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Does Credit Supply Accelerate Business Cycle Changes in Korea?: Some New Evidence by Incorporating Regime Changes

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Abstract This work empirically investigates how commercial banks' aggregate credit supply is associated with business cycle over different regimes of the Korean economy. Linear empirical models employed in most of previous studies are subject to a potential missapecification problem because it is well known that both real GDP and credit supply reveal different dynamic properties over different regimes. This work finds that credit supply has asymmetric effect on business cycle for expansion and contraction phases when the Smooth Transition Autoregressive Vector Error Correction Model (or STAR-VECM) is employed. Our empirical findings are as follows. Firstly, we find that credit supply has procyclical effect on real GDP in all phases. Secondly, the procyclical effects are significantly intensified especially in contractionary phases which indicates asymmetry of its effect. In sum, this result supports 'Credit Acceleration Hypothesis' of Bernanke *et al.* (1999). Lastly, we further find that real GDP has asymmetric effects on banks' credit supply with countercyclical effect on expansionary regimes.

Keywords Credit Supply, Business Cycle, Pro-Cyclicality, VEC Model, STAR Model

JEL Classification E32, G21, G28

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1. INTRODUCTION

This paper investigates how commercial banks' aggregate credit supply influences real GDP over different business cycle regimes in Korea. A considerable amount of literature on the relation between commercial banks' credit supply and business cycle is available. However, few papers cover how the relation between credit supply and business cycle changes over different business cycle regimes. By incorporating regime shifts with Smooth Transition Autoregressive (or STAR) specification in a standard Vector Error Correction model (or VECM), this work contributes to the empirical investigation of the credit supply's effect on business cycle.

The existing literature theoretically and empirically finds that credit supply has a positive impact on business cycle.[1] According to Bernanke *et al.* (1999)'s 'Credit Acceleration Hypothesis', particularly, credit supply's effect on economy is intensified in terms of its strength and duration under contractionary status of credit due to financial market's incompleteness. This study employs the insights from 'Credit Acceleration Hypothesis' to empirically identify credit supply's impact on business cycle. Brunnermeier *et al.* (2009) also report frictional factors, like restrictions on loans, generate even stronger impact of credit supply on business cycle particularly under contractionary credit status.[2]

After experiencing global financial crisis of 2008, one of the most important research topics of central banks and BIS is about understanding how credit supply plays a crucial role in generating or degenerating business cycle in country level. For this purpose, the aggregate credit supply of banks and other financial institutions are employed in related studies. In previous studies, it has been found that real business cycle is dynamically affected by credit supply of financial institutions like banks. However, to the best of our knowledge, this paper is the first attempt in literature which incorporates smooth transition regime changes for investigating different credit supply's effect on real GDP.

There are several competing regime shifting empirical models in literature including Markov switching model, Threshold auto regressive mode (TARM),

[1] To list a few, Sidrauski (1967), Greenwood and Jovanovic (1990), King and Levine (1993), and Levine, Loayza, and Beck (2000) support credit supply's positive effect on growth.

[2] On contrary, the 'Credit Crowding-Out Hypothesis' argues that credit supply stagnates or even worsens economic growth with a negative (or null) relation between credit supply and business cycle. Mendoza (2010), Bianchi (2011), and Bianchi and Mendoza (2011)'s researches find excessive credit supply induces inflation or asset pricing bubble which worsens economic growth in excess supply of loan status. But we have decided to focus on the 'Credit Acceleration Hypothesis' in this work.

and Smooth transition autoregressive vector error correction model (STAR-VECM). However, it should be noted that the multi-variable smooth transition autoregressive vector error correction model (STAR-VECM) is the most appropriate specification in estimating aggregate credit supply and real GDP.

Figure 1. Real GDP and Aggregate Credit Supply in Korea (1973Q1 - 2017Q4)[3]

notes: Both variables are logarithm value and gray bars represent recession periods. In the periods where the coincident composite index exceeds the baseline of 100, the economy is under an expansion phase or boom. In contrast, in the periods where the coincident composite index is below the baseline of 100, the economy is under a contraction phase or recession (highlighted with gray).

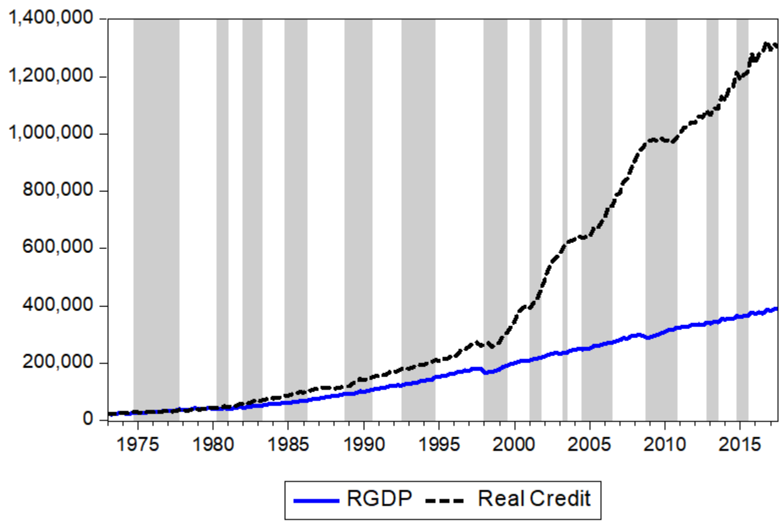

Figure 1 depicts the dynamic relation between real GDP and aggregate real credit supply in Korea from 1973 Q1 to 2017 Q4, where gray highlighted regions represent recession period.[4] We can easily view that the two variables are highly correlated dynamically. However, the observed correlation may be quite

