The Economic Growth of Korea after 1990: Identifying Contributing Factors from Demand and Supply Sides

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Abstract
This study is purposed to identify major factors that explains the path of the Korean economy in the past decades and evaluate their relative contributions. To that end, we devise two economic models, which contrast the recent changes in the determination of foreign exchange rate as well as the monetary policy rule Korean economy underwent right after the East Asian Currency Crisis in 1998. Converted into the corresponding SVAR systems with long-run restrictions, their estimation results confirm that the decreased rate of economic growth of Korea since 2000 seems attributable to the decrease in Korea’s potential growth rate.
I. Introduction

Our study stems from a question, "How should we understand the pattern of the Korean economy after the 1990s?" Among various analytic methods applicable, this study chooses a Structural Vector Autoregression (SVAR) with long-run restrictions following Blanchard and Quah (1989)'s tradition, identifies diverse impacts from either demand or supply sides that gave rise to the current status of the Korean economy, and differentiates relative contributions of those impacts.

As of year 2007, looking back to 1990s, the East Asian Currency Crisis in 1997 marks a break point for the Korean economy. Especially, in the foreign exchange rate and monetary policy, a flexible exchange rate system and an inflation targeting rule were introduced. Needless to say, all the reform measures taken since the financial crisis had huge impact on the whole economy. Among them, however, transition from a fixed exchange rate system to a floating one as well as from a monetary aggregate targeting to an inflation targeting regime were very crucial.

This paper, to begin with, introduces two linear stochastic differential systems of equations, both of which contrast such drastic institutional changes while adhering to the same backbone in other aspects. In the next step, by solving the models we represent key macro variables as linear functions of exogenous shocks coming possibly from various sources and derive long-run identification restrictions following Blanchard and Quah (1989). Then, we levy the identifying restrictions to VAR systems consisting of the key variables and estimate them with the Korean data. Finally, we demonstrate estimation results in terms of Impulse Responses (IR) and Forecasting Error Variance Decomposition (FEVD) and interpret them in the context of changes in economic growth. Eventually, it is our destination to discern what portion of the economic growth of Korea is influenced by either the impact of productivity growth through technological progress, or changes in the aggregate demand induced by fluctuating consumption and investment, or exogenous shocks like ones from oil price.

The contents of this paper are construed as follows: The second section observes the recent trend of the economic growth of Korea and relevant domestic literature, which might help in clearly defining the scope and analytic methodology of this study. The third section provides an analytical model to be used in this study, which is Structural VAR as mentioned above. Accordingly, variables used, estimation equations, and identification conditions of impacts are also explained here. The fourth section reports estimation results derived by the previously introduced models, and the fifth section concludes.
II. The Economic Growth of Korea: A Phenomenon and Discussions

In this section, we exhibit the economic growth of Korea in the past decades and summarize the relevant domestic literature. Despite the abundant existing literature on the issue, we restrict our attention to the ones using the methodology of SVAR.

1. A Phenomenon

<table>
<thead>
<tr>
<th>(Table 1) Averages and Standard Deviations of Real GDP Growth Rate (1971.1Q~2007 2Q)</th>
<th>(Year-on-Year % Change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>8.1</td>
</tr>
<tr>
<td>S.D</td>
<td>3.4</td>
</tr>
</tbody>
</table>

The fast growing Korean economy, dating back to 1960s, has been showing a sign of gradual slowdown up to present. Especially, the lowered economic growth after the financial crisis in 1997 is worried to indicate slowdown in the growth of potential GDP, which attributes at least partly to the fast aging demographic composition. As seen in <Table 1>, the average real GDP growth has been falling from marvellous 8.1% during 1970s to 5.0% during 2000s.

In the meantime, the standard deviation of the GDP growth, an indicator of business cycle amplitude, rose from 3.4% during 1970s to 4.8% during 1990s and fell again to 2.1% during 2000s. Reminded that the East Asian Currency Crisis broke out in the fourth quarter of 1997, it seems that the severity of business cycle fluctuations stayed more or less at the same level up to late 1990s and it was subdued in 2000s (see [Figure 1]). Such dampening business fluctuation seems to be related with the global prevalence of low interest rate and the emergence of China as a new world economic power.

Putting all these into consideration, it would be pivotal to identify post crisis changes in various market institutions of Korea and the global environments surrounding them for understanding the growth of Korean economy at least after 1990s. In details, most remarkable post crisis reform measures\(^1\) are taken in restructuring financial institutions as well as introducing a inflation targeting rule and a floating exchange rate system.

Especially, financial restructuring led to changes of behavior in both demand and supply sides of domestic capital market. Banks moved their concentration from business finance to consumer loans in

\(^1\) Equally notable is that some of these changes were caused by the Crisis but others happened to be taken after the outbreak of the Crisis. Here, however, we do not discern the possibilities of relation.
order to reduce risk exposure while enhancing profitability. As a result, households could enjoy the benefit of consumption smoothing from the alleviation of liquidity constraints (Hur and Sung(2003)). On the other hand, mainly large firms, enforced to lower the debt/equity ratio, began to accommodate required capital by IPOs or internal reserves rather than by bond financing. By that much, the banks could hold excess capacity to lend, which in turn directed towards consumer credit. In addition, the global phenomenon of low interest rates and mild inflation, which sustained stable growth for the last decade, contributed to settling the newly adopted inflation targeting rule and the flexible exchange rate system at that time.

