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Transmission of Systemic Risk Through Latent Leverage Channel

Myeong Hyeon Kim Researcher, Korea Housing & Urban Guarantee Corporation, Asian Institute of Corporate Governance at Korea University

Baeho Kim* Professor, Korea University Business School

Abstract

This paper examines the mechanism of systemic risk propagation through system-wide latent leverage channel. We focus on the hidden leverage-induced asset value dynamics in the financial markets, intertwined with balance-sheet components of the banking system. We propose a *latent leverage* index by estimating smooth transition regression models based on the intrinsic element of the financial system, off-balance-sheet transaction, and cross-border activities of the Korean commercial banking system. We find that a shock to the latent leverage index impacts the macroeconomy with the lag of three quarters. This finding provides an important policy-oriented implication for macroprudential supervision of banking system.

Keywords Latent Leverage Index, Systemic Risk, Balance-Sheet Information, Procyclicality, Korean Banking System

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* Corresponding Author, Address: Korea University, 145 Anam-ro, Sungbuk-gu, Seoul, 02841, Korea; E-mail: baehokim@korea.ac.kr; Tel: 82-2-3290-2626.

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Ⅰ. Introduction

A system-wide leverage expansion generally entails common exposures to hidden risk factors. For instance, the stacking up of balance-sheet vulnerabilities combined with a run-up of asset prices causes more severe economic downturns, and leverage build-up is inseparable from an accumulation of excessive risks. Excessive growth of credit tends to be followed by a crisis, as prevailing financial risk is underestimated in the business cycle upswing. As a result, financial crises commonly occur when too much debt is combined with a sharp fall in asset price; see Reinhart and Rogoff (2008), Adrian and Shin (2010). Extensive financial distress stems from the unwinding of financial imbalances cloaked by optimistic economic conditions (Borio and Lowe, 2002). This phenomenon is coined as *volatility paradox*, which has attracted policy makers' attention to the failure of micro-prudential regulations. Kim and Kim (2014) argue that such macro-financial vulnerabilities are rooted in a procyclical interaction between market-wide risk perception and system-wide asset management behavior.

Overall, financial cycles are typically more than proportional to the dynamics of economic activity through a mutually amplifying feedback loop in an asymmetric manner. Brunnermeier and Sannikov (2014) point out that financial frictions lead to the amplifying shocks, directly through leverage and indirectly through asset prices. Hence, we highlight the interaction between the business and financial cycles in terms of their bilateral transmission of systemic shocks through credit channels, of which an example is the balance-sheet channel providing a logical link between the financial system and the real economy; see Bernanke and Gertler (1995), Kiyotaki and Moore (1997), Bernanke, Gertler, and Gilchrist (1999) for similar arguments. Another channel of credit flow is through the banks' lending activities. This bank lending channel delivers a theoretical framework for the existence of bank-originated systemic shocks. This channel indicates that factors impacting a lender's balance sheet can magnify economic downturns, as banks with weak capital become more reluctant to provide additional credits to the real economic sectors or can even be forced to deleverage by selling non-toxic loans.

Based on these arguments above, this paper examines the nonlinear transmission mechanism in the time-series dimension. For this purpose, we propose a concept of system-wide *latent leverage* in the sense that building up leverage entails the lurking systemic risks at the aggregate level.[1)] Specifically, we construct a latent leverage index from commercial banks' balance-sheet information with market-wide risk factors based on the theoretical foundation to capture the source of macro-financial vulnerability. Our propsed latent leverage index is based on the aggregate balance-sheet information in the banking system. Specifically, we employ a set of system-wide latent leverage components, as the information set contained in latent leverage components is closely connected to system-wide risk perceptions. To do so, we use sub-components of the latent leverage in that different types of leverage, such as economic and embedded leverages, should be considered simultaneously, as no single measure can capture the multiple dimensions of a financial crisis (D'Hulster, 2009).