[3]Figure 1's structural break in credit supply around 2000 is related to structural changes of loan after 1997's economic crisis. Banks' loan to private corporations (particularly to big firms) is stagnated until 2010 but there was a rapid increase of loan to households in the period. We believe the structural break of credit supply around 2000 represents this structural changes in banking industry.

[4]In the periods where the coincident composite index exceeds the baseline of 100, the economy is under an expansion phase or boom. In contrast, in the periods where the coincident compos-

different over the two distinct business cycle regimes of the economy. In Table 1 of cointegration equation, we reconfirm a strong linear binding between real GDP and real credit supply in Korea with highly significant coefficient (β_1) of credit supply against real GDP with 0.6766 at 1% significance level in the whole period. However, when the sample is divided into two sub-periods of expansion and contraction, the credit supply coefficients (β_1) are estimated to be 0.3741 and 0.8912 at 1% significance level, respectively. The significantly different credit supply coefficients (β_1) over two different regimes suggests that we need to use a more appropriate empirical model of Vector Error Correction Model (VECM) that incorporates regime changes. Credit supply's stronger impact on real GDP will not be reflected in a simple linear model which are commonly used in the existing empirical works. Linear empirical models that do not incorporate regime changes have a potential misspecification issue when we are empirically investigating credit supply's procyclical properties.

Table 1. Cointegration between RGDP and Aggregate Credit Supply (1973Q1 - 2017Q4) notes: Values under regression coefficients in parenthesis are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

$$y_{1t} = \beta_0 + \beta_1 y_{2t} + \varepsilon_t$$

where y_{1t} is the log of real GDP and y_{2t} is the log of real credit supply.

1. **Whole Period**

$y_{1t} = 3.4166^{***} + 0.6766^{***} y_{2t} + \varepsilon_t$

(0.0000) (0.0000) Adjusted R^2 = 0.9807

2. **Expansion Period**: the coincident composite index exceeds the baseline of 100.

$y_{1t} = 3.4417^{***} + 0.3741^{***} y_{2t} + \varepsilon_t$

(0.0000) (0.0000) Adjusted R^2 = 0.9821

3. **Contraction Period**: the coincident composite index is below the baseline of 100.

$y_{1t} = 3.4125^{***} + 0.8912^{***} y_{2t} + \varepsilon_t$

(0.0000) (0.0000) Adjusted R^2 = 0.9808

ite index is below the baseline of 100, the economy is under a contraction phase or recession (highlighted with gray).

This paper reports the following two main results. First, we provide empirical evidence of commercial bank credit supply's procyclical property in Korea. Second, our empirical evidence shows that credit supply's effects are significantly contrasting over different business cycle regimes of the economy. Particularly we find that credit supply's procyclical property is intensified in the contractional regimes of economy which supports 'Credit Acceleration Hypothesis.'

Kim and Mok (2018) empirically study how Korean banks' loan portfolio is associated with business cycle changes. It needs to be pointed out that these two independent works both employ the multi-variable smooth transition autoregressive vector error correction model (STAR-VECM). However, the two studies' empirical focuses are different to each other. In this work, we focuses on nonlinear dynamic relation between banks' aggregate credit supply and real GDP. This approach is academically and practically beneficial to both macro analysis and central banks' credit supply control. In Kim and Mok (2018), however, authors investigate nonlinear dynamic relation between five different loans and real GDP. The five different loans are loans on small corporations, loans on large corporations, households mortgage loan, households credit loan, and loans on public sectors, respectively. Their major finding is that there is a significant positive effect of real GDP on the bank loan portfolio over different loans and vice versa. Over the expansionary regime of real GDP, the real GDP has the largest cumulative net effects on the weight of households' mortgage loan and the smallest cumulative net effects on the weight of small-medium sized corporate loan. In the contractionary regime of real GDP, on the other side, it has been found that the real GDP's effect on banks' loan portfolio is almost neutralized.

The remainder of this paper is organized as follows. Section 2 describes the appropriateness of the Smooth Transition Autoregressive Vector Error-Correction Model (STAR-VECM) in our study. Section 3 provides construction of data employed and empirical results such as nonlinear Granger causality and cumulative net effects between endogenous variables of real GDP and real credit supply. Section 4 further investigates real GDP's dynamic effects on credit supply. Section 5 concludes our investigation.