Admitted that those internal and external environmental changes resulted in lowering the business cycle amplitude, still it remains a puzzle to explain the lowered economic growth of Korea. Hence, it would be crucial to devise models beyond merely introducing the institutional changes so as to include certain shocks and their transmission channels, which may hinder the economic growth.

2. Literature

Aforementioned, we introduce three papers, all of which explore the economic growth and/or the business cycle of Korea since 1990s using SVAR. In common with others, each of the papers analyzes the same topic. However, they differ in the time span of data set used and the pool of variables chosen. Accordingly, direct comparison of their results may be not much of consequence. Instead we highlight their methodological differences.

system of sectoral equations, intended for deriving long-run restrictions, is arranged so that its Structural Moving Average Representation (SMAR) or a long-run impulse response matrix could be formed into a lower or upper triangular one\(^2\). Furthermore, Shim(2001) does not consider post-crisis changes in the monetary policy rule and the exchange rate system\(^3\), let alone foreign sectors.

Second, Kim(2005) concentrates on analyzing the impact of foreign shocks on the domestic business cycle. Hence, Kim uses foreign variables, such as oil price and exchange rates, jointly with domestic ones including interest rate, CPI, and the growth rate. Kim(2005)'s model, in common with Shim(2001)'s, does not derive the relationship among shocks from an economic model. Instead it orders them in a Cholesky way a priori.

Third, Oh(2007) considers an open economy version of the B-Q model. Matched with three key variables of world import volume, GDP, and CPI, he introduces three shocks of domestic supply, demand, and world supply. In terms of shock identification, Oh(2007) also assigns long-run restrictions to disturbances a priori.

To begin with, he assumes that domestic demand shocks have only temporary effect while domestic supply shocks persist in the long-run. Next, world supply shocks increase world production and have permanent effect on world demand for imports whereas domestic supply shocks have only temporary effect on the world demand for imports.

Under such presumptions, the estimation results report that world supply shocks have larger impact in contrast with the shrunken influence of domestic supply shocks after the financial crisis. It is also revealed that the impact of domestic demand shocks has been magnified in the short-run.

Keeping distance from the predecessors, our paper is based on economic models, which allow the presence of shocks from various sources and introduces institutional changes in the monetary policy regime and the foreign exchange market. Then, we derive long-run restrictions by solving the models and use them in estimating corresponding SVAR models.

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2) In other words, Shim(2001)'s system of equations is simply reduced to a VAR with Cholesky ordering.

3) Monetary aggregate targeting and inflation targeting diverge from each other in the treatment of a money supply schedule. Under the monetary aggregate targeting, LM curve is derived from money demand=money supply whereas money supply is replaced by an interest rate setting rule, such as a Taylor rule under the inflation targeting. Furthermore, autonomy of monetary policy is not guaranteed in a fixed exchange rate system because the domestic interest rate should be always equal to the foreign interest rate. Otherwise, the exchange rate would fluctuate.
III. Models

In a neoclassical framework, it is somewhat inevitable that an economy experiences slowdown of growth in the long run. In reality, however, it is very intricate to distinguish the long-run trend of slowdown from the short-run business downturns. There are various statistical methods for decomposing the path of economic growth into the long run trend and the short-run fluctuations. Provided that the long series of variables are prepared, these statistical methods are relatively easy to implement but the results are hard to interpret under conventional economic reasoning.

On other hand, there have been many trials of identifying transmission channels of shocks with perception that the change of economic growth is accumulated responses of various sectors to external shocks. Analysis in this category, based an economic model (however simple it may be), allows economic intuition to work. Instead, a slight change in the architecture of the model may lead to different result. In this context, separate robustness check would be required.

This study encompasses the first approach from the standpoint of the second one. In details, it derives long-run restrictions of an SVAR representation from a simple macro economic model. In the meantime a number of shocks are introduced in the model. Some of them affect a sector while others have influence on the economy beyond a sector. Roughly speaking, those shocks are categorized into two groups- demand and supply shocks, which are, in turn, believed to match with business cycle and long-run trend of growth respectively. Behind such a logic lies a general notion that demand shocks are transient whereas supply ones are permanent. As admitted by B-Q(1989), however, transient supply shocks or persistent demand ones may exist in reality. Thus, it would be absurd to associate demand shocks with volatile business cycle and supply ones with the changing growth trend. In this context, our paper keeps itself apart from trials to decompose the economic growth into the long-run trend and the short run fluctuations

1. Sources of Shocks and Transmission Channels

In the following models all the shocks are classified into demand driven and supply driven ones, which are, in turn, grouped into domestic and foreign ones. In addition, we admit the possibility that the changes of economic environments (internal or external) Korean economy has experienced since 1990 may have altered transmission channels while providing new sources of shocks.

To begin with, noticeable internal changes of the economic environments are found in the restructure of financial markets, the inflation targeting rule and the floating exchange rate. Most of these changes
seem to contribute to altering transmission channels. On the while, external changes of the economic environments surrounding Korea are the global phenomenon of low interest rates, housing price hike and emergence of China as a world economic power.