At the aggregate level, we propose a model-induced latent leverage index to investigate how this latent leverage propagates to the business cycle corresponding to various exogenous shocks implied by a reduced-form vector autoregressive (VAR) model. We employ policy rate, land price,

1) In this context, we emphasize that the term leverage can be misguiding in the sense that leverage as such contains no direct connection to asset prices. In line with our proposed concept of system-wide latent leverages, two new liquidity measures among the Basel Committee's key reforms to promote a more resilient banking sector (the Liquidity Coverage Ratio [LCR] and the Net Stable Funding Ratio [NSFR]) are suggested in the Basel III regulation scheme.

equity and exchange rate based on economic arguments as measures of exogenous shocks. Then, we examine how these outer shocks propagate to the latent leverage index and, in turn, from the latent leverage index to the economic fluctuations using an impulse response analysis.[2)]

This paper makes several contributions both to the literature on systemic risk and the literature on systemic risk measures, including the financial stability index, by identifying lurking systemic risk factors from balance-sheet information. As our proposed latent leverage index directly incorporates the quality of asset/liability in the balance sheet, our approach is preferable to the mere leverage regulation for complementing the existing risk-sensitive capital requirements, as Kalemli-Ozcan, Sorensen, and Yesiltas (2012) show that excessive risk taking tendencies before a crisis are hard to detect due to the lack of information about the quality of assets. As central regulators have access to the monthly balance-sheet data with detailed components, our proposed methodology can be used as a practical macro-prudential toolkit for regulating latent leverage at the macro level.[3)] By associating four latent leverage components with hidden system-wide risks, we propose a macro-framework for regulating latent leverages under the Basel III framework.

Ⅱ. System-wide Latent Leverage

This section develops the concept of system-wide latent leverage and its components. We discuss the economic implication of latent leverage by decomposing it into its components with a special focus on the transition

2) It is noteworthy that bank credit expansion can predict increased crash risk in the bank equity index and equity market index (Baron and Xiong, 2014).

3) For an extensive review of macroprudential policies, see Hanson, Kashyap, and Stein (2011) and Crowe, DellAriccia, Igan, and Rabanal (2011) on the pros and cons of various policy options.

mechanism from the time-series perspectives. Such a decomposition is based on the multifaceted balance-sheet items so that each component has its own macroprudential implication. Accordingly, the system-wide latent leverage has a close connection to diverse transmission channels. As different latent leverage components can imply different risks intertwined systemically, we decompose the latent leverage into four components. borrowing capability, intrinsic element of the financial system, off-balance-sheet transaction, and foreign exchange leverage-from the Korean commercial bank financial statements. This decomposition is compatible with a framework for dealing with domestic systemically important banks (D-SIBs), as recently suggested by the Basel Committee on Banking Supervision (BCBS, 2012).4)

First of all, we naturally consider the *borrowing* (BOR) leverage as the total leverage at the aggregate level in that the core business of the commercial banking system is channeling leverages for other agents. Specifically, the BOR leverage is defined as traditional on-balance-sheet banking assets (including loans and securities, and other forms of security assets) over the aggregate equity capital. Note that the BOR leverage encompasses the system-wide latent leverage components as we introduce in the following paragraphs.

The second latent leverage component is the *intrinsic* (INT) leverage within the financial system, as interbank loans in the bank's balance sheet contains information about the degree of interconnection with the exposure to potential contagion effect or adverse feedback loop in the banking system. The intrinsic leverage captures the interdependence within the financial system that increases through exposures among financial institutions. We incorporate these exposures using the trading account

4) In a similar vein, Ryoo and Kim (2012) propose the concept of systemic leverage as a macroprudential indicator by focusing a procyclical impact of the aggregate leverage specific to Korean banking system on the real economy.

and available-for-sale securities on the asset side and wholesale funding on the liability side; they include financial bonds, CDs, repos, call loans, interbank lending, and deposits. In this context, the INT leverage is defined as exposures among financial institutions divided by equity capital.

Next, we consider the *off-balance-sheet* (OBS) leverage, which measures the leverage effect hidden in derivatives and contingent liabilities. Financial institutions can increase their leverage using derivative contracts, which are usually not obliged to report or to materialize until the counterparty fails to meet its obligations. Financial institutions with lots of off-balance-sheet components witnessed their leverages rise sharply because of counterparty default risk during the financial crisis. In this regard, Zawadowski (2011) argues that banks in a web of hedging contracts fail to internalize the negative externality caused by their own failure. Other contingent liabilities include guarantees and loan commitments and these hidden debts also increase leverage if they are realized. We define the off-balance leverage as derivatives and contingent liabilities divided by equity capital to imply accounting (i.e., information opaqueness) risk due to uncertain assets or liabilities and hidden spillover.

We should not neglect the *foreign borrowing* (FX) leverage in emerging economies, where external borrowing through foreign financial institutions can serve as the major channel of financial distress. For instance, the Korean financial system experienced severe financial turmoils in 1997 and 2008 when massive capital outflows incured. FX borrowing peaked right before these two crisis episodes. The main reason is that since FX borrowing positions of domestic banks were closely intertwined with forward buying contracts with shipbuilders, foreign bank branches operating in Korea utilized their advantages in funding cost by heavily borrowing from their headquarters to provide currency swaps before the 2008 global crisis.[5)]

5) See Ryoo and Park (2008) for more detailed explanation.