2. EMPIRICAL MODEL: SMOOTH TRANSITION AUTOREGRESSIVE VECTOR ERROR CORRECTION (STAR-VECM) MODEL

Given the significant evidence on cointegration between real GDP and credit supply in Korea, a model of particular interest is the one in which the endogenous variables are linked by a linear long-run equilibrium relation. In addition, adjustment toward this equilibrium is nonlinear and can be characterized by a slow regime switch triggered by the long run relation between real GDP and credit supply or the error correction term.[5] Here, the regimes are determined by the size and sign of the deviation from the equilibrium relation between real GDP and credit supply. Therefore, in terms of time series analysis perspective, we fully take into account non-linearity, linear cointegration, and regime changes.

In linear time series framework, this type of behavior is captured by a cointegration and a linear vector error-correction model (VECM) (Engle and Granger, 1987).[6] Escribano and Mira (2002) extend the linear VECM to a general nonlinear VECM by employing the Near Epoch Dependence (NED) concept suggested by Gallant and White (1988) and Wooldridge and White (1988). In particular, they show that the nonlinear VECM can be theoretically formalized by incorporating a smooth transition autoregressive (STAR) model among many possible nonlinear parameterizations.[7]

In preliminary tests, we find strong evidence in favor of smooth transition dynamics over a linear VECM using nonlinearity tests.[8] Therefore, we incorporate nonlinearity into the VECM by following recent developments in nonlinear models. Specifically, we incorporate a smooth transition mechanism into a VECM to allow for a nonlinear or asymmetric adjustment, which is called a smooth transition autoregressive vector error-correction model (hereafter STAR-VECM).[9] This model can be viewed as a special case of vector smooth transition

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[5]There are two types of nonlinear regime-switching models regarding the speed of transition between regimes: the threshold autoregressive model (TARM) developed by Tsay (1989) and the smooth transition autoregressive model (STARM) developed by Luukkonen, Saikkonen, and Terävirta (1988), Terävirta and Anderson (1992), and Terävirta (1994). While the TARM specifies a sudden transition between regimes with a discrete jump, the STARM allows a smooth transition between regimes.

[6]See also Johansen (1995) and Hatanaka (1996).

[7]For details of the proof, see Escribano and Mira (2002).

[8]We carry out Lagrange Multiplier-Smooth Transition (LM-STR) test for test of linearity. It is available upon on request to author.

[9]See Granger and Swanson (1996) for a more general discussion, and Escribano (1987) and

autoregressive model (STARM).

$$\Delta y_{1t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\rho_i^j \Delta y_{jt-i}\right] F(\Delta y_{t-d}^c) + \varepsilon_t^1$$

$$\Delta y_{2t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\rho_i^j \Delta y_{jt-i}\right] F(\Delta y_{t-d}^c) + \varepsilon_t^2 \quad (1)$$

For the two integrated variables in Korea – log of real GDP (y_{1t}) and log of real credit supply (y_{2t}) - a smooth transition vector error-correction model (STAR-VECM) is given in general form by:[10] where Δy_{1t} is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or growth rate) of real credit supply. z_t denotes an error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta\prime y_t$ = 0. $F(\Delta y_{t-d}^c)$ is the transition function, and Δy_{t-d}^c is a *common* transition variable.

For the STAR-VECM, two types of the transition function specification, $F(\Delta y_{t-d}^c)$, are available: the logistic smooth transition vector error correction model (LSTAR-VECM) and the exponential smooth transition vector error correction model (ESTAR-VECM). The LSTAR-VECM is useful in describing a stochastic process that is characterized by an alternative set of dynamics for either the large or small value of the transition function. In the LSTAR-VECM, the transition function is given by the following logistic function:[11]

$$F(\Delta y_{t-d}^c) = \frac{1}{[1+\exp\{-\gamma(\Delta y_{t-d}^c - c)\}]}, \gamma > 0 \quad (1.1)$$

Escribano and Pfann (1998) for an early empirical example of nonlinear error-correcting mechanisms.

[10] All variables are log valued.

[11] The logistic function, $F(\Delta y_{t-d}^c)$, takes a value between 0 and 1, depending on the degree and direction by which Δy_{t-d}^c deviates from *c*, the switching value of the transition variable. The estimated value for *c* defines a transition between the two regimes: $0 < F(\Delta y_{t-d}^c) < 0.5$ (a lower regime) for $\Delta y_{t-d}^c < c$ and $0.5 < F(\Delta y_{t-d}^c) < 1$ (an upper regime) for $\Delta y_{t-d}^c > c$. When $\Delta y_{t-d}^c = c$, $F(\Delta y_{t-d}^c) = 0.5$ so that that the current dynamics of Δy_t (or growth rate) is half-way between the upper and lower regimes, especially when Δy_{t-d}^c takes a large value (i.e., $\Delta y_{t-d}^c >> c$), $\exp\{-\gamma(\Delta y_{t-d}^c - c)\}$ is close to zero. As a result, the value of $F(\Delta y_{t-d}^c)$ approaches one, and the dynamics of Δy_t are generated by both ϕ_i^j and ρ_i^j in equation (4). In addition, for a small value of Δy_{t-d}^c (i.e., $\Delta y_{t-d}^c << c$), $\exp\{-\gamma(\Delta y_{t-d}^c - c)\}$ is close to a big number. Then, the value of the transition function $F(\Delta y_{t-d}^c)$ approaches zero, and the dynamics of Δy_t are generated by only the ϕ_i^j parameter in equation (4).