Next, understanding demand and supply shocks within the framework of AD-AS, we represent internal demand shocks as idiosyncracies in consumption, investment, government budget, and domestic and foreign currencies, and represent external demand shocks to be rooted in the terms of trade and the world economic growth. On the other hand, we comprehend that supply shocks are caused internally by changes in factor and total factor productivities and externally by price fluctuations of raw materials (such as oil and iron ore) and technology spill-over.

A notable point here is that such a way of sorting shocks (and discerning changes in transmission channels from those in the magnitudes of shocks) is rather conceptual and does not provide a reliable yardstick to apply in the reality. For example, alleviation of household credit constraints induced by the restructuring of the financial sector accompanies consumption growth. Also, it is not fully convincing to define TFP growth to be a sole domestic supply shock. TFP growth may results from international competition or TFP growth may interact with the increased demand for investment. In this regard, we our way of introducing shocks has limitations.

2. Equations of Estimation and Identifying Restrictions

This study applies SVAR with long run restrictions (suggested by Blanchard and Quah(1989)) to modified versions of Stock and Watson(2002), which include more variables and shocks than the original model.

Our models use the four key variables of real GDP growth($\Delta Y_t$), inflation($\pi_t$), and interest rate($R_t$). Depending on the types of the monetary policy regime and the foreign exchange rate system, monetary aggregate growth($\Delta m_t$) and/or exchange rate change($\Delta e_t$) are added or subtracted.

2.1 An Economy under Inflation Targeting Rule and Flexible Exchange Rate System

The following model is an open economy version of Stock and Watson(2002) with New Keynesian flavor. In this economy, the government carries out a monetary policy based on inflation targeting$^4$). In

$^4$) Fiscal policy, another pilar of economic policy, is not considered in the model, which is partly due to the long-time(at least since mid 1980s) held fiscal stance of so called "expenditure-within-revenue". In addition, some empirical works report that fiscal stimuli through either increasing expenditure or reducing tax revenue have not been effective in boosting the Korean
details, it adjusts the short-term interest rate in response to the anticipated inflation and GDP gap following so called a Taylor rule.

For the features of an open economy, we need to define the trades of commodities, services and currencies across borders. Hence, we describe an equilibrium condition for the foreign exchange market and include the terms of trade \( q_t \) as a determinant of IS curve.

(1) IS curve

\[
y_t = \kappa r_t - q_t + \theta r_t, \quad \theta r_t = \theta r_{t-1} + \epsilon_t
\]

\[
r_t = R_t - \frac{1}{k} \sum_{j=1}^{k} E_t[\pi_{t+j}], \quad q_t = p_t - (e_t + p_t')
\]

(2) New Keynesian Phillips curve (Aggregate supply curve)

\[
\pi_t = \gamma \sum_{i=0}^{\infty} \theta_i E_t[\pi_{t+i}] + \epsilon_t^\pi
\]

(3) A forward looking Taylor rule

\[
r_t = \beta_s E_t[\pi_{t+h}] + \beta_y \sum_{j=1}^{h} E_t[y_t^p - y_t + j]
\]

(4) An equilibrium condition in foreign exchange market

\[
R_t = R_t^f + E_t[e_{t+1} - e_t]
\]

Equation (1)–(4) consist of two orthogonal external shocks \( \epsilon_t^r, \epsilon_t^\pi \) and five variables \( y_t, R_t, \pi_t, E_t[y_t^p - y_t + i], e_t \) \( 6 \). Dealing with the mismatch, we introduce two additional shocks as follows:

First, the GDP gap is defined to be an AR(1) process \( 7 \) with a noise of \( \epsilon_t^p \), which is, in turn, defined to be potential GDP growth shock \( \epsilon_t^{gp} \) minus a fraction of demand shock \( \alpha \epsilon_t^p \).

\[
X_t \equiv y_t^p - y_t = \rho X_{t-1} + \epsilon_t^x, \quad \epsilon_t^x \equiv \epsilon_t^{gp} - \alpha \epsilon_t^p
\]  \( 5 \)

Then, Equation (5) could be represented in moving averages assuming stationarity.

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5) \( q_t = p_t - e_t - p_t' \Rightarrow \ln Q_t = \frac{1}{\ln E_t P_t^f} \Rightarrow Q_t = \frac{P_t}{E_t P_t^f} \).

6) Based on the concept of "a small open economy", we assume that interest rate \( R_t^f \), price level \( P_t^f \) and inflation \( \pi_t^f \) of a foreign country are exogenously given.

7) The author's pretest using the quarterly data of Korea (1979–2001) shows that the GDP gap \( \equiv GDP- Hodrick-Prescott \) filtered GDP follows a stationary AR(1) process \( (0 < \rho < 1) \).
\[ X_t (1 - \rho L) = \epsilon_t^x \Rightarrow X_t = \frac{\epsilon_t^x}{1 - \rho L} = \sum_{j=0}^{\infty} \rho^j \epsilon_{t-j} \]

Second, the equilibrium condition of the foreign exchange market in (4) is transformed into the following by adding another orthogonal shock \( \epsilon_t^e \).

\[
e_t = (R_{t-1} - R_{t-1}^f) + \epsilon_{t-1} + \epsilon_t^e
\]
\[
= (R_{t-1} - R_{t-1}^f) + (R_{t-2} - R_{t-2}^f) + \epsilon_{t-2} + \epsilon_{t-1} + \epsilon_t^e
\]
\[
= \sum_{j=0}^{\infty} (R_{t-j} - R_{t-j}^f) + \theta_t^e
\]
\[
\theta_t^e = \sum_{j=0}^{\infty} \epsilon_{t-j}
\]

Now, we represent the four variables of real GDP \( y_t \), inflation \( \pi_t \), nominal interest rate \( R_t \), and the exchange rate \( e_t \) to be linear function of the four orthogonal shocks \( \epsilon_t^1, \epsilon_t^2, \epsilon_t^3, \epsilon_t^4 \) and their lags.