Furthermore, as Kaminsky and Reinhart (1999) point out, a currency crisis deepens a banking crisis, activating a vicious spiral. We calculate the FX leverage ratio as external borrowing divided by equity capital to capture the rollover and currency risk of FX nominated debts.

Ⅲ. Methodology and Data

This section describes our modeling approach used to construct the latent leverage index and the homogeneity-based marginal contribution of individual banks to the systemic vulnerability. Then, we describe our data and sample for the empirical analyses.

3.1 Model Specification

Let A^i be the i-th aggregate asset value component, assumed to follow the Geometric Brownian Motion given by[6)]

$$\frac{dA_t^i}{A_t^i} = (r_t + \lambda_t^i + u_t^i)dt + \sigma_A^i dW_t^i \quad (1)$$

where λ_t^i is the market-wide risk premium, u_t^i is the system-wide asset management, and σ^i is the volatility of the i-th asset component value, respectively.

Extending the specification of Kim and Kim (2014), we further postulate that (i) the market-wide risk premium $\lambda_t^i = \beta_A^i \xi_t$ captures the CAPM-based systematic risk premium, where ξ_t is the systematic (market) risk factor,

6) The intuition behind the expression comes from the definition of the value, which is a multiplicative form of price and quantity.

and (ii) the system-wide asset management u_t^i denotes the system-wide leverage management whose functional form is given by $u_t^i = g^i(Y_{t-d})X_t$, where $g^i(Y_{t-d})$ captures the nonlinearity causing the boom/burst sentiment by measuring how much the financial risk appetite is deviated from the economic fundamental. Specifically, we take the vector of latent leverage components as the transition variable Y_{t-d} with one-quarter lag (i.e., d = 0.25) to avoid the endogeneity issue, and the credit-to-GDP gap as our measure of the deviation between financial and business cycles, denoted by X_t.

Further, we let $\ell^i = A^i/E$ be the *i*-th latent leverage component, where *E* represents the system-wide aggregate equity value whose dynamics can be expressed as

$$\frac{dE_t}{E_t} = (r_t + \beta_E \xi_t + u_t^E)dt + \sigma_E dB_t,$$

where β_E is the CAPM-based equity risk premium, and $E(dW_t^i dB_t) = \rho_t^i dt$. Here, we assume $u^{E_t} \approx 0$ grounded in the argument of Adrian and Shin (2010). Applying Ito's lemma yields the dynamics of the latent leverage component given by

$$d\log \ell_t^i = \alpha^i dt + (\beta_A^i - \beta_E)\xi_t dt + g^i(Y_{t-d})X_t dt + \Sigma_t^i d\hat{z}_t \tag{2}$$

where $\alpha^i = \frac{1}{2}\{(\sigma_A^i)^2 - (\sigma_E)^2\}$, $\Sigma_t^i = \sqrt{(\sigma_A^i)^2 + (\sigma_E)^2 - 2\rho_t^i \sigma_A^i \sigma_E}$. For estimation purposes, we adopt the smooth transition regression (STR) model for specifying a *continuum* of regime shifts triggered by the gradual realization of the latent leverage throughout the entire system. The STR model presumes the transition dynamics based on continuous transition functions that allow smooth regime changes. By discretizing (2), we derive a version of the STR equation given by

$$\Delta \log \ell_t^i = \widehat{\alpha}^i + \widehat{\beta}^i \xi_t + \widehat{g}^i(Y_{t-d}) X_t + \widehat{\Sigma}_t^i \epsilon_t^i \tag{3}$$

where $\hat{\alpha}^i = \alpha^i \Delta t$ denotes the intercept, and $\hat{\beta}^i = (\beta_A^i - \beta_E)\Delta t$ captures the systematic risk factor loading.[7] Hence, we can re-arrange the expression as

$$\hat{g}^i(Y_{t-d}) = \kappa^i \Delta t + \frac{\delta^i \Delta t}{1+\exp(-c^i(Y_{t-d} - \zeta^i))} = \hat{\kappa}^i + \frac{\hat{\delta}^i}{1+\exp(-c^i(Y_{t-d} - \zeta^i))}$$

denotes a nonlinear function of Y_{t-d} for the i-th latent leverage component.[8]

3.2 Data and Sample

We use balance-sheet data for Korean domestic banks provided by the Financial Supervisory Service through the Financial Analysis Information Retrieval System.[9] <Table 1> reports the descriptive statistics of our full data set. Our dataset has a quarterly frequency and its time-span is ranging from the first quarter of 2000 to the third quarter of 2014. The domestic banks included are seven commercial banks (KB Kookmin, Shinhan, Woori, Hana, Standard Chartered, Citibank Korea and KEB), and six local banks (Kyongnam Bank, Kwangju Bank, Daegu Bank, Busan Bank, Chunbuk Bank and Jeju Bank).