In contrast, the ESTAR-VECM is more appropriate in generating alternative dynamics for both large and small values for the transition variable. In the ESTAR-VECM, the transition function is given by: [12]

$$F(\Delta y^c_{t-d}) = 1 - \exp\{-\gamma(\Delta y^c_{t-d} - c)^2\}, \gamma > 0 \tag{1.2}$$

The adjustment parameter, γ, in both models governs the speed of transition between the two regimes: the greater the value of γ, the faster the transition between the regimes. In the limit, as the value of γ approaches infinity, the model degenerates to the conventional threshold autoregressive model (TARM) of Tsay (1989). Alternatively, if γ approaches zero so that the value of the transition function $F(\Delta y^c_{t-d})$ approaches zero, then the model degenerates to a linear AR model, with ρ_i^j parameters unidentifiable. In specifying the STAR-VECM, the error correction term (z_{t-d}) is selected as the common transition variable in $F(\Delta y^c_{t-d})$ through Lagrange Multiplier-Smooth Transition (LM-STR) test for linearity.

For visual understanding of the two STAR models, the dynamics of LSTAR and ESTAR specifications are compared in the following Figure 2. LSTAR model specifies two distinct regimes of expansion and contraction while ESTAR model does between the outer regime (either expansion or contraction) and the middle regime.

In accordance with the above discussions on STAR-VECM model specification, common transition variable selection, cointegration test, nonlinearity test, and model selection test, we specify our STAR-VECM as follows:

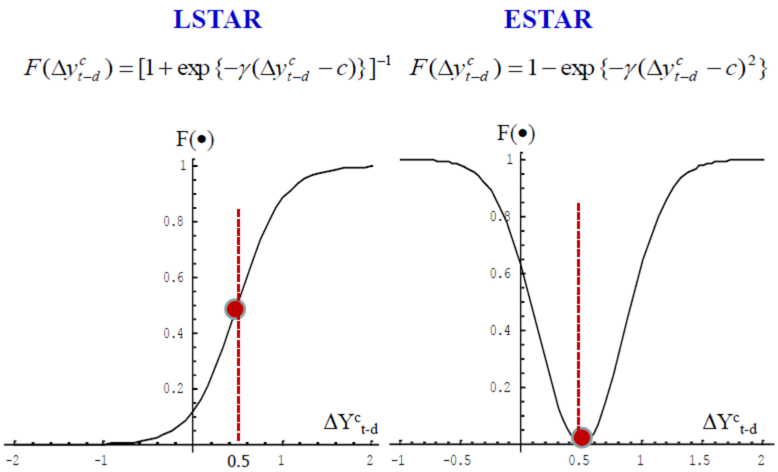
$$\begin{aligned}
\Delta y_{1t} &= \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(\Delta y^c_{t-d}) + \varepsilon_t^1 \\
\Delta y_{2t} &= \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(\Delta y^c_{t-d}) + \varepsilon_t^2
\end{aligned} \tag{2}$$

where $\Delta y_{1t}$is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or growth rate) of real credit supply. z_t denotes an error-correction

[12]For a large or small value of Δy^c_{t-d}, the value of $\exp\{-\gamma(\Delta y^c_{t-d} - c)^2\}$ approaches zero, and the value of the transition function approaches one. The dynamics of Δy_t are generated by both ϕ_i^j and ρ_i^j in equation (4). When the value of Δy^c_{t-d} is close to c, the value of $\exp\{-\gamma(\Delta y^c_{t-d} - c)^2\}$ approaches one and the value of the transition function approaches zero. In these cases, the dynamics of Δy_t are generated only by the ϕ_i^j parameters in equation (4).

term. That is, z_t is the deviation from the equilibrium relation given by $\beta' y_t = 0$. $F(z_{t-d})$is the transition function, and z_{t-d} is a *common* transition variable.

Figure 2. Dynamics of the two Smooth Transition Models.
The following two graphs show different regime shifting property of Logistic STAR (LSTAR) and Exponential STAR (ESTAR) model. The LSTAR model specifies two distinct regimes of expansion and contraction while the ESTAR does two distinct regimes of outer and middle.