First, we obtain the following expressions by plugging (5) to the right hand side of (2) and (3).

\[
\pi_t = \gamma \sum_{i=0}^{\infty} \delta^i E_t [\rho X_{t+i-1} + \epsilon_{t-i}^x] + \epsilon_t^\pi
\]
\[
= \gamma \sum_{i=0}^{\infty} \delta^i \rho^i X_t + \epsilon_t^\pi
\]
\[
= \gamma \frac{1 - \delta \rho}{1 - \delta \rho} + \epsilon_t^\pi \quad (0 \leq \delta \rho < 1)
\]
\[
= \frac{1 - \delta \rho}{\gamma} \sum_{j=0}^{\infty} \rho^j \epsilon_{t-j}
\]
\[
= \sum_{i=1}^{h} E_t [y_{t+h}^p - y_{t+h}] = \sum_{i=1}^{h} \rho^i X_t = \rho \frac{1 - \rho^h}{1 - \rho} X_t = \frac{1 - \rho^h}{1 - \rho} \frac{\gamma \rho}{1 - \delta \rho} \sum_{j=0}^{\infty} \rho^j \epsilon_{t-j}
\]

Second, plugging the above equations back to (3), we could represent the real interest rate \( r_t \) as a function of external shocks.

\[
r_t = \beta_x E_t [\pi_{t+h}] + \beta_y \sum_{j=1}^{h} E_t [y_{t+j}^p - y_{t+h}^p]
\]
\[
= \beta_x E_t [\gamma \frac{1 - \delta \rho}{1 - \delta \rho} + \epsilon_{t+h}^\pi] + \beta_y \rho \frac{1 - \rho^h}{1 - \rho} X_t
\]
\[
= \beta_x \gamma \frac{\rho^h}{1 - \delta \rho} X_t + \beta_y \rho \frac{1 - \rho^h}{1 - \rho} X_t
\]
\[
= \left( \beta_x \gamma \frac{\rho^h}{1 - \delta \rho} + \beta_y \rho \frac{1 - \rho^h}{1 - \rho} \right) X_t
\]

8) \( \epsilon_t^y \) is assumed to be orthogonal to the other external shocks.
Third, converting the expression on the real interest rate \((r_t)\) to that on the nominal interest rate \((R_t)\) and combining the new expression with (6), we derive the following.

\[
R_t = r_t + \frac{1}{s} \sum_{j=1}^s E_t[\pi_{t+j}] = AX_t,
\]

\[
A = \beta_z \gamma p^b \frac{1}{1 - \delta p} + \beta y \rho \frac{1 - \rho}{1 - \rho} + \frac{1}{s} \gamma p \frac{1 - \rho}{1 - \rho}
\]

\[
e_t = \sum_{j=1}^\infty (AX_{t-j} - R_{t-j}^f) + \theta_t^f, \quad \theta_t^f = \sum_{j=0}^\infty \epsilon_{t-j}
\]

Finally, plugging the above equation to (1), we could also represent the real GDP as a function of external shocks.

\[
y_t = \kappa r_t - q_t + \theta_t^y = BX_t - q_t + \theta_t^y,
\]

\[
B = \kappa \left( \beta_z \gamma p^b \frac{1}{1 - \delta p} + \beta y \rho \frac{1 - \rho}{1 - \rho} \right)
\]

Combining all the equations so far derived, we could represent \((y_t, \pi_t, R_t, e_t)\) as moving averages of \((\epsilon_t^y, \epsilon_t^\pi, \epsilon_t^r, \epsilon_t^e)\). However, as for logarized real GDP \((\Delta y_t)\) and the exchange rate \((\Delta e_t)\), we use the first order differences due to their apparent non-stationarity. Accordingly, the first order differences of logarized real GDP \((\Delta y_t)\) and the exchange rate \((\Delta e_t)\) are represented as follows.

\[
\Delta y_t = B\Delta X_t - q_t + q_{t-1} + \theta_t^y - \theta_{t-1}^y
\]

\[
= B\Delta X_t - \pi_t + (e_t - e_{t-1}) + \pi_t^f + \epsilon_t^f
\]

\[
= B\Delta X_t - \frac{\gamma}{1 - \delta p} X_t - \epsilon_t^f + \Delta e_t + \pi_t^f + \epsilon_t^f,
\]

\[
\Delta X_t = (1 - \rho L)X_t - (1 - \rho)X_{t-1}
\]

\[
= e_t^x - (1 - \rho)X_{t-1}
\]

\[
= e_t^x - \sum_{j=0}^\infty \rho^j (1 - \rho) e_{t-1-j}^x
\]

\[
\Delta e_t = \epsilon_t - e_{t-1}
\]

\[
= \sum_{j=1}^\infty (A\Delta X_{t-j} - \Delta R_{t-j}^f) + \sum_{j=0}^\infty \epsilon_{t-j} - \sum_{j=0}^\infty \epsilon_{t-j-1}
\]