Presumably, the credit-to-GDP gap is the most relevant proxy for the deviation between the financial and business cycles. For example, Borio

7) Note that the estimable equation (3) matches the stylized fact (see <Figure 1>) that latent leverages show a smooth transition dynamics due to the existence of many different agents and different degrees of institutional investing inertia with time lags.

8) To estimate logistic smooth transition regression models (3), we use a set of Matlab codes, implemented by McAleer and Medeiros (2008).

9) http://sis.fss.or.kr/fss/fsi/id/fssmain.jsp.

and Drehmann (2009) find that the credit-to-GDP gap is the best performing one across various variables considered by the authors. We construct the credit-to-GDP following the BCBS guide 187. We obtain credit and domestic GDP series for the empirical analysis from the bank of Korea (BOK)

<Table 1> Summary Statistics

Panel A: Summary Statistics of The Latent Leverage Components

	BOR	INT	OBS	FX	CP-CD	C to G
Mean	16.6570	9.6767	16.4577	2.8322	0.2564	0.0040
Median	15.4046	9.3482	17.1660	2.5259	0.1700	-0.0243
Maximum	24.9864	12.5839	31.6244	5.3648	1.6700	0.2620
Minimum	11.8533	7.7896	5.3576	1.9009	0.0500	-0.1319
Std. Dev.	3.7423	1.4507	6.9640	0.9019	0.2615	0.0977
Skewness	0.4771	0.5920	0.0387	1.4235	3.5194	0.8972
Kurtosis	2.0171	2.1212	2.0637	4.4340	17.6861	3.0176
Jarque-Bera	4.6132	5.3443	2.1698	24.9819	652.0094	7.9158
Probability	0.0995	0.0691	0.3379	0.0000	0.0000	0.0191

Panel B: Summary Statistics of the Macro-Economic and Financial Variables

	PRATE	HP	KOSPI	EX	RGDP
Mean	3.5975	0.0180	0.0260	-0.3610	0.0276
Median	3.7500	0.0131	0.0401	-3.1000	0.0279
Maximum	5.2500	0.0700	0.2334	39.7000	0.0549
Minimum	2.0000	-0.0091	-0.3091	-18.2000	0.0077
Std. Dev.	1.0107	0.0197	0.1154	11.4253	0.0112
Skewness	-0.0166	1.1101	-0.7477	1.7213	0.2885
Kurtosis	1.8377	3.7141	3.3529	6.1698	2.4632
Jarque-Bera	3.3240	13.3724	5.8039	53.8352	1.5266
Probability	0.1898	0.0012	0.0549	0.0000	0.4661

Note) Descriptive statistics. This table reports the indicated summary statistics of the selected variables at quarterly frequencies from 2000 to 2014. Panel A reports summary statistics of three latent leverage components and two risk factors considered in the equation (2). CP–CD denotes the interest rate differential between the yield on the commercial paper (CP) for non financial firms and the yield on the certificate of deposit (CD). C to G denotes the credit–to–GDP constructed by following the BCBS guide 187. Panel B reports the summary statistics of macroeconomic and financial variables for the Vector Autoregressive Regression. PRATE represents a policy rate; HP is an annual growth rate of the housing price; KOSPI is an annual growth rate of the Korean stock index; EX represents an annual growth rate of exchange rate; RGDP is the Korean real gross domestic product. Our study period includes 59 quarters.

website.[10] Then, we apply the Hodrick-Prescott (HP) filter to detrend the gap. The smoothing parameter, generally referred to as λ in the literature, is typically set to 1,600 for quarterly data to capture the long-term trend in the behavior of the credit-to-GDP ratio in each jurisdiction.

