when the factor value breaches the predetermined threshold, for instance when it is at 75% or 90%, we switch $\alpha_{95\%}$ to α_{Ft}, a new confidence interval over which the systematic factor hovers. We then calculate the value of α_{Ft} given the new confidence interval $CI\left(F_t\right)$. Afterward, we multiply the current exposures by the numeric of α_{Ft} to determine the VaR amounts. One conceptual advantage worth mentioning is that because the confidence interval is a function of the predicted systematic factor, setting risk limits can be implemented in a timely and forward-looking manner.

VI. Policy Implications

In addition to the risk-management application, we investigate whether it is possible to search for policy implications using the estimated housing cycle. To do this, we initially examine how shocks to the Korean housing cycle propagate to economic fluctuations using an impulse-response analysis based on equation (1).

The upper panel of Figure 5 exhibits how the real GDP variable responds over time to a one-unit increase in the exogenous housing cycle shock and the lower panel shows how the inflation variable reacts over time to a one-unit increase in the

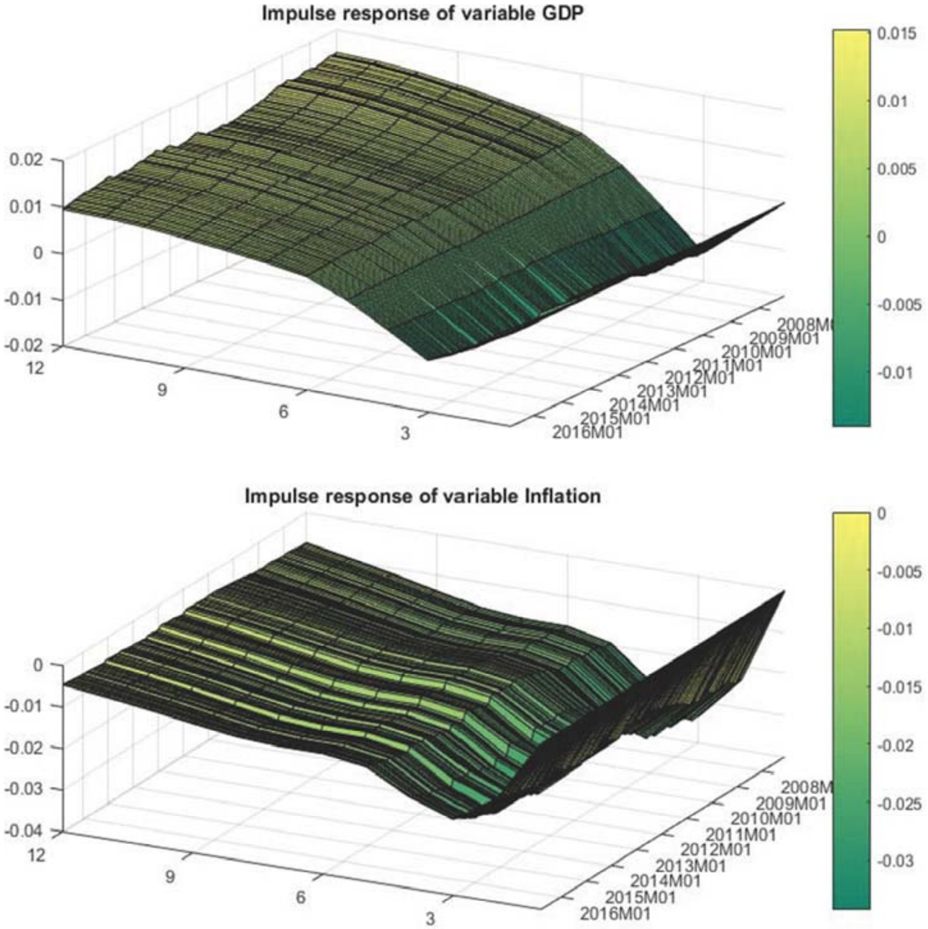

FIGURE 5. IMPULSE-RESPONSE DYNAMICS OF REAL GDP AND INFLATION

Note: The upper panel plots the impulse-response dynamics of housing market shocks to the real gross domestic product in a time-varying manner. The lower panel plots the time-varying impulse-response dynamics of housing market shocks to inflation. Response periods are 12 months and the data ranges from the beginning of 2006 to the end of 2016.