3. DATA AND EMPIRICAL RESULTS

3.1. DATA

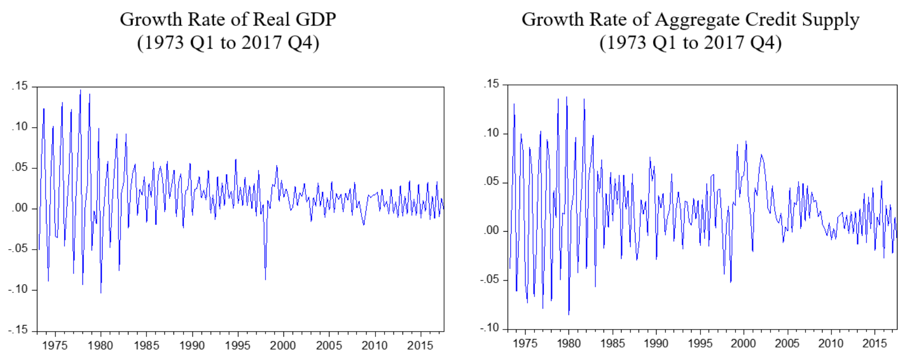
In conducting empirical work, we employ Korean real GDP and real aggregate credit supply compiled from the Bank of Korea data archive. The data used is organized as a quarterly time series observations from 1973 Q1 to 2017 Q4, comprising 180 quarterly observations in total for each variable which is seasonally adjusted through X13 option at Eviews. Credit supply includes total bank credit supplies of commercial banks, regional banks, foreign banks, and special banks. Within the sample period, there were quite a few merges and bankruptcies of banks which led us to employ the aggregate credit supply data.

For a robust nonlinear estimation purpose, we need a relatively long time series. Thus we have included all observations available from central banks' data archives. Summary statistics for each variable are presented in Table 2 along with graphs in Figure 3.

Table 2. Summary Statistics This table reports the summary statistics for four variables employed.

Variable	Mean	Std. Dev.
Log of Real GDP (1973Q1 - 2017Q4)	11.7289	0.8709
Log of Aggregate Credit Supply (1973 Q1 to 2017 Q4)	12.2850	1.2748
Growth Rate of Real GDP (1973 Q1 to 2017 Q4)	0.0160	0.0374
Growth Rate of Aggregate Credit Supply (1973 Q1 to 2017 Q4)	0.0225	0.0405

Figure 3. Growth Rates of Real GDP and Growth Rates of Aggregate Credit Supply in Korea(1973Q1 - 2017Q4)



3.2. EMPIRICAL RESULTS: CREDIT SUPPLY EFFECT ON REAL GDP

Although a multitude of factors are related to real GDP and banks' credit supply, this work focuses on bilateral dynamic relation between credit supply and real GDP for pursuing parsimonious empirical relation between the two variables.

We present estimation results of the simple linear VECM and those of the STAR-VECM in Table 3 and Table 4, respectively. The simple linear VECM estimation of Table 3 can serve as a benchmark result to compare with the STAR-VECM results in Table 4. First, we find that the simple linear VECM results in Table 3 do not show significant effects of credit supply (Δy_{2t}) on real GDP (Δy_{1t}) and vice a versa. In the second equation of linear VECM reported, the coefficients of real GDP (0.1684 and 0.1042) are not significant at 10% significance level. Also, in the first equation, the real credit supply's coefficients (0.0713 and -0.0735) are not significant either at 10% significance level. However, we find the long run linear relation between real GDP (Δy_{1t}) and real credit supply (Δy_{2t}) with negatively significant error correction term (z_{t-1}) coefficient of -0.0335.

The STAR-VECM estimations show contrasting results. In Table 4, the value of the γ-parameter is statistically significant at the 10% significance level for the real GDP growth (Δy_{1t}) and real credit supply growth (Δy_{2t}) equations in the sample period of 1973 Q1 to 2017 Q4. This indicates that the transition between regimes is significant for both real GDP and real credit supply.

In addition, estimates of the γ-parameters for real GDP growth (Δy_{1t}) and for real credit supply (Δy_{2t}) in the whole sample estimation are 13.0600 and 7.4233, respectively. These relatively small estimates of γ suggest a slower transition from one regime to another, compared to the TARM or Markov regime-switching models, where γ is infinity and there is a sudden switch between regimes. There are several competing regime shifting empirical models in literature including Markov switching model, Threshold auto regressive mode (TARM), and Smooth transition autoregressive vector error correction model (STAR-VECM). However, it should be noted that the multi-variable smooth transition autoregressive vector error correction model (STAR-VECM) is the most appropriate specification in estimating aggregate credit supply and real GDP. This provides additional support for our choice of the STAR model against other nonlinear regime shifting models. The c-parameter estimates of 0.0235 and 0.1485 indicate the halfway point between the expansion and contraction phases of real GDP and real credit supply.

In STAR-VECM estimation results, our focus is on the dynamic effect of real credit supply (Δy_{2t}) on real GDP (Δy_{1t}) over different regimes of economy. For this purpose, we carry out both of nonlinear Granger causality test and estimation of *cumulative net effect* from real credit supply (Δy_{2t}) to real GDP (Δy_{1t}) over different regimes of variables. [13] These results are summarized in Table 5.