Properly rearranged, the vector of \((\Delta y_t, \pi_t, R_t, \Delta e_t)\) is represented as a SVMAR(Structural Moving Average Representation) system of exogenous shocks \((\epsilon_t^y, \epsilon_t^\pi, \epsilon_t^r, \epsilon_t^e)\).
\[
\begin{bmatrix}
\Delta y_t \\
\pi_t \\
R_t \\
\Delta e_{t-1}
\end{bmatrix}
= A(L) \begin{bmatrix}
\epsilon_{t-1} \\
\epsilon_{t-2} \\
\epsilon_{t-3} \\
\epsilon_{t-4}
\end{bmatrix}
+ \begin{bmatrix}
1 & -1 \\
0 & 0 \\
0 & 0 \\
0 & -1
\end{bmatrix}
\begin{bmatrix}
\pi_t \\
R_t \\
\Delta e_{t-1}
\end{bmatrix}
= \sum_{j=0}^{\infty} A_j \begin{bmatrix}
\epsilon_{t-j} \\
\epsilon_{t-j} \\
\epsilon_{t-j} \\
\epsilon_{t-j}
\end{bmatrix}
+ \begin{bmatrix}
1 & -1 \\
0 & 0 \\
0 & 0 \\
0 & -1
\end{bmatrix}
\begin{bmatrix}
\pi_t \\
R_t \\
\Delta e_{t-1}
\end{bmatrix}
\]

\(A_j\) is a 4x4 matrix.

Furthermore, we could find \(6 = \frac{k \times (k-1)}{2}, k = 4\) restrictions on the coefficients of \(A_\infty = A(1) = \sum_{j=0}^{\infty} A_j\).

In other words, (7) is exactly identified.

\[
A_\infty = \begin{bmatrix}
NA & NA & NA & NA \\
NA & NA & NA & 0 \\
NA & NA & 0 & 0 \\
NA & 0 & 0 & 0
\end{bmatrix}
\]

The above long-run restriction matrix \(A_\infty\) indicates the following properties of the model economy, which is characterized by Equation (1)-(5). First, the productivity shock \((\epsilon_p)\) has permanent impact on the real GDP, price level, and the exchange rate. Second, the demand shock \((\epsilon_d)\) and the price(or inflation) shock\((\epsilon_i)\) have permanent effect on the real GDP and the price level, but they have transient effect on the interest rate and the exchange rate. Third, the impact of the exchange rate shock \((\epsilon_e)\) is transient on all the variables except the real GDP.

2.2 An Economy under Monetary Aggregate Targeting Rule and Fixed Exchange Rate System

The next model differs from the previous one in the selection of the monetary policy regime and the foreign exchange rate system. First, the monetary authority controls a monetary aggregate instead of the short-term interest rate, which describes the policy regime of Bank of Korea before 1998.

Second, the exchange rate is assumed to be fixed at a certain level by the government. In order to balance the capital account or clear the currency exchange market at the prespecified exchange rate, interest rate differential with other countries is not allowed and the monetary aggregate is constantly controlled for maintaining zero interest rate differential. Accordingly, autonomy of the monetary policy

9) Instead of taking the first order differences of I(1) variables (such as real GDP\((y)\) and the exchange rate of US S to Korean Won\((e)\)), we could adopt a Structural Vector Error Correction Model (SVECM) with cointegrating equations, as suggested by King, Plosser, Stock, and Watson(1991). However, following B-Q(1989), we form a system of SVAR with long-run identifying restrictions, which consists of I(0) variables and first-order differences of I(1) variables. Another reason for not following King et. al.(1989) is to avoid disentangling permanent shocks from transient shocks.
is missing under the fixed exchange rate system. As in the case of the monetary aggregate targeting, such a fixed or managed exchange rate system existed until the financial crisis in 1997.

(1) IS curve

\[ y_t = \kappa r_t - q_t + \theta_t t, \theta_t t = \theta_t t_{t-1} + \epsilon_t t, \]

\[ r_t = R_t - \frac{1}{k} \sum_{j=1}^{k} E_t [\pi_{t+j}], \quad q_t = p_t - (e_t + p_t^t), \]

\[ \pi_t^t = p_t^t - p_{t-1}^t = S_{f, t} X_t^f + \epsilon_t^\pi, \]

\[ X_t^f = y_t^f - p_t^t = \rho X_{t-1}^f + \epsilon_t^x. \]

(2) LM curve

\[ m_t - p_t = y_t + bR_t \]

Combining (1) and (2), we derive an aggregate demand schedule as follows:

\[ y_t = \frac{\kappa (m_t - p_t) - \frac{\kappa}{k} \sum_{j=1}^{k} E_t [\pi_{t+j}] - q_t}{(1 + \frac{\alpha r}{b})} + \theta_t^y, \quad \theta_t^y = \frac{\theta_t t_{t-1}}{1 + \frac{\alpha r}{b}} = \theta_t^y_{t-1} + \epsilon_t^y \]