To incorporate the systematic (market) risk factor, ξ_t, we consider the interest rate differential between the yield on the commercial paper (CP) for non-financial firms and the yield on the certificate of deposit (CD). Ra and Yan (2000) show that the excessive use of commercial paper by financial institutions and corporations contributed to the vulnerability of the Korean economy to external shocks; we thus focus on the economic role of the commercial paper during the financial crisis. In principle, the CP is a price proxy for the business cycle measured by the yield, as commercial paper issuers tend to use the proceeds from issuance to cover their short-term financing needs for working capital and inventory, which are directly related to the economic fluctuations. Therefore, the spread between the CP and CD is a price differential proxy for the deviation between the financial and business cycles. We obtain both yield series from the Bank of Korea.

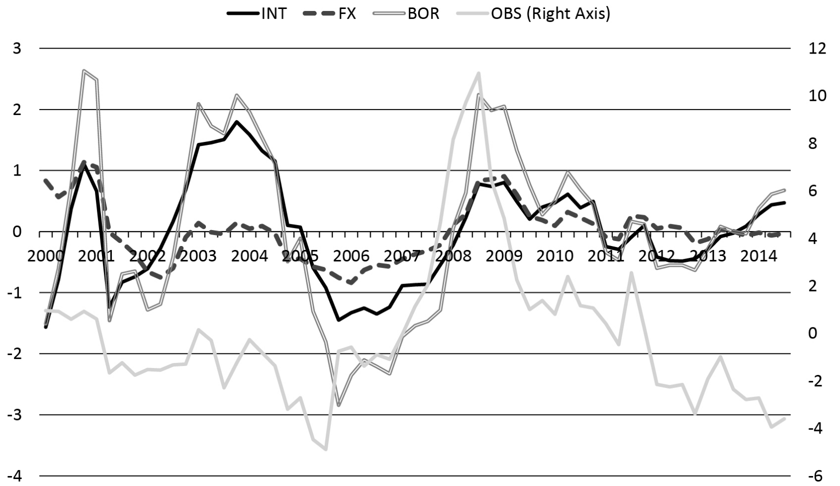
Ⅳ. Empirical Results

This section presents our empirical results to examine the transmission mechanism of systemic risk propagation within a nonlinear framework. We conjecture that a logistic transition function represents the asymmetric and nonlinear transition from one regime to the other. Viewed in this vein, we focus on the coefficients on the amplification and asymmetry

10) http://www.bok.or.kr.

components in the fitted model to the balance-sheet information of the banking system.

<Figure 1> Time-Series Dynamics of the Filtered Latent Leverage Components



Note) Time-series dynamics of the HP-filtered latent leverage components of the borrowing leverage (BOR), intrinsic element of the financial system (INT), off-the-balance-sheet transaction (OBS), and foreign exchange leverage (FX) from the Korean commercial banks' financial statements. A value for the smoothing parameter is 1600, a norm for quarterly data.

4.1 Estimation Results

We first test for linearity to detect the potential nonlinear transmission mechanism in the latent leverage management in an asymmetric manner. Motivated by van Dijk, Franses, and Paap (2002), the linearity test is based on the third-order Taylor series expansion of the logic function around the null hypothesis against our logistic STR model specification. The results indicate that the linearity in the elasticity of the deviation between financial and business cycles on the latent leverage management can be rejected at the 5% significance level except for the intrinsic leverage.[11] This observation highlights the importance of the nonlinearity in our

11) The p-values of the linearity test for INT, OBS, FX leverage components are 0:0200, 0:1416, 3:119 $\times 10^{-7}$, 4.382 $\times 10^{-4}$, respectively.

proposed STR model specification, if we consider the potential transmission mechanism beyond the domestic financial system.