[13] The '(cumulative) net effect' is estimated by the sum of the lagged coefficients of the Granger-causing variable. Before adding up the coefficients, we test whether the sum of the lagged coefficients is significant by Wald test. For example, in equation (2), $\Delta y_{1t} = [\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\phi_i^j \Delta y_{jt-i}] + [\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p}\rho_i^j \Delta y_{jt-i}]F(z_{t-d}) + \varepsilon_t^1$ if real credit supply (Δy_{2t})

In the *expansion regime* of real GDP (Δy_t^1) where the transition function $F(z_{t-4})$ = 1, the cumulative net effect from real credit supply (Δy_{2t}) to real GDP (Δy_{1t}) is estimated by +0.0045. It indicates, on average, one-unit increase of real credit supply (Δy_{2t}) growth increases real GDP (Δy_{1t}) growth by 0.0045 units over the next two quarters (or six months). On the contrary, in the *contraction regime* where the transition function $F(z_{t-4})$ = 0, the cumulative net effect is estimated as +0.0132 which indicates one-unit increase of real credit supply (Δy_{2t}) growth increases real GDP (Δy_{1t}) growth by 0.0132 units over the next two quarters (or six months). Therefore by employing regime shifting STAR-VECM, we find a significant evidence that real credit supply (Δy_{2t}) is associated with real GDP (Δy_{1t}) in asymmetric way under the *expansion* and *contraction* regimes of real GDP. We believe these results based on Korean data support Bernanke *et al.* (1999)'s 'Credit Acceleration Hypothesis,' particularly with intensified effects over contraction regime of real GDP.

It should be noted that this work's focus is different from Kim and Mok (2018) in two respects. Firstly, in data perspective, this work employs aggregate banks' credit supply and real GDP for economy-wide understanding of credit supply's role on business cycle. Macro economists and central banks will find this aggregate variable based empirical work is more appropriate in understanding credit supply's effect on business cycle. Secondly, the direction of effect is more focused on from aggregate credit supply to real GDP (or business cycle) because we are interested in banks' role in generating or degenerating business cycle.

Table 3. Estimation of linear VECM: Real GDP and Aggregate Credit Supply (1973Q1 - 2017Q4

notes: Values under regression coefficients in parenthesis are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

$$\Delta y_{1t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \varepsilon_t^1$$
$$\Delta y_{2t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \varepsilon_t^2$$

where Δy_{1t} is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or

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Granger causes real GDP (Δy_{1t}), we test the null hypothesis of $H_0 : \sum_{i=1}^{p} \phi_i^j = 0$ and $\rho_i^j = 0$. When the null hypothesis is rejected, we add up the coefficients as an estimate of the (cumulative) net effect from real credit supply (Δy_{2t}) to real GDP (Δy_{1t}).

growth rate) of real credit supply. z_t denotes an error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta' y_t = 0$.

Real GDP (Δy_{1t})

$$y_{1t} = \underset{(0.0000)}{0.0136^{***}} - \underset{(0.0536)}{0.0335} z_{t-1} + \underset{(0.7482)}{0.0286} \Delta y_{1t-1} + \underset{(0.1114)}{0.1162} \Delta y_{1t-2}$$
$$+ \underset{(0.2876)}{0.0713} \Delta y_{2t-1} - \underset{(0.2303)}{0.0735} \Delta y_{2t-2} + \varepsilon_t^1$$

Adjusted $R^2 = 0.0159$

Real Credit Supply (Δy_{2t})

$$y_{2t} = \underset{(0.0101)}{0.0120^{**}} + \underset{(0.2531)}{0.0197} z_{t-1} + \underset{(0.1512)}{0.1684} \Delta y_{1t-1} + \underset{(0.3082)}{0.1042} \Delta y_{1t-2}$$
$$+ \Delta \underset{(0.0003)}{0.2884^{***}} y_{2t-1} + \underset{(0.2531)}{0.0197} \Delta y_{2t-2} + \varepsilon_t^2$$

Adjusted $R^2 = 0.2985$

Table 4. Estimation of STAR-VECM: Real GDP and Aggregate Credit Supply (1973Q1 - 2017Q4)

notes: Values under regression coefficients in parenthesis are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

$$\Delta y_{1t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2} \sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2} \sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^1$$

$$\Delta y_{2t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2} \sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2} \sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^2$$

$$F(z_{t-d}) = \frac{1}{[1 + \exp\{\gamma(z_{t-d} - c)\}]}, \gamma > 0 : \text{LSTAR}$$

$$F(z_{t-d}) = 1 - \exp\{\gamma(z_{t-d} - c)^2\}, \gamma > 0 : \text{ESTAR}$$

where Δy_{1t} is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or growth rate) of real credit supply. z_t denotes an error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta' y_t = 0$. $F(z_{t-d})$ is the transition function, and z_{t-d} = common transition variable.