(3) New Keynesian Phillips curve (Aggregate supply curve)

\[ \pi_t = \gamma \sum_{i=0}^{\infty} \delta E_t [y_{t+i}^p - y_{t+i}] + \epsilon_t^\pi \]

(4) An equilibrium condition in foreign exchange market

\[ R_t = R_t^f, \quad e_t = e, \quad R_t^f = S_{f, t} X_t^f \]

(5) Money Supply

\[ m_t = y_t + bR_t + p_t \]

Equation (1)~(4) consist of four mutually independent exogenous shocks \((\epsilon_t^f, \epsilon_t^r, \epsilon_t^x, \epsilon_t^\pi)\) and five macro variables \((y_t, R_t, \pi_t, m_t, \pi_t^f)\). In order to handle with the mismatch, we introduce an additional shock \(\epsilon_t^\pi\) and define the GDP gap to be an AR(1) process with a noise of \(\epsilon_t^\pi\), which is, in turn, defined to be potential GDP growth shock \((\epsilon_t^p)\) minus(-) a fraction of demand shock \((\alpha e_t^y)\).
\[ X_t \equiv y_t^p - y_t = \rho X_{t-1} + \epsilon_t^\rho, \quad \epsilon_t^\rho = \epsilon_t^\rho - \alpha \epsilon_t^\rho \]  \hspace{1cm} (6)

Then, Equation (6) could be represented in moving averages assuming stationarity.

\[ X_t (1 - \rho L) = \epsilon_t^\rho \Rightarrow X_t = \frac{\epsilon_t^\rho}{1 - \rho L} = \sum_{j=0}^{\infty} \rho^j \epsilon_{t-j}^\rho \]

Now, we represent the five variables of the real GDP \((y_t)\), inflation \((\pi_t)\), nominal interest rate \((R_t)\), and the monetary aggregate \((m_t)\), and the inflation of a foreign economy \((\pi^f_t)\) as functions of the five exogenous shocks \((\epsilon_t^\rho, \epsilon_t^\delta, \epsilon_t^\pi, \epsilon_t^{1,x}, \epsilon_t^{1,\pi})\) in the following procedure. First, by plugging (6) into (3), we describe the inflation \((\pi_t)\) to be a function of \((\epsilon_t^\rho, \epsilon_t^\delta)\) and their lags.

\[
\pi_t = \gamma \sum_{i=0}^{\infty} \delta^i E_i \left[ \rho X_{t+i-1} + \epsilon_{t+i}^\rho \right] + \epsilon_t^\pi \\
= \gamma \sum_{i=0}^{\infty} \delta^i \rho X_t + \epsilon_t^\pi \\
= \frac{\gamma}{1 - \delta \rho} + \epsilon_t^\pi \quad (0 \leq \delta \rho < 1) \\
= \frac{\gamma}{1 - \delta \rho} \sum_{j=0}^{\infty} \rho^j \epsilon_{t-j}^\pi + \epsilon_t^\pi
\]

Then, considering the working mechanism of the fixed exchange rate system, we note that the domestic interest rate \((R_t)\) has the following relationship with the inflation of the foreign economy \((\pi^f_t)\).

\[ R_t = R_t^f + \lambda \pi_t^f = S_{f,R} X_t^f + \lambda \pi_t^f, \quad \pi_t^f = S_{f,\pi} X_t^f + \epsilon_t^{1,\pi} \]  \hspace{1cm} (7)

Now, we take the first order differences of the real GDP \((y_t)\) and the monetary aggregate \((m_t)\) in consideration of their non-stationarity.

\[
(1 + \frac{\alpha \kappa}{b}) \Delta y_t = \frac{\kappa}{b} (\Delta m_t - \Delta p_t) - \frac{\kappa}{b} \sum_{j=1}^{b} \frac{\gamma}{1 - \rho^j} \rho^j \Delta X_t \\
- \left( \frac{\gamma}{1 - \rho^\delta} X_t + \epsilon_t^\pi - S_{f,\pi} X_t^f - \epsilon_t^{1,\pi} \right) + (1 + \frac{\kappa}{b}) \epsilon_t^\rho \\
= \Delta m_t - \Delta p_t = \Delta y_t + b \Delta R_t^f
\]

Then, combining the first order differenced real GDP \((y_t)\) and monetary aggregate \((m_t)\) in the above, we represent the real GDP growth \((\Delta y_t)\) and the money growth \((\Delta m_t)\) to be also moving averages of the exogenous shocks.
Rearranging the equations derived so far, we represent the vector of \((\Delta y_t, \pi_t, R_t, \Delta m_t, \pi_t')\) to be a SVMAR of the orthogonal exogenous shocks \((\epsilon^y_t, \epsilon_t^\pi, \epsilon_t^\pi, \epsilon^f_{-x}, \epsilon^f_{-x})\).

\[
\begin{pmatrix}
\Delta y_t \\
\pi_t \\
R_t \\
\Delta m_t \\
\pi_t'
\end{pmatrix} = A(L) 
\begin{pmatrix}
\epsilon^y_t \\
\epsilon_t^\pi \\
\epsilon_t^f_{-x} \\
\epsilon_t^f_{-x} \\
\epsilon_t^\pi'
\end{pmatrix} = \sum_{j=0}^{\infty} A_j \begin{pmatrix}
\epsilon^y_{t-j} \\
\epsilon_t^\pi_{t-j} \\
\epsilon_t^f_{-x, t-j} \\
\epsilon_t^f_{-x, t-j} \\
\epsilon_t^\pi'_{t-j}
\end{pmatrix}, A_j \text{ is a } 5 \times 5 \text{ matrix.} \tag{8}
\]