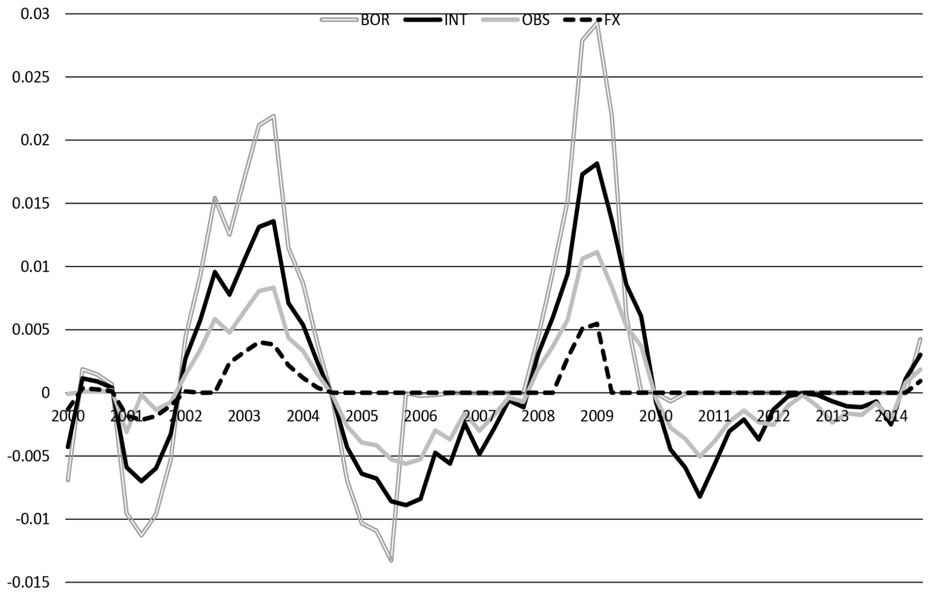
We next estimate the nonlinear equation (3) with four contemporaneous systemic leverage components by maximum likelihood estimation. <Table 2> reports the estimation results based on the aggregate balance-sheet data. We find strong evidence that the non-linear amplifying coefficients show strong statistical significances across different latent leverage components (except the OBS component). Positive coefficients indicate a strong procyclicality in terms of quantity controls in the balance sheet management. Moreover, the estimated coefficients ($\hat{\beta}^i$) on the systematic risk factor (CP-CD) capturing the sensitivity to the market-wide risk perception are significantly negative for BOR and INT leverage components. The negative coefficients on the systematic factor indicate that the aggregate commercial banks deleverage their market positions, when the systematic risk increases and vice versa. As the negative sign of $\hat{\beta}^i$ implies the procyclical relationship between latent leverages and systematic risk factor ξ_t, it is particularly nontrivial to observe the evidence that the borrowing and intrinsic leverages show a strong procyclicality.

<Table 2> Estimation Results for System-Wide Latent Leverage Components

Components	$\hat{\beta}$	$\hat{\delta}$	$\hat{c}$	$\hat{\zeta}$	Adj.R^2
BOR	-0.0100** (0.0052)	0.1118*** (0.0175)	26.98 (91.51)	4.1438*** (0.0843)	0.3971
INT	-0.0081*** (0.0030)	0.0693*** (0.0083)	10.80 (33.4)	5.5733*** (0.4980)	0.5565
OBS	0.0189* (0.0125)	0.0425 (0.0357)	25.24 (125.72)	0.9239*** (0.2955)	0.0343
FX	0.0001 (0.0016)	0.0213*** (0.0084)	27.08 (84.74)	3.5363*** (0.1606)	0.1878

Note) Estimation results for the systematic beta ($\hat{\beta}$), amplification ($\hat{\delta}$), shape ($\hat{c}$), and asymmetry ($\hat{\zeta}$) coefficients using aggregate BOR, INT, OBS, and FX leverage components. Standard errors are reported and *, ** and *** indicate two-tailed statistical significance at the 10%, 5% and 1% levels, respectively.

<Figure 2> Time-Series of Latent Leverage Management Specific to Each Component



Note) This figure plots the time series of u_t^i's procyclical dynamics for all latent leverage components with different magnitudes. u_t^i is constructed based on estimation results from the nonlinear equation (2) and u_t^i denotes the system-wide leverage management whose dynamics is composed by combining the nonlinearity causing the boom/burst sentiment with the deviation between financial and business cycles. A detailed description of ut u_t^i is given in Section III.

One notable finding is that the negative relationship between the estimated coefficients on the price-and quantity-proxy variables. Specifically, the BOR and FX leverages share the same patterns to include negative signs for beta and positive signs for amplification coefficients. This finding has an important policy-oriented implication from the macroprudential perspective: a key prerequisite for policy makers is to capture the procyclicality at the right time. Then, the policy priority should be arranged by decomposing the latent leverage into sub-components so that one can differentiate the degree of the procyclical and countercyclical effects of each component. Different latent leverage components can have different cyclicalities, leading to the policy implication that the role of the nonlinear amplifying effect should be curbed according to the degree of procyclicality.