Real GDP (Δy_t^1:LSTAR)

$$
\begin{aligned}
\Delta y_{1t} = {} & [\underset{(0.0005)}{0.0107^{***}} - \underset{(0.0802)}{0.0385^{*}} z_{t-1} + \underset{(0.0580)}{0.2021^{*}} \Delta y_{1t-1} + \underset{(0.4824)}{0.0569} \Delta y_{1t-2} \\
& + \underset{(0.0798)}{0.1057^{*}} \Delta y_{2t-1} - \underset{(0.0909)}{0.0924^{*}} \Delta y_{2t-2}] + [\underset{(0.5536)}{0.0077} + \underset{(0.1011)}{0.0320} z_{t-1} \\
& - \underset{(0.3864)}{0.3907^{**}} \Delta y_{1t-1} + \underset{(0.0387)}{0.2226} \Delta y_{1t-2} - \underset{(0.1051)}{0.1495} \Delta y_{2t-1} + \underset{(0.0802)}{0.1408^{*}} \Delta y_{2t-2}] \\
& \times \left[\frac{1}{[1+\exp\{\underset{(0.0828)}{13.0600^{*}} (z_{t-4} - \underset{(0.0000)}{0.0235^{***}})\}]} \right] + \varepsilon_t^1
\end{aligned}
$$

Adjusted $R^2 = 0.3912$

Real Credit Supply (Δy_t^2:LSTAR)

$$
\begin{aligned}
\Delta y_{2t} = {} & [\underset{(0.0240)}{0.0109^{**}} - \underset{(0.4595)}{0.0139^{*}} z_{t-1} + \underset{(0.0323)}{0.2436^{**}} \Delta y_{1t-1} + \underset{(0.3265)}{0.1091} \Delta y_{1t-2} \\
& + \underset{(0.0066)}{0.2958^{***}} \Delta y_{2t-1} - \underset{(0.0002)}{0.3211^{***}} \Delta y_{2t-2}] + [\underset{(0.0015)}{-0.2679^{***}} + \underset{(0.0099)}{1.9952^{***}} z_{t-1} \\
& - \underset{(0.0158)}{0.2588^{**}} \Delta y_{1t-1} - \underset{(0.0727)}{0.1278^{*}} \Delta y_{1t-2} + \underset{(0.0585)}{2.9905^{*}} \Delta y_{2t-1} - \underset{(0.2828)}{1.4123} \Delta y_{2t-2}] \\
& \times \left[\frac{1}{[1+\exp\{\underset{(0.0204)}{7.4233^{**}} (z_{t-4} - \underset{(0.0000)}{0.1458^{***}})\}]} \right] + \varepsilon_t^2
\end{aligned}
$$

Adjusted $R^2 = 0.3738$

Table 5. Comparison of Net Effects between STAR-VECM and VECM[14]

notes: Values under regression coefficients in parenthesis are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

$$\Delta y_{1t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^1$$

$$\Delta y_{2t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^2$$

$$F(z_{t-d}) = \frac{1}{[1+\exp\{\gamma(z_{t-d}-c)\}]}, \gamma > 0 : \text{LSTAR}$$

$$F(z_{t-d}) = 1 - \exp\{\gamma(z_{t-d}-c)^2\}, \gamma > 0 : \text{ESTAR}$$

where Δy_{1t} is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or growth rate) of real credit supply. z_t denotes an error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta' y_t = 0$. $F(z_{t-d})$ is the transition function, and z_{t-d} = common transition variable.

Real credit supply's (Δy_2) net effect on real GDP (Δy_1)	
Linear VECM	-0.0022 (0.1487)
Nonlinear STAR-VECM	(Expansion regime) 0.0045* (0.0639) (Contraction regime) 0.0132* (0.0172)

[14]Before estimating the net effect of real credit supply (Δy_{2t}) on real GDP (Δy_{1t}), we test whether the sum of estimates is zero [i.e., $H_0 : \sum_{i=1}^{3}\{\hat{a}_i + \hat{b}_i\} = 0$]. For details of estimating net effect, see Sarantis (2001) and Kim, Lee, and Kim (2014).

4. FURTHER DISCUSSIONS ON THE REVERSE RELATION: REAL GDP'S EFFECT ON CREDIT SUPPLY

In this section, we further provide empirical interpretation of STAR-VECM in terms of banks' perspective. Commercial banks' credit supply (or loan supply) to private sectors is the main source of bank profit. Therefore, for banks, it would be crucial how business cycle or real GDP (Δy_{1t}) affects banks' credit supply (Δy_{2t}) over expansionary and recessionary phases of economy.

From previous section's STAR-VECM estimation, we report cumulative net effect of real GDP (Δy_{1t}) on credit supply (Δy_{2t}) in Table 6 below. According to Table 6, the real GDP (Δy_{1t})'s '*cumulative net effect*' on real credit supply (Δy_{2t}) is estimated by -0.0331 in the *expansion regime* of real credit supply (Δy_{2t}). It can be interpreted as one-unit increase of real GDP (Δy_{1t}) growth decreases real credit supply (Δy_{2t}) growth by 0.0331 units over the next two quarters (or six months). In contrast, in the *contraction regime* of real credit supply (Δy_{2t}), the cumulative net effect of real GDP (Δy_{1t}) is estimated by +0.3526. It indicates real GDP (Δy_{1t}) has a positive effect on real credit supply (Δy_{2t}) over contraction regime's two quarters.