Based on (8), we obtain the restrictions on the coefficients of \(A_\infty = A(1) = \sum_{j=0}^{\infty} A_j\) but find that the SVMAR of (8) is unidentifiable due to the singularity of the matrix \(A_\infty\). Such difficulty in identification seems to be related to the fact that the autonomy of monetary policy is limited under the fixed exchange rate system. Therefore, we start a new procedure of reducing the number of shocks and variables until we obtain an identifiable version of (8).

\[
A_\infty = \begin{pmatrix}
NA & NA & NA & NA & NA \\
NA & NA & NA & 0 & 0 \\
0 & 0 & NA & NA & 0 \\
0 & NA & 0 & NA & NA \\
0 & 0 & 0 & NA & NA
\end{pmatrix} \tag{9}
\]

To begin with, we take shocks from the foreign economy \((\epsilon^f_{-x}, \epsilon^f_{-x})\) as exogenously given\(^{10}\), and eliminate \(\pi_t\) and \(\pi_t'\) from the list of the key variables. Then, repeating the same procedure as before,

---

\(^{10}\) In the following SVAR model, both \(\pi_t'\) and \(\Delta R_t'\) are treated as exogenous. However, in the estimation procedure, only \(\pi_t'\) is used as an exogenous variable in order to avoid over-differencing.
we could obtain an identifiable $A_{\infty}$. However, in this case four restrictions are given to the $3 \times 3$ matrix $A_{\infty}$. Thus in order to deal with over-identification, we run a log-likelihood $\chi^2$-test additionally. 

\[
\begin{bmatrix}
\Delta y_t \\
R_t \\
\Delta m_t
\end{bmatrix} = \sum_{j=0}^{\infty} A_j
\begin{bmatrix}
\epsilon_{t-j}^x \\
\epsilon_{t-j}^y \\
\epsilon_{t-j}^z
\end{bmatrix} + \begin{bmatrix}
\pi_t^f + \kappa \Delta R_t^f \\
0 \\
\pi_t^r + (\kappa + b) \Delta R_t^r
\end{bmatrix} \approx \sum_{j=0}^{\infty} A_j
\begin{bmatrix}
\epsilon_{t-j}^x \\
\epsilon_{t-j}^y \\
\epsilon_{t-j}^z
\end{bmatrix} + \begin{bmatrix}
\pi_t^f \\
\pi_t^r
\end{bmatrix} \begin{bmatrix}
n_1 \\
n_2 \\
n_3
\end{bmatrix} \tag{10}
\]

\[
A_{\infty} = \begin{bmatrix}
NA & NA & NA \\
0 & 0 & NA \\
0 & NA & 0
\end{bmatrix}
\]

According to the $A_{\infty}$ in (10), the productivity shock ($\epsilon_t^x$) and the price shock have permanent effect on the real GDP but have temporary effect on the interest rate and monetary aggregate. In contrast, the demand shock ($\epsilon_t^y$) has permanent effect on the real GDP and the monetary aggregate but its impact is transient on the interest rate.

IV. Estimation Results

1. Data

The data used in our paper are obtained from the Bank of Korea. Time coverage and special notes for each variable are as follows. First, in terms of time coverage, the data for real GDP, price level(GDP deflator), the exchange rate of US dollar to Korean won, and the monetary aggregate(M2) are available from the first quarter of 1970 to the second quarter of 2007, while the yields of 1 year government bond and 3 months CD start from the first quarter of 2000 and from the first quarter of 1991 respectively. Considering short history of the government bond market in Korea, we also include return on 3-month CD for which longer time series is available. However, it should borne in mind that contrary to return on government bond, return on CD has clear limitation to be considered as a good proxy for monetary policy.

---

11) $4 > \frac{3 \times 2}{2} = 3$
The next point to note is that we do not use call rate in our analysis even though it is the official target of monetary policy in Korea. The choice is mainly attributable to the fact that call rate has serious defects in depicting effects of interest rate on various sectors in the economy other than financial market such as IS curve including Fisher effect. Yields on 1 year government bond or 3-month CD relatively free from those kinds of criticism on call rate. Moreover, it should be also pointed out that serial correlations between call rates and other return indexes we use in the analysis are significant.

Third, we measure quantity of money with end-of-quarter M2 balance. Bank of Korea switched to M2 from M1 for aggregate measure of quantity of money. Average balance is conceptually better suited for our analysis but we could not use data on average balance since it is available only from 1986.

As the first step toward in-depth analysis, we examine the existence of unit root in time series of the variables employing DF-GLS procedure proposed by Eliot, Rothenberg and Stock(1996). Even though we fail to reject the null hypotheses of unit root in various nominal interest rates, those variables are used in terms of level rather than differenced version. It is now a well-known proposition that when co-integration relation holds among the variables ordinary VAR procedure results in a consistent estimator and its asymptotic distribution is the same as the VAR with differenced series\(^{12}\) (Hamilton[1994]). Another advantage of not taking difference on interest rates is that we can easily obtain identification constraints with the original series.