4.2 Construction of the Latent Leverage Index

By the macroprudential nature of procyclicality, constructing a latent leverage index requires employing aggregate balance-sheet data. Based on equation (2), we construct a nonlinear function $\hat{g}^i(Y_{t-d})$. <Figure 2> exhibits the time-series behavior of latent leverage management, denoted by $u_t^i = \hat{g}^i(Y_{t-d})X_t$, specific to each component. The economic implication of u_t^i is the aggregate asset management behavior for individual latent leverage components. We observe a significant degree of difference among nonlinear amplifying effects and strong procyclical asset management behavior across different latent leverage components. It certainly captures a sensitivity to procyclicality measured from its contribution to the deviation between the financial and business cycles in that all the destructive economic activities including a re-sale or a market freeze are related to the nonlinearity. It is also directly connected to the macroprudential policy responses to the deviation in a nonlinear way as represented by the transition function $\hat{g}^i(Y_{t-d})$. In this regard, we construct an aggregate latent leverage index (LLI) using the information of $\hat{g}^i(Y_{t-d})$. We propose a simple weighting scheme of the amplifying effects given by

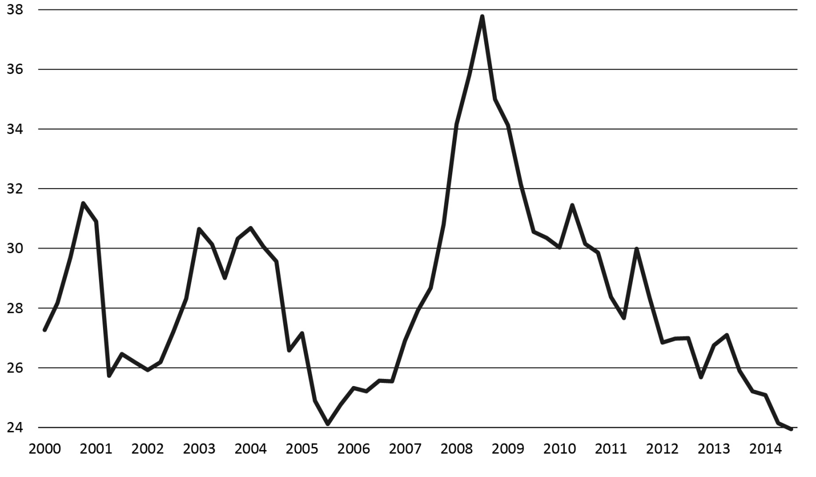
$$\mathrm{LLI}_t = \Sigma_i \, w_t^i \, \ell_t^i \tag{4}$$

where $w_i = \Phi(\hat{u}^i(X_t))$ for i = {BOR, INT, OBS, FX}, $\Phi(\cdot)$ denotes the cumulative distribution function of a standard normal variable, and $\hat{u}^i(X_t)$ is the standardized value of $u^i(X_t)$ so that it has zero mean and unit variance.

<Figure 3> depicts the time-series dynamics of the aggregate latent leverage index. One particular feature is that the latent leverage index exhibits a procyclical dynamics. Note that the latent leverage index is

constructed by using the information from both the latent leverage components and market risk perception. The procyclicality implies that the interaction between the system-wide portfolio management behavior and the market-wide risk perception is procyclical, as Korean commercial banks are actively adjusting their asset portfolios in a procyclical manner. Unlike the continuing boom period when other countries enjoyed the appreciation of housing prices, the Korean economy experienced a period of hardship from 2004 to 2006 owing to a credit-card crisis with a significant impact on both the financial system and the real economy. Later, the Korean banking system expanded its balance sheet rapidly until late 2008, mostly by increasing mortgage loans. Although the credit expansion measured by our calculation was similar to the housing market booms of the U.S., the Korean economy was relatively resilient to the 2008 global shock. From <Table 2>, we verify that the amplification coefficient for the OBS leverage is not statistically significant. The strict application of macroprudential policies such as DTI and LTV combined with the non-existence of the OBS leverage effect is recognized as a potential ex-

<Figure 3> The latent leverage index



Note) This figure illustrates the time-series behavior of the aggregate latent leverage index defined as (4).

planation for why the Korean economy was relatively resilient to the 2008 global shock. Interestingly, after the global financial crisis, the Korean commercial banking system kept shrinking their balance sheet aggressively until the third quarter of 2014.

4.3 Propagation Mechanism of Systemic Risk

The time-series behavior of the latent leverage index implies how the macroprudential policy responses to the deviation between the financial and business cycles manifest themselves in a nonlinear way, which we refer to as *the latent leverage propagation mechanism*.