The above empirical results find that there are significant differences in the effect of real GDP (Δy_{1t}) on real credit supply (Δy_{2t}) under the two regimes of Korean economy. In particular, the real GDP (Δy_{1t})'s effect is counter-cyclical in the *expansion regime* of real credit supply (Δy_{2t}). The counter-cyclical impact of real GDP (Δy_{1t}) on real credit supply (Δy_{2t}) in the *expansion regime* may be mainly due to the fact that Korean firms quickly reduce demands for bank loans in the expansion regime.[15] Also strict regulation on mortgage loans to households is another reason for the counter-cyclical effect.[16]

[15]Recently Korean large companies became more inclined to use retained earnings for financing investment.

[16]In every rapidly increasing housing prices, Korean government has implemented mortgage loans restrictions through DTI and LTV measures. For example, 2009 September's DTI restriction decreased mortgage loan by about 30% in given year.

Table 6. Comparison of Net Effects between STAR-VECM and VECM[17]

notes: Values under regression coefficients in parenthesis are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively. Values under regression coefficients in parenthesis are p-values.

$$\Delta y_{1t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^1$$

$$\Delta y_{2t} = \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \phi_i^j \Delta y_{jt-i}\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{2}\sum_{i=1}^{p} \rho_i^j \Delta y_{jt-i}\right] F(z_{t-d}) + \varepsilon_t^2$$

$$F(z_{t-d}) = \frac{1}{[1+\exp\{\gamma(z_{t-d}-c)\}]}, \gamma > 0 : \text{LSTAR}$$

$$F(z_{t-d}) = 1 - \exp\{\gamma(z_{t-d}-c)^2\}, \gamma > 0 : \text{ESTAR}$$

where Δy_{1t} is the log difference (or growth rate) of real GDP, Δy_{2t} is the log difference (or growth rate) of real credit supply. z_t denotes an error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta' y_t = 0$. $F(z_{t-d})$ is the transition function, and z_{t-d} = common transition variable.

Real GDP's (Δy_1) net effect on real credit supply (Δy_2)	
Linear VECM	0.2727 (0.4610)
Nonlinear STAR-VECM	(Expansion regime) -0.0331^* (0.0587) (Contraction regime) 0.3526^* (0.0694)

[17] Before estimating the net effect of real credit supply (Δy_{2t}) on real GDP (Δy_{1t}), we test whether the sum of estimates is zero [i.e., $H_0 : \sum_{i=1}^{3}\{\hat{a}_i + \hat{b}_i\} = 0$].

5. CONCLUSION

By incorporating endogenous regime changes with Smooth Transition Autoregressive Model (STAR), this work empirically investigates the impact of Korean banks' credit supply on business cycle over different regimes of economy. A considerable amount of literature on the relation between commerical banks' credit supply and business cycle is available. However, little of it covers how the regime change affects the fundamental relation between credit supply and business cycle changes. This work contributes to the understanding of the credit supply's effect on business cycle by incorporating regime changes based on non-linear empirical framework of STAR-VECM.

After experiencing global financial crisis of 2008, one of the most important research topics of central banks and BIS is about understanding how credit supply plays a crucial role in generating or degenerating business cycle in country level. For this purpose, the aggregate credit supply of banks and other financial institutions are employed in related studies. In previous studies, it has been found that real business cycle is dynamically affected by credit supply of financial institutions like banks. However, to the best of our knowledge, this paper is the first attempt in literature which incorporates smooth transition regime changes for investigating different credit supply's effect on real GDP.

There are several competing regime shifting empirical models in literature including Markov switching model, Threshold auto regressive mode (TARM), and Smooth transition autoregressive vector error correction model (STAR-VECM). However, it should be noted that the multi-variable smooth transition autoregressive vector error correction model (STAR-VECM) is the most appropriate specification in estimating aggregate credit supply and real GDP.

This paper's main findings are as follows. First, we provide empirical evidence of bank credit supply's procyclical property in Korea. Second, our empirical evidence shows that these effects are significantly different over different regimes of the economy. Particularly we find that credit supply's procyclical property is intensified in the contraction regime of economy. It means that our results are in line with Bernanke *et al.* (1999)'s 'Credit Acceleration Hypothesis' which argues credit supply's effect on economy is intensified in terms of its strength and duration under contractionary status of economy. Lastly, through extended interpretation of empirical works, we provide evidence that real GDP has a counter-cyclical effect on real credit supply in the *expansion regime*. The counter-cyclical effect of real GDP on credit supply may be related to Korean firms' changing attitudes on bank loans and supervisory institution's changing regulations over business cycle. However, this issue needs further investigation by employing firm-level data in the near future. Particularly, to expand this work, studies with disaggregated data on bank loans, corporate loans, and loans to households will be helpful.

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