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

Preliminary Draft. Comments Welcome.

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Abstract

This paper proposes an integrated risk management framework that includes 1) measuring risk of credit portfolios, 2) implementing (macro) stress-test, and 3) setting risk limits by 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 how to apply the estimated systematic factor to the risk management specific to the housing market in an integrated way within the Vasicek one-factor credit model. Our proposed methodology is very fitted to analyze risk of slow-moving and low-defaultable capitals such as alternative investments.

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1. Introduction

South Korea's housing market has been lit by spotlight 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, thanks to record-low interest rates and cheap household mortgage, is touching the boundary of a speculative bubble.[1] Now, an oversupply of new houses and tighter lending rules may signal the property market bubble within coming years. The importance of risk management in the real-estate market is bulging rapidly.[2]

However, identifying the risk profile faces the Herculean tasks when it comes to the real estate markets. The practitioners have relied on a rather ad-hoc approach to calculating default probability of housing & construction firms. To be specific, employing loan-specific predictors such as delinquencies, interest in arrears or loan-to-value (or debt-equity) ratio, and other idiosyncratic drivers have been a norm after controlling macroeconomic variables. In terms of holding portfolios, however, these idiosyncratic drivers should be diversified away.[3] Empirically, Duffie et al. (2009) find strong evidence for the presence of common latent factors and Aron and Muellbauer (2016) make an emphasis on the role of the latent factor in modeling and forecasting mortgage delinquency and foreclosure.

In this paper, we ask a relevant but nuanced question: what is the systematic (latent) factor within the housing market and its role in the risk management? To study this issue, we posit the Vasicek one-factor credit model as our baseline model, which has served as the basis of the Basel II's internal ratings-based approach (see Vasicek (1987, 1991, 2002)). We illustrate the Vasicek one-factor model where defaults are determined by a latent common factor. A borrower i's asset value A_i is assumed to depend on a systematic factor Z and an 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 $A_i < \Phi^{-1}(\overline{PD}_i)$. Here, $\overline{PD}_i$ is a unconditional default probability. The parameter ω_i is an asset value correlation between A_i and A_j. In the case of $\omega_i = \omega$ for all i, the

[1] "Apartment prices have soared 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.

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

[3] The model is very similar to the traditional CAPM: 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 to be diversified away. However, as Chen et al. (2006) point out, since the bank's aggregate terminal payoff is significantly (left) fat tailed, this skewness remains even when holding an infinitely large number of loans in its portfolio does not disappear unless they are uncorrelated. We assume no left fat tail in the payoffs of housing market firms for the illustration purpose.

parameter ω is called the common asset correlation and we assume that ω_i is a constant for the same credit grade i.[4] Then, conditional default probability(PD) is given as follows:

$$\begin{aligned} \text{PD}_i(Z) &= \text{Prob}(A_i \leq \Phi^{-1}(\overline{PD}_i)|Z) \\ &= \text{Prob}(\omega_i Z + \sqrt{1-\omega_i^2}\varepsilon_i \leq \Phi^{-1}(\overline{PD}_i)) \\ &= \Phi\left[\varepsilon_i \leq \frac{\Phi^{-1}(\overline{PD}_i)-\omega_i Z}{\sqrt{1-\omega_i^2}}\right] \end{aligned}$$

In the context of the Vasicek single factor model, a certain difficulty arises regarding how to define the systematic factor(Z) in the housing market. An economic interpretation of the latent factor is by nature the state of the economy since their 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 & construction firms are a function of the housing cycle, in which conditional PDs decrease during the housing bubble period and increase during the housing bust time.

This paper aims to deliver an integrated risk management methodology to include 1) measuring risk of credit portfolios, 2) implementing (macro) stress-test, and 3) calculating risk limits for the resource allocation by using the estimated systematic factor specific to capture the housing market cycle. Using proprietary parameters from the Korea Housing & Urban Guarantee corporation (KHUG) whose main business includes guarantee business, we propose a new integrated way of doing 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 a common practice 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 the risk management specific to the housing market in an integrated way.

Managing risks at the KHUG is particularly challenging because the guarantee exposures are listed as off-balance-sheet items and its exposures are closely related to the most durable goods, especially houses, thus risk profiles between houses and financial products such as stock and bond are significantly different in terms of the distribution of the default probability and liquidity. Therefore, applying the traditional risk management scheme would be naive and misleading to measure the exact risk amount. 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 cycles because the risk is highly interdependent among the guarantee exposures

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

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

[6] See Appendix B for details

and the scale of damage is closely related to economic fluctuations.[7] Secondly, there are considerable limitations to the risk diversification among the guarantee exposures due to the strong positive correlation, thus guarantee insurance has a special characteristic closely related to the systemic risks of the whole economy. We believe that our proposed methodology is very fitted to analyze the risk of slow-moving and low-defaultable capitals such as alternative investments.