exogenous shock according to the estimated systematic factor in a time-varying manner in both cases. The impulse response dynamics are the estimated change in a set of macroeconomic variables following a one-standard-deviation shock to the Korean housing cycle. As indicated by the two panels in Figure 5, this type of shock to the Korean housing cycle leads to a decline both in the real GDP and inflation within the first three months. Considering the fact that housing capital is a slow-moving and low-defaultable variable, this result is rather surprising because the two macroeconomic variables respond very quickly to the housing market shock. Past that point, the real GDP and inflation gradually return to their initial values in nine months. One intriguing observation is that the degree of the responses of the two macroeconomic variables to a one-unit increase of the exogenous shock according to the estimated systematic factor decreases mildly. For example, the magnitude of the declines in the real GDP and inflation continue to decrease from 2008 to 2016. This result is comparable to the findings of Koop and Korobilis (2014), who proposed a financial condition index and investigated the impulse response dynamics of a set of macroeconomic variables to a shock to the index. They found that this type of shock to the financial condition index causes rather wild impulse responses of the macroeconomic variables and that the magnitude of the response increases dramatically after the 2008 global financial crisis. These findings provide several important economic implications for policymakers, especially for macroprudential supervision purposes.

VII. Conclusion

This paper proposes an integrated risk-management methodology that includes 1) measuring the risk of credit portfolios, 2) implementing a (macro) stress test, and 3) calculating risk limits using the estimated systematic factor specific to capture the housing market cycle. To be a good proxy for the housing market cycle, it is indispensable to capture the effects of housing policies, as Korean house market cycles are strongly steered by the government in a ‘fool in the shower’ manner. To this end, we construct a systematic factor from real-estate market variables based on the FAVAR methodology proposed by Bernanke *et al*. (2005). The proposed methodology is particularly useful for analyzing the risks of alternative investments, whose risk profiles are significantly different from those of financial products such as stocks and bonds in terms of the distribution of the default probability and liquidity. Furthermore, our impulse response analysis provides important implications for policymakers.

Our study has several limitations. The role of interest rates in the housing market has been well recognized; thus, a single-factor model is needed as an extension to include the interest rate factor for a clearer picture of the conditional PDs. In addition, our empirical analysis is restricted to guarantee portfolios with A^+ credit grades only; thus, incorporating the correlation between loss given default measure and the default probabilities, or between the default probabilities for different credit grades in the calibration of the relevant credit models, is omitted. This would be tolerable in the sense that our main focus is on proposing a new risk management approach. An interesting development would be to explore the role of a discrete survival model and a dynamic conditional correlation within the scope of risk-management applications.

APPENDIX

Description of Jeonse: Jeonse, or key money deposit, is a real-estate term unique to South Korea that refers to the way apartments or other types of housing are leased. Instead of paying monthly rent to a landlord, a large lump-sum payment is deposited into the landlord’s bank account for the duration of the contract. By law, Jeonse contracts

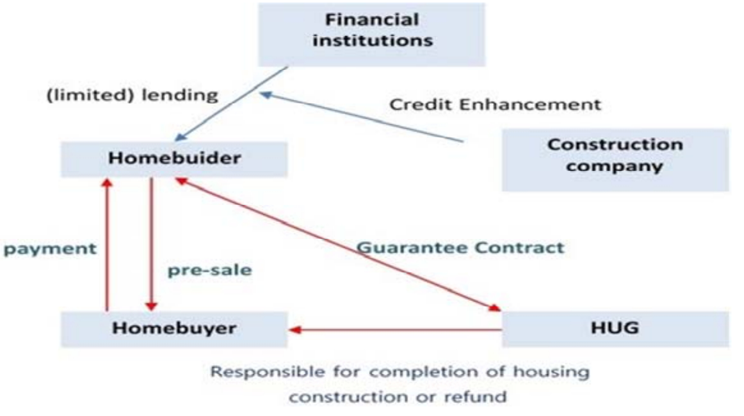

FIGURE A1. CONSTRUCTION FINANCE UNDER PRE-SALE SCHEMES

usually apply for two years. At the end of the contract, the deposited amount is returned to the renter. Jeonse does not involve monthly rental payments. Instead, tenants provide landlords with a deposit for the duration of the lease and landlords should repay the lump sum to tenants at the end of the tenancy, as noted above. Jeonse has been mutually beneficial both for landlords and tenants because the landlord can expect capital gains from rising housing prices during housing booms and tenants can also lease at prices which are lower relatively to real-estate sales prices. In addition, the Jeonse system eliminates the likelihood that tenants will default on monthly rents. In general, landlords prefer Jeonse because Jeonse enables them to purchase property leveraged with Jeonse contract funds. There also exists a rollover and possibly liquidity risk in the sense that landlords may not be able to pay back the full sum at the end of the contract, as they typically invest the large sum of money from Jeonse contracts to buy other properties or invest in longer-term financial assets. In this regard, Kim and Shin (2012) analyzed rents from the viewpoint of financial transactions and defined Jeonse as a housing repo contract between a homeowner and a tenant as collateral for housing. Understanding the Jeonse system is crucial to understand the Korean housing market more deeply.