Next, we investigate how this latent leverage propagates to the business cycle corresponding to various exogenous shocks implied by a reduced-form vector autoregressive (VAR) model given by

$$Z_t = a + \sum_{i=1}^{p} A_i Z_{t-i} + W_t \tag{5}$$

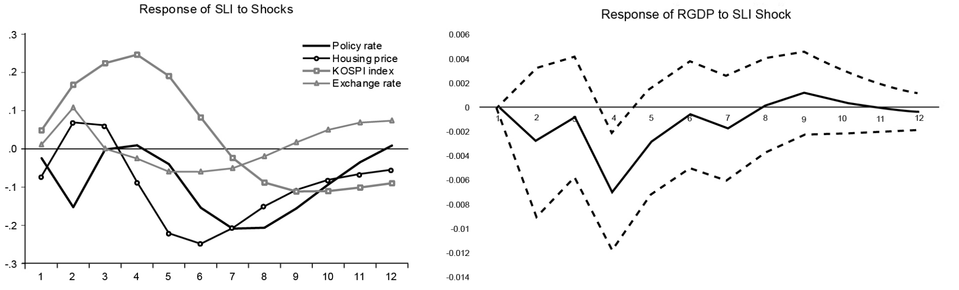
where $W_t \sim N(0, Q)$ and $Z_t = [PR_t, HOUSING_t, KOSPI_t, EX_t, LLI_t, RGDP_t]'$ is a vector of five variables juxtaposed corresponding to the degree of being exogenous. PR_t represents a policy rate; $HOUSING_t$ is a year-over-year growth rate of the housing price; $KOSPI_t$ is a year-over-year growth rate of the Korean stock index; LLI_t represents the aggregate latent leverage; and $RGDP_t$ is the Korean real gross domestic product. All variables are observed on a quarterly basis and seasonally adjusted. In this framework, we employ a set of macroeconomic variables including policy rate, land price, equity and exchange rate as a proxy of exogenous shocks based on the literature. We first examine how these shocks propagate to the latent leverage index (LLI) and in turn, from the latent leverage index to the economic fluctuations both using an impulse-response analysis. The number of autoregressive terms with lag 1 is selected for parsimony.[12]

The left panel of <Figure 4> exhibits how the latent leverage index responds over time to a one-unit increase of exogenous shocks and the right panel shows how the macroeconomy reacts over time to a one-unit increase of exogenous shock by the latent leverage index. The impulse response dynamics of the left panel are the estimated change in the latent leverage index following a one-standard-deviation shock to a set of macro-economic variables. The magnitude of the latent leverage index response to the year-over-year growth rate of the KOSPI index is the biggest, followed by the exchange rate and the growth rate of the housing price. The results are as expected via a univariate reasoning. The impulse response dynamics of the right panel is the estimated change in the real gross domestic product (RGDP) provided by the Bank of Korea following a one-standard-deviation shock to the latent leverage index. Two dotted grey lines represent the one-standard error confidence band for the estimate.[13] As indicated by the solid line, the shock to the LLI leads to a decline in the real gross domestic product within the first three quarters. After that point, the real gross domestic product gradually returns to its initial value. The decline in the real gross domestic product is significantly different from zero, as indicated by the fact that the condence band lies entirely below zero. This result is comparable to Hakkio and Keeton (2009), who employed the Chicago Fed National Activity Index (CFNAI) and the Kansas City Financial Stability Index (KSFSI). They found that the shock to the KCFSI led to a decline in CFNAI within the first six months, whereas the shock to the latent leverage index yielded similar but short-lived effects on the real gross domestic product with a three-quarter lag.

12) In a similar vein, Hubrich and Tetlow (2015) investigated the interaction between a practical financial stress index and real activity, inflation and monetary policy using a Markov-switching VAR model.

13) We report 68% confidence bands estimated for the impulse-response functions using the asymptotic calculation, which is common in the VAR literature (Stock and Watson, 2002).

<Figure 4> Impluse-Response Dynamics of the Latent Leverage Index



Note) The left panel plots an impulse-response dynamics of policy rate, land price, equity and exchange rate shocks to the latent leverage index and the right panel shows the impulse-response dynamics of the latent leverage index to the real gross domestic product (RGDP). Response periods are 12 quarters.

V. Conclusion

This paper proposes a latent leverage measure for assessing multifaceted mechanism of systemic risk propagation. We decompose the system-wide latent leverage into four balance-sheet components of borrowing, intrinsic, off-balance-sheet, and FX leverages to capture the mark-to-market (MtM) valuation for procyclicality from the time-series perspective along with its systemic risk propagation. Our empirical results confirm the existence of economic and statistical significances across latent leverage components.

These findings provide a variety of important implications for policy makers for the purpose of macroprudential supervision. As our proposed latent leverage index is constructed by directly incorporating the quality of asset/liability in the balance sheet, the proposed latent leverage index can complement existing risk-sensitive capital requirement and bank-specific leverage regulation to monitor the time-series behavior of system-wide vulnerability and imbalance.

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