The remainder of this article is organized as follows: Section 2 describes how we construct the systematic factor. Section 3 describes our choice of real-estate variables. Section 4 presents the estimated latent factor and its power to capture the Korean housing cycle, and Section 5 proposes three risk management applications. Section 6 offers concluding remarks and limitations.

2. 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 in forecasting.[8] Factor-augmented Vector Autoregressive (FAVAR) models have enjoyed increasing popularity for forecasting macroeconomic variables(see; Abbate et al. (2016), D'Agostino et al. (2013)). In the 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 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 as follows:

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 $\mathit{\Gamma}_t = (F_t', Y_t')$ are given by the following two equations:

$$\mathit{\Gamma}_t = c_t + \sum_{i=1}^{p} B_{t,i} \times \mathit{\Gamma}_{t-i} + \upsilon_t, \tag{1}$$

$$X_t = \Lambda_t^z Z_t + \Lambda_t^y Y_t + \varepsilon_t \tag{2}$$

where the Y vector consists of a set of three endogenous economic variables, $Y_t = [\text{real GDP}_t, \text{inflation}_t, \text{policy rate}_t]$. These variables constitute a general equilibrium of

[7] Generally speaking, a guarantee business looks like financially sound with big profits during economic booms, but it suffers big losses and is likely to become insolvent during economic depressions.

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

[9] FAVAR model has several merits. Employing the factor model is a way to mitigate omitted variable bias and FAVAR model has been proved to have superior longer-term predictability useful for the stress-test.

the Korean economy. Z_t is the latent factor which we interpret as the housing market cycle. The error terms, υ_t & ε_t are assumed to follow the normal distributions with mean zeros and covariance matrix Q_t and V_t, respectively. Time-varying coefficients are assumed to evolve as follows:

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

All errors in the equations above are uncorrelated over time and with each other and all elements in the coefficient matrix, $B_{t,i}$ is 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 of Koop and Korobilis (2014). The equation (1) is used to extract the latent housing market index from various real-estate variables X_t and the equation (2) is employed to model the dynamic interactions of the index with macroeconomic variables Y_t.

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

3. 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 variables following DiPasquale and William (1996)'s 4-quadrant model of the real estate market. Four factor dimensions of the 4-quadrant model are rent, price, construction, and stock. On top of these factors, we consider three more factor dimensions. First, we take the dynamic (transaction amount) factor into account since the 4-quadrant model has been criticized for its static nature. Next, we consider the credit factor to include price and quantity of the mortgage. Our last factor of interest is unique real-estate contract called 'Jeonse'

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

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

which contains the cross-market information on rent, Jeonse, and property market.[12]

Table 1: 16 candidate real-estate variables (X_t)

Factor Dimension	Variable Name
Price	Transaction-based Sales Price Indice for Apartment
	House Price Index
	Jeonse Price Index
	Ratio of Jeonse to Purchase Price for Apartment
	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 Apartment
	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

For the practical purpose of the policy and economic analysis, we have four factor dimensions after regrouping abovementioned seven factors (rent, price, construction, and stock, transaction, credit, Jeonse) into smaller groups. In sum, we consider total 16 real-estate variables from 4 factor dimensions (price, construction, stock&tranaction, and others). Note that we separate quantities of the 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).

These data contain information on several types of price indices, new residential constructions, housing starts, apartment transaction volume and mortgage amounts, etc. We also include cross-market information such as a ratio of Jeonse to purchase price for the apartment. We access data on a monthly frequency from the beginning of 2006 through to the end of 2016 and all the non-stationary data are properly transformed to ensure stationarities. Total 16 variables are described in Table 3.[13]