Description of Pre-Sale Guarantee System: Korea has pre-sale and pre-sale guarantee systems which apply to the supply of new houses. The housing pre-sale system permits housing builders to receive a portion of the house price from the buyer before the housing is completed. This is equivalent to those activities in which construction companies receive the construction costs in advance. The Korea Housing and Urban Guarantee Corporation (HUG) was established in accordance with Article 16 of the NHUF (National Housing and Urban Fund) Act to improve housing well-being and encourage urban regeneration projects, thereby contributing to a better quality of life of the public by providing various guarantees, implementing national projects, and effectively operating and managing NHUF. Its main business areas include a guarantee business for housing that guarantees housing completion, guarantees rental deposits, and guarantees cooperative housing completions. Examples include the completion of housing construction or the refund of a down-payment and intervening payments made in cases where a project owner fails to fulfil its obligations under pre-sale agreement due to bankruptcy, insolvency, or other circumstances. A detailed business description is provided on the HUG homepage

In Korea, the pre-sales system is very popular. Homebuyers pay a certain percentage of the deposit (usually 10% of housing price) upon signing the contract, paying the remaining balance based on an installment schedule that is linked to the construction schedule. When they move into a newly constructed house, they pay the last installment, which is at least 20% or more of the contract price. Figure A1 shows the development finance under pre-sale schemes. To purchase land, homebuilders make use of their equity or loans. In a pre-sale scheme, homebuyers are exposed to the risk of default of the homebuilders; therefore, in order to eliminate this risk, the KHUG provides construction completion guarantee services for future homeowners.

TABLE A1—DESCRIPTION OF 16 CANDIDATE VARIABLES (X_t)

Factors	ariables	Description
Price	ransaction-based Apartment Price Index	This index provides market trend information by analyzing the transaction price level and the rate of change of the declared apartment in the inventory of apartments nationwide and is used as reference data for government policies (Source: Korea Appraisal Board).
	Housing Price Index	The housing price index is a weighted value of the housing, housing type, and housing stock computed using the Laspeyres formula (Source: Kookmin Bank).
	Jeonse Price Index	The Jeonse Price Index is a weighted value of the Jeonse, Jeonse type, and Jeonse stock computed using the Laspeyres formula (Source: Kookmin Bank).
	Ratio of Jeonse to Apartment Prices	The Jeonse-to-apartment-price ratio is the ratio of the yearly rental to the house price (Source: Kookmin Bank).
	Construction Cost Index	This index is based on direct construction costs provided by Korea Institute of Construction Technology.
Quantity 1: Construction	The Number of Households Approved for Sale	The number of housing units approved for pre-sale public notice by authority (Source: Ministry of Land, Infrastructure and Transport)
	Value of Construction Completed at Current Prices	The amount of construction investment that the construction company can receive from owners or developers after the completion of construction (Source: Ministry of Land, Infrastructure and Transport)
	Number of Orders Received for Housing Construction	The number of contracts between developers and construction companies (Source: Ministry of Land, Infrastructure and Transport)
	Ratio of Sold Units to Total Units of New Apartments	The ratio of sold units to total units of new apartments that developers can sell (Source: Ministry of Land, Infrastructure and Transport)
	Number of Guaranteed Housing Units	The number of houses guaranteed by the KHUG
Quantity 2: Stock	Apartment Transaction Volume	Residential apartment transaction volume (Source: Korea Appraisal Board)
	Number of Unsold New Apartment Housing Units after Completion	The number of unsold new apartment housing units among new apartments that developers can sell after completion (Source: Ministry of Land, Infrastructure and Transport)
	Unsold New Apartment Housing Units	The number of unsold new apartment housing units among new apartments that developers can sell before completion (Source: Ministry of Land, Infrastructure and Transport)
Others	KB's Buyer's Market Response Index	The Buyer's Market Response Index is constructed by selecting one of the three types of real-estate brokerage: selling advantage, buying superiority, and coherence. When the Buying Leading Index is 100, the selling price and purchase price are at the same level.
	Amount of Mortgage Loans	The total amount of credit incurred by financial institutions (Source: Bank of Korea)
	Mortgage Spread	The mortgage spread is the difference between treasury yields and interest rates on mortgages (Source: Bank of Korea).