The next step is to choose lag length. <Table 3> illustrates the result of lag order selection for the variables in our models. Since various lag order selection criteria do not offer us a reasonably consistent result\(^{13}\), we choose 4 lags in the following analysis in order to secure the degrees of freedom.

\(^{12}\) Rothenberg and Stock(1997) demonstrate that the coefficients of a VAR system are consistently estimated even if any of the variables follows I(1).

\(^{13}\) All the data are recorded quarterly.
2. Impulse Responses(IR) and Forecasting Error Variance Decomposition (FEVD)

Impulse Response analysis tracks down the impact of a shock on an endogenous variable along the passage of time. On the other hand, Forecasting Error Variance Decomposition measures the fraction of the error in forecasting the future value of a variable that is attributable to a shock. The estimation results of SVAR models are demonstrated in these two methods.

2.1 An Economy under Inflation Targeting Rule and Flexible Exchange Rate System

This section reports the estimation results of the SVAR model under the inflation targeting and the flexible exchange rate system. Accordingly, the estimation covers the post-crisis period from the first quarter of 2000 to the second quarter of 2007, in which the yield series of 1-year government bond are available 14) .

[Figure 2] and [Figure 3] summarize the estimation results of SVAR consisting of four endogenous variables (the real GDP growth ($\Delta y_t$), domestic inflation ($\pi_t$), the yield of 1-year government bond ($R_t$), and the change rate of the exchange rate of US dollar to Korean Won ($\Delta e_t$)) and two exogenous variables (inflation of the US ($\pi_t^F$) and the yield of 1-year T-bond($R_t^T$) ).

First, the IR graphs in [Figure 2] demonstrate that the real GDP and the interest rate are more sensitive to supply shock while price level is so to demand shock. On the other hand, the exchange rate

14) Generally, it would be more appropriate to use the observations starting from the first quarter of 1998, in which both the inflation targeting rule and the flexible exchange rate system were enforced. However, in order to exclude idiosyncrasies commonly observed in the recovery period after the financial crisis, we set the starting date of the data to the first quarter of 2000. Furthermore, availability of interest rate series blocks our analysis from covering the period earlier than the first quarter of 2000.
responds more or less equally to both demand and supply shocks. The impacts of shocks disappears almost completely after 70 quarters but they become virtually negligible approximately after 30–40 quarters.

Second, the FEVD analysis confirms that the productivity shock contribute most to explaining the fluctuations in the real GDP, inflation and the interest rate whereas changes in the exchange rate attribute most to the demand shock (see [Figure 3]).

[Figure 2] Impulse Response: 2000.1/4~2007.2/4

Real GDP

Price index

Interest rate

Exchange rate

Note: Each of shock 1,2,3,4 represents a shock from productivity, or aggregate demand, or price, or exchange rate.
[Figure 3] Forecast Error Variance Decomposition: 2000.1/4–2007.2/4

Note: Each of shock 1, 2, 3, 4 represents a shock from productivity, or aggregate demand, or price, or exchange rate.
2.2 An Economy under Monetary Aggregate Targeting Rule and Fixed Exchange Rate System

This section reports the estimation results of the SVAR model under the monetary aggregate targeting and the fixed exchange rate system. Accordingly, the estimation covers the pre-crisis period (from the first quarter of 1991 to the third quarter of 1997) in which the monetary aggregate targeting and the fixed exchange rate system were present. Due to unavailability, we substitute the yield series of 3 month CD for that of the 1-year Korean government bond.

[Figure 4] and [Figure 5] summarize the estimation results of SVAR\(^{15}\) consisting of three endogenous variables (the real GDP growth ($\Delta y_t$), the yield of 3-month CD ($r_t$), and M2 growth ($\Delta m_t$)) and an exogenous variable (inflation of the US ($\pi^*_t$)).

First, the IR graphs in [Figure 4] demonstrate that the real GDP and the monetary aggregate are more sensitive to demand shock while CD rate is to price shock. Regardless of variables, shocks dissipate before 30~40 quarters.

Second, the FEVD analysis confirms that the productivity shock contribute most to explaining the fluctuations in the real GDP whereas changes in the monetary aggregate and the interest rate attribute most to the price shock (see [Figure 5]).

Needless to say, it would be worthwhile to compare these results with those from the previous model of the inflation targeting regime and the flexible exchange rate system. An only concern is that different interest rates are used in the two models (1-year government bond Vs. 3-month CD).

Anyhow, comparing the results from the two models, we note the following points. First, compared with 1990s, the magnitudes of impulse responses become smaller in 2000\(^{16}\). Second, in 1990s the responses to demand or price shock are greater than to other shocks while the responses to supply shock increase in 2000s. This results from IR analysis is consistent with that from FEVD, which also confirms the importance of supply shocks .

---

\(^{15}\) Reminded that this model includes monetary aggregate targeting as well as the fixed exchange rate system, the long-run impulse-response matrix ($A_{\infty}$) is over-identified. We find the log-likelihood $\chi^2(1)$ test statistic of 2.647, whose p-value is 0.104. Accordingly, we cannot reject a null hypothesis that additional restrictions are