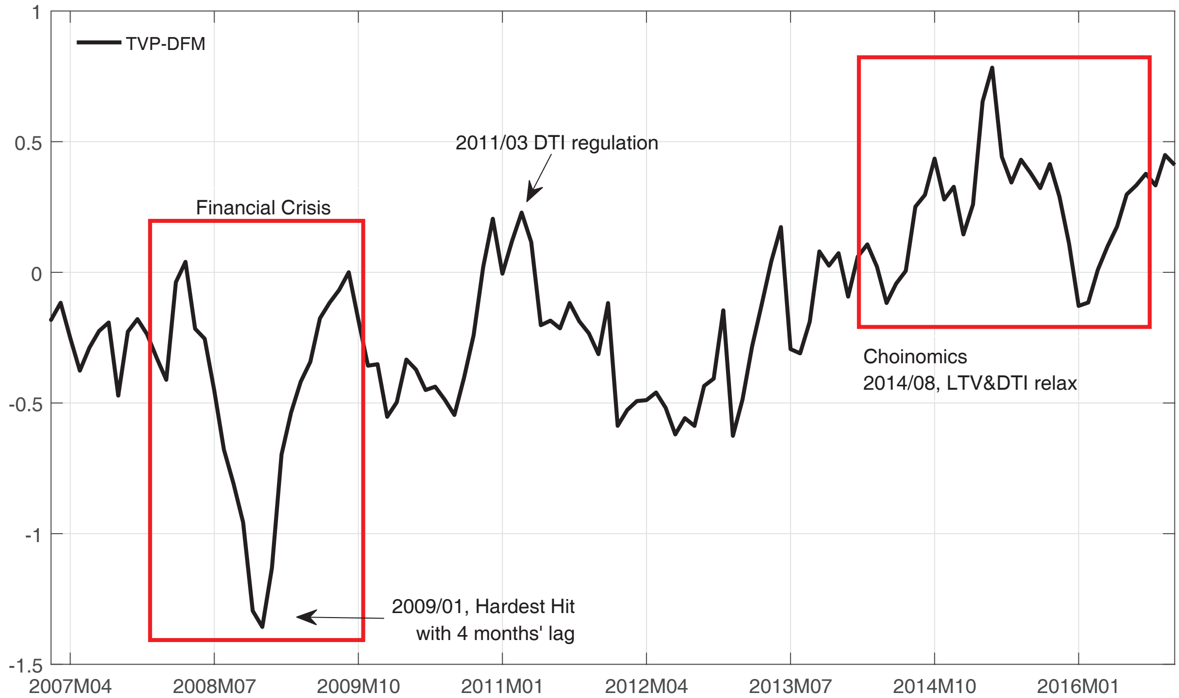
[12] Jeonse, or the full rent deposit is a real-estate term unique to South Korea that refers to the way apartments or other types of the house are leased. The Korean Jeonse takes an intermediate form of lease and home sales markets both in legal term and economic sense. See Appendix A for details

[13] Refer to Appendix B for detailed description. Here, KB reprsents Kookmin Bank, which is among the four largest banks ranked by asset value in South Korea.

4. Estimated Systematic Factor

This section contains our estimated systematic factor describing the Korean housing cycle. Figure 1 captures 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 activities including the 2008 financial crisis. To be specific, The factor reached to its lowest level four months after Lehman Brothers collapsed in September 2008. Secondly, the estimated factor seems to conform to major real-estate policies including 2011's DTI regulation and 2014's loosened LTV&DTI regulations effectively.

Figure 1: Estimated Systematic Factor



Note. Time-series of the estimated systematic factor.

Since 2008, the Lee Myung-Bak administration (17th term for 2008 - 2012) announced about 18 real estate measures and since its inauguration in 2013, the Park Geun-Hye (17th term for 2013 - currently suspended) administration has announced real estate policy packages 14 times. Many housing policies have exhibited different and possibly paradoxical effects on the real-estate markets, thus stood out a phenomenon of 'the fool in the shower'.[14] The bottom line is that Korean house cycles are strongly steered by the

[14] Before 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 Lee's presidency were largely attributable to the expansion of supply in the public sector, the revitalization of transactions centering

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 the systematic factor responds to two representative policy events well.

The 2011's DTI regulation had several adverse effects on the housing market. The biggest impact was the sharp cut in transaction volume. In February 2012, the number of apartment transactions across the country decreased by 20% compared to February 2011, when there was no DTI regulation. The impact of DTI regulation on housing prices was even greater. As of the end of February 2012, the housing market in the Seoul metropolitan area fell 0.2% in the past one year, while the apartment market fell 0.4%. Our estimated factor kept decreasing since the 2011's DTI regulation. It was a turning point to see how DTI regulation is affecting the market.

The 2014's relaxed LTV&DTI regulations were a part of the gigantic government policy packages called "Choinomics."[15] 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 borrowings for long-term rent increased significantly.[16] The 2014's relaxed LTV&DTI regulation contributed to the recovery and lost its contributional power for late 2015 and 2016. Ever since the 2014's de-regulations, our estimated factor kept increasing till early 2015 and reversed to decrease till early 2016 due to the supply-side shocks.

Based on the anecdotal interpretations, we verify that the estimated systematic factor captures the effects of the housing policies, thus represents the Korean housing cycle well. We have also verified that the estimated factor dynamics conforms to time-seies of the auction price in the Apartment auction market. The auction price is generally known to reflect the housing market dynamics well.[17]

on unsold pre-sale units, and stabilization of the pre-sale and rental market. However, the effects of the countermeasures announced by Lee's administration were limited, and despite the fact that many measures to stimulate the market were included, the effect of price stabilization on monthly rents was not sufficient. The policy packages during Park's regime, except for the latest one released on Nov. 3 in 2016, other 13 packages focused on deregulation and boosting the market.

[15] A 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 to boost the sagging property market and the construction industry, and expanded fiscal spending by unleashing a US$39 billion fiscal stimulus package.