REFERENCES

Abbate, Angela, Sandra Eickmeier, Wolfgang Lemke and Massimiliano Marcellino. 2016. "The Changing International Transmission of Financial Shocks: Evidence from a Classical Time-varying FAVAR." *Journal of Money, Credit and Banking* 48 (4): 573–601.

Aron, Janine and John Muellbauer. 2016. "Modelling and Forecasting Mortgage Delinquency and Foreclosure in the UK." *Journal of Urban Economics* 94: 32–53.

Bańbura, Marta, Domenico Giannone and Lucrezia Reichlin. 2010. "Large Bayesian Vector Auto Regressions." *Journal of Applied Econometrics* 25(1): 71–92.

Basel Committee on Banking Supervision. 2005. "Validation of Low-default Portfolios in the Basel II Framework." Basel Committee Newsletter.

Bernanke, Ben S., Jean Boivin and Piotr Eliasz. 2005. "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach." *The Quarterly Journal of Economics* 120 (1): 387.

Bruche, Max and Carlos Gonzlez-Aguado. 2010. "Recovery Rates, Default Probabilities, and the Credit Cycle." *Journal of Banking & Finance* 34 (4): 754–764.

Carriero, A., G. Kapetanios and M. Marcellino. 2009. "Forecasting Exchange Rates with a Large Bayesian VaR." *International Journal of Forecasting* 25 (2): 400–417.

Carriero, Andrea, George Kapetanios and Massimiliano Marcellino. 2011. "Forecasting Large Datasets with Bayesian Reduced-rank Multivariate Models." *Journal of Applied Econometrics* 26 (5): 735–761.

Carriero, Andrea, George Kapetanios and Massimiliano Marcellino. 2012. "Forecasting Government Bond Yields with Large Bayesian Vector Auto-regressions." *Journal of Banking & Finance* 36 (7): 2026–2047.

Chen, Andrew H., Nengjiu Ju, Sumon C. Mazumdar and Avinash Verma. 2006. "Correlated Default Risks and Bank Regulations." *Journal of Money, Credit and Banking* 38 (2): 375–398.

Chun, Hae-Jung. 2013. "The Empirical Study on the Correlation between House Sale Price and the Winning Bid to Appraised Price Ratio." *Journal of the architectural institute of Korea planning & design* 29 (7): 111–118 (*in Korean*).

D'Agostino, Antonello, Luca Gambetti and Domenico Giannone. 2013. "Macroeconomic Forecasting and Structural Change." *Journal of Applied Econometrics* 28 (1): 82–101.

DiPasquale, Denise and Wheaton William. 1996. "Urban Economics and Real-Estate Markets." Pearson.

Duffie, Darrell, Andreas Eckner, Guillaume Horel and Leandro Saita. 2009. "Frailty Correlated Default." *The Journal of Finance* 64 (5): 2089–2123.

Hatzius, Jan, Peter Hooper, Frederic S. Mishkin, Kermit L. Schoenholtz and Mark W. Watson. 2010. "Financial Conditions Indexes: A Fresh Look after the Financial Crisis." Working Paper 16150. National Bureau of Economic Research.

Kim, Se-Jik and Hyun Song Shin. 2012. "Analysis of Jeonse price determinants, Technical Report, Economic History Society of Australia and New Zealand." Asia-Pacific Economic and Business History Conference 2012.

Koop, Gary and Dimitris Korobilis. 2014. "A New Index of Financial Conditions." *European Economic Review* 71: 101–116.

Primiceri, Giorgio E. 2005. "Time Varying Structural Vector Auto-regressions and Monetary Policy." *The Review of Economic Studies* 72 (3): 821.

Seo, Seong-Soo and Dong-Joon Jeong. 2013. "An Empirical Study on the Interrelationship between Apartment Trading and Auction Markets." *Housing Studies Review* 21 (1): 37–57 (*in Korean*).

Sims, Christopher A. 1980. "Macroeconomics and Reality." *Econometrica* 48 (1): 1–48.

Vasicek, Oldrich A. 1987. "Probability of Loss on Loan Portfolio." KMV Corporation.

Vasicek, Oldrich A. 1991. "Limiting Loan Loss Probability Distribution." KMV Corporation.

Vasicek, Oldrich A. 2002. "The Distribution of Loan Portfolio Value." KMV Corporation.

LITERATURE IN KOREAN

서성수·정동준. 2013. 「아파트 매매시장과 경매시장의 상호관계에 관한 실증 연구」. 『주택연구』. 제21권 제1호.

전해정. 2013. 「주택매매가격과 경매낙찰가율 간의 상관관계에 대한 실증연구」. 『대한건축학회논문집 계획계』. 제29권 제7호.