[16] During 2014, South Korea achieved varying degrees of success in terms of economic growth and inflation ranging between 2.5 and 3.5 percent. Without the stimulus measures, Korea's economic growth would have been much lower than the estimated 2.6 percent in 2014.

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

5. Risk Management Applications

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

5.1. Risk Measurement

The first application of practical interest is measuring risk of holding credit portfolios. Measuring a credit risk requires key risk components such as exposures, conditional default probability, and loss given default. Marginal default probabilities can be calculated based on different methodologies such as a structural model or a reduced form model or from rating agencies about default probabilities. We calculate conditional default probabilities of the Vasicek model, $\text{PD}_i(Z)$ based on the estimated systematic factor(Z_t) from the equation (2). Here, i denotes credit gradings ranging from AAA to D, total 15 classifications.[18] We set $\Phi^{-1}(PD_i)$ to be i grade's long-term unconditional default probability, μ_i. Then we have the following:

$$\text{PD}_i(Z_t) \;=\; \Phi\left[\varepsilon_i \le \frac{\mu_i-\omega_i Z_t}{\sqrt{1-\omega_i^2}}\right] \tag{3}$$

We borrow empirical parameters for exposures, LGDs and CCFs from the KHUG.[19] Regarding losses given default, the convention is to use historical data depending on the seniority of the claims analyzed and assuming they are constant across time and across seniorities.[20]

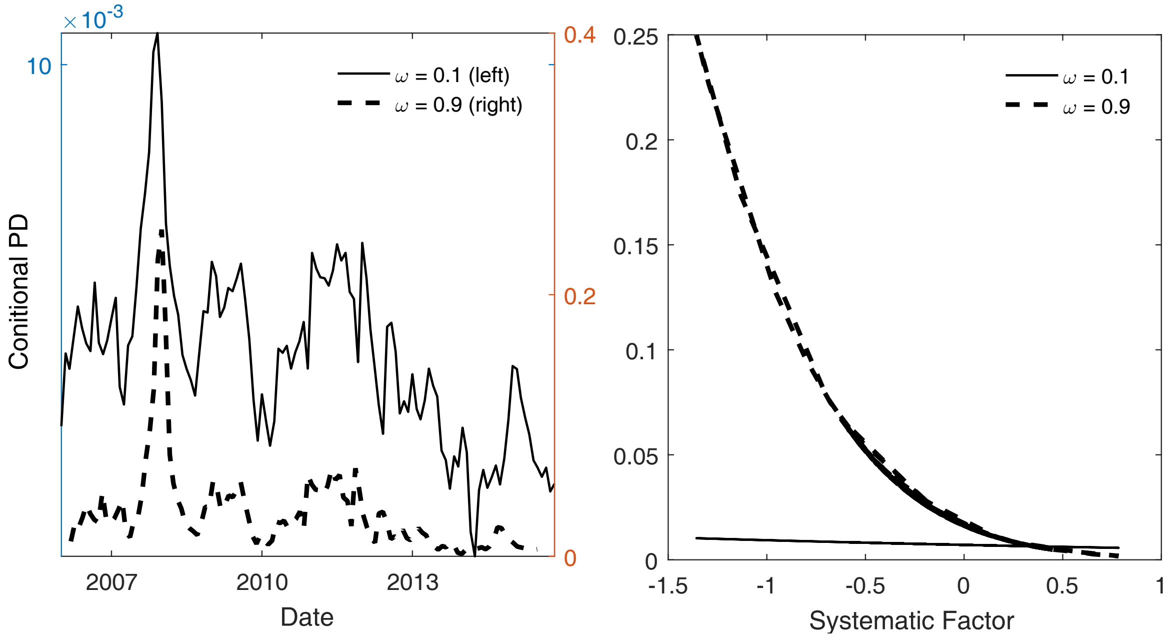
Two panels in Figure 2 display time-series of the conditional PDs of portfolios with credit grade A^+ and the relationship between the conditional PDs and the realization of Z depending upon the parameter ω, respectively. The risk dynamics of two conditional PDs is plotted in the first panel in which several empirical anecdotes mentioned in the section 4 seem to be well captured. The conditional PDs spiked during the financial crisis given two ω values, say 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 systematic factor realization is given in the second panel. For a given housing market shock, Z, we have the conditional probability of default on assets within the same credit grade. The ratio of conditional PDs for two ω values varies, ranging from minimum value 0.3190 to maximum value 24.3071.

[18] All credit gradings are as follows: AAA, AA, $\text{A}^+, \text{A}^-, \text{BBB}^+, \text{BBB}^-, \text{BB}^+, \text{BB}^-, \text{B}^+, \text{B}^-, \text{CCC}^+, \text{CCC}^-$, CC, C, and D(Default).

[19] Credit conversion factor(CCF) is an additional risk component for the guarantee product.

[20] The Loss Given Default Working Group in Basel Committee of Banking Supervision analyze the relationship between loss given default and economic conditions. Their main findings emphasize that losses given default are lower than average during times of high default rates, and that there is currently little consensus (across banks) with respect to the way of incorporating the correlation between losses given default and default probabilities in the calibration of their credit models.

Figure 2: Risk dynamics for A^+ credit grade



Note. Time-series of conditional PDs for given two ω values and the relationship between the realization of Z and the conditional PDs.

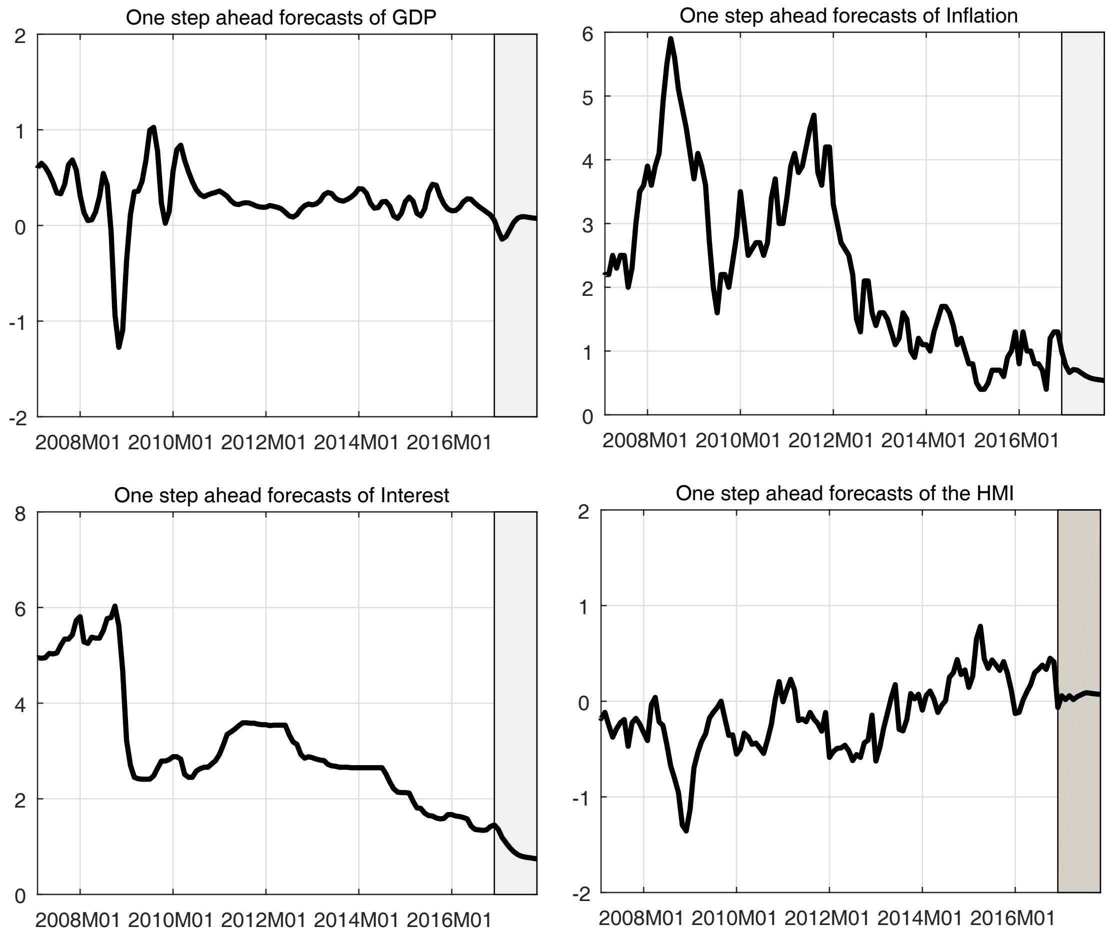
The role of ω in calculating the conditional PDs are relatively larger for the realm of lower realization of Z and smaller otherwise, thus there exists an asymmetric effect.

5.2. Forecasting and Stress-test

This section presents a method of how to combine a structural recursive forecast with (macro) stress-testing in a structural framework. Unlike the stress-testing practice in the banking sector, it is hard to implement stress-testing properly in the housing market. The main reason is that a credit risk of holding housing related claims and portfolios is difficult to model and simulate the conditional PDs because the 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 form a probability of default estimate, since few defaults are observed.(Basel Committee on Banking Supervision (2005)) These low-default assets pose an estimation problem, along with a difficulty in simulating expected default rates.

Our proposed methodology is to utilize the estimated systematic factor. Since 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 to simulate the default rates based on the Vasicek one-factor model in a structural framework. Figure 3 displays time-series of three macroeconomic variables and the estimated latent factor. The shaded area in Figure 3 exhibits predicted paths of four variables

Figure 3: The systematic factor forecast under the DSGE Framework



Note. A set of three endogenous economic variables, real $\text{GDP}_t, \text{inflation}_t, \text{policy rate}_t$ along with the systematic factor. These endogenous variables constitute a general equilibrium of the Korean economy together with the housing market.

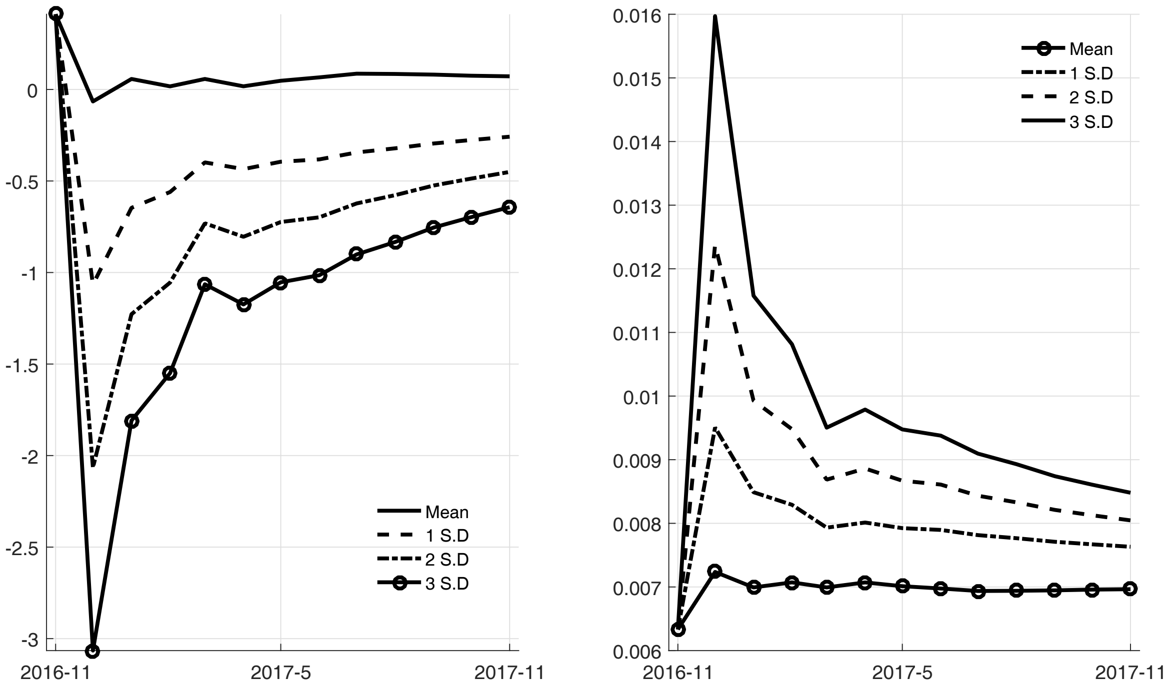
for one year period spanning from Nov. 2016 to Nov. 2017. Two panels in the first row show time-series of real GDP and inflation, whilst two panels in the second row exhibit policy rate and the estimated factor. We observe that the conditional mean prediction of the housing cycle exhibits a sharp fall for the two consecutive months and stays stable dynamics for the remaining period.

Along with the conditional mean 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.[21] The sizes of shocks applied to structural VAR systems are traditionally measured

[21] In statistics, the 68-95-99.7 rule represents 68.27%, 95.45% and 99.73% of the values lie within one,

as either one unit or one standard deviation shocks of the structural error. Note that the conditional mean forecast is implemented under a structural VAR framework, whilst other three shock-incurred paths are imposed on the systematic factor in a reduced-form setting and those paths are added to the conditional mean forecast.

Figure 4: (Macro) Stress-Testing



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

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

two and three standard deviations of the mean, respectively.

Table 2: VaR amounts for A^+ credit grade (0.1 Billion won unit)

Date	Panel A: $\omega = 0.1$				Panel B: $\omega = 0.5$			
	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

Table 2 contains risk measures as VaR(Value at Risk) amounts for A^+ credit grade. Two panels in Table 2 exhibit VaR amounts for parameter with $\omega = 0.1$ and $\omega = 0.5$, respectively. We observe the important role of parameter ω capturing a 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 2016, while VaR amounts with $\omega = 0.5$ increase rapidly from 242.6 billion won to 1170.1 billion won for increasing simulated shocks. An interesting observation is time-series dynamics of VaR amounts in Panel B with $\omega = 0.5$. VaR amounts plummet as time passes by. On the other hand, VaR amounts in Panel A with $\omega = 0.1$ decrease moderately. A surprising result is that at the end of the risk horizon in Nov. 2017, final VaR amounts in Panel B with $\omega = 0.5$ are far less than those in Panel A with $\omega = 0.1$.

5.3. Credit Risk Limit

Theoretically speaking, setting risk limits and tolerance goes through the process, first, defining the risk capacity by identifying regulatory constrains that restrict the ability to accept risk, second, establishing and regularly confirming the risk appetite with self-imposed constraints and risk drivers chosen to limit or influence the amount of risk undertaken.[22] Setting risk limits is a function of the risk policy to include the risk capacity and appetite inside the organization. We describe briefly how to set the risk limits when the confidence interval(CI) is set to be 95%. Currently, the KHUG calculates the credit risk limit(CRL) using the following formula:

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

where $\alpha_t = \frac{UL_t}{\text{Exposure}_t}$ and the denominator, UL_t is the unexpected loss amount. We estimate the value of $\alpha_{95\%}$ from its historical probability distribution with 95% confidence interval. The economic meaning of *alpha* is a time series of internal risk perception and risk tolerance manifestations inside the KHUG. This approach is vulnerable to the criticism that setting risk limits is being done in a *backward-looking* way. 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_{Z_t} through $CI(Z_t)$ conditioning on the size of housing market shock.

[22] This Risk Appetite Framework is consistent with current industry best practices and regulatory expectations.

In practice, a risk limit has three components to include risk metric, a risk measure that supports the risk metric, and a certain bound. Following the practice, our approach to setting limits is as follows: We start with fitting historical data of the estimated systematic factor to the probability distribution. Then, we calculate which area the predicted mean path of the systematic factor falls into. In the case of a normal distribution, for example, we verify whether the values of the predicted systematic factor lie in 68%, 95%, and 99.73%.

When the predicted systematic factor falls into the normal region such as within 90%, then we calculate VaR amounts under the predetermined confidence interval. We proceed to calculate $\alpha_{95\%}$ from its probability distribution. On the contrary, when the factor value breaches the predetermined threshold such as 75% or 90%, we switch $\alpha_{95\%}$ to α_{Z_t}, a new confidence interval where the systematic factor hovers over. Then, we calculate the value of α_{Z_t} given the new confidence interval($CI(Z_t)$). Afterward, we multiply current exposures by the numeric of α_{Z_t} to have the VaR amounts. One conceptual advantage worth mentioning is that since the confidence interval is a function of the predicted systematic factor, setting risk limits can be implemented in a timely and *forward-looking* manner.

6. Conclusion

This paper proposes an integrated risk management methodology that includes 1) measuring the risk of credit portfolios, 2) implementing (macro) stress-test, and 3) calculating risk limits by 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 since Korean house market cycles are strongly steered by the government in the fool in the shower's 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). Our proposed methodology is particularly useful for analyzing the risks of the *alternative investment* whose risk profiles are significantly different from financial products such as stock and bond in terms of the distribution of the default probability and liquidity.

Our study has some limitations. The role of interest rate in the housing market has been well recognized, thus a single factor model is needed to extend to include the interest rate factor to better capture the conditional PDs. In addition, our empirical analysis is restricted to the guarantee portfolios with A^+ credit grade only, thus incorporating the correlation between losses given default and default probabilities, or between default probabilities for different credit grades in the calibration of their credit models is omitted. This would be tolerable in the sense that our main focus is to propose a new risk management approach. An interesting development would be to explore the role of a discrete survival model and dynamic conditional correlation within the scope of risk management applications.

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Appendix A.

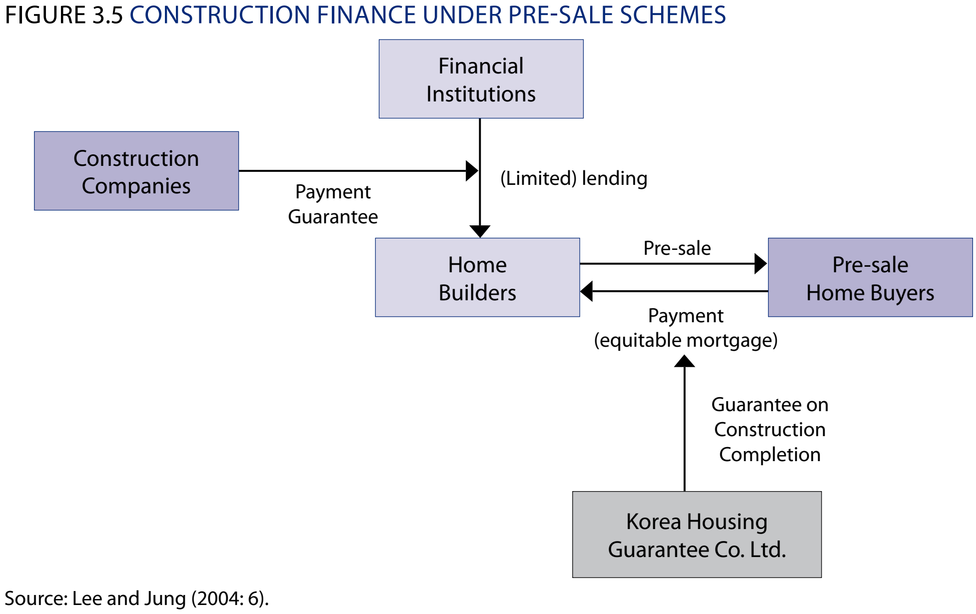
Description of Jeonse: Jeonse, or the key money deposit, is a real estate term unique to South Korea that refers to the way apartments or other types of the house are leased. Instead of paying monthly rent to a landlord, a large lump-sum payment is deposited into the landlords bank account for the duration of the contract. By law, Jeonse contracts are signed 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. Property owners keep the returns and then repay the lump sum at the end of the tenancy. Jeonse has been mutually beneficial both for landlords and tenants because the landlord can expect capital gains from rising housing prices during the housing boom, and tenants can also lease at prices lower than real estate sales prices. In addition, the Jeonse system eliminates the likelihood of tenants default on monthly rents. In general, landlords prefer Jeonse because Jeonse enables them to purchase the property levered with Jeonse contracts. There also exists a rollover and possibly liquidity risk in the sense that landlords can not pay back the full deposited sum at the end of the contract because they usually invest a large sum of money from Jeonse contracts to buy other properties or invest in the longer-term financial assets. The Jeonse system is key to understand the Korean housing market deeply. In this regard, there have been published many practical and academic studies on Jeonse, recently. Among them, Kim and Shin (2012) analyzed rents from the viewpoint of financial transactions and defined Jeonse as housing repo contracts of homeowners and tenants as collateral for housing.

Appendix B.

Korea has a pre-sale and pre-sale guarantee system to supply new houses. The housing pre-sale system permits housing builders to receive a portion of house prices from the buyer before the housing is to be completed. This is equivalent to those activities which construction companies receive the construction cost in advance. The Korea Housing and Urban Guarantee Corporation (KHUG) was established in accordance with Article 16 of NHUF (National Housing and Urban Fund) Act to improve housing well-being and revitalize urban renewal 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 area includes guarantee business for housing that includes guarantee for housing completion, guarantee for rental deposit, guarantee for cooperative housing completion. For example, the completion of housing construction or the refund of down payment and middle payments made in cases where a project owner fails to fulfil its obligations under pre-sale agreement due to bankruptcy, insolvency, etc. See for detailed business description at the KHUG homepage

In Korea, pre-sales system is very popular. Home buyers pay a certain percentage of the deposit upon signing the contract, paying the remaining balance based on an

Figure B.5: Construction Finance under Pre-Sale Schemes



installment schedule that is linked to the construction schedule. When they move into a newly constructed house, they pay the last installment, at least 20% or more of the contract price. Figure B.5 shows development finance under pre-sale schemes. To purchase land, home builders make use of their equity. In very restricted cases, land loans are available. In general, financial institutions provide mezzanine or bridge loans only when pre-sales are successful. In a pre-sale scheme, home buyers are exposed to home builders' default risk, therefore in order to eliminate these risks, the KHUG provides construction completion guarantee services for future homeowners. See more details at Housing Finance Mechanisms in Republic of Korea

Table 3: Description of 16 candidate variables (X_t)

Factors	Variables	Description
Price	Transaction-based Apartment Price Index	This index provides the market trend information by analyzing the transaction price level and the rate of change of the declared apartment in the inventory apartment of nationwide and is used as reference data for the government policy. (source: Korea Appraisal Board)
	Housing Price Index	The housing price index is a weighted value of the housing, housing type, and housing stock computed by 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 by using the Laspeyres formula. (source: Kookmin Bank)
	Ratio of Jeonse to Apartment Price	The Jeonse to Apartment price ratio is the ratio of the yearly rental to the house price. (source: Kookmin Bank)
	Construction Cost Index	The index based on direct construction cost provided by Korea Institute of Construction Technology)
Quantity1: Construction	The number of Households Approved for Sale	The number of housing which was approved for pre-sale public notice. (source: Ministry of Land, Infrastructure and Transport)
	Value of Construction Completedat Current Prices	The amount of construction that the construction company can receive from owners or developers after construction completion. (source: Ministry of Land, Infrastructure and Transport)
	Amount of Order 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 Apartment	The ratio of sold units to total units of new apartment. (source: Ministry of Land, Infrastructure and Transport)
	Number of Guaranteed Housing Units	The number of houses that the KHUG guarantees
Quantity2: 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 after completion (source: Ministry of Land, Infrastructure and Transport)
	Unsold New Apartment Housing Units	Unsold new apartment housing units before completion (source: Ministry of Land, Infrastructure and Transport)
Others	KB's Buyer's Market Response Index	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 purchasing price are at the same level.
	Amount of Mortgage Loans	The total amount of credit incurred by the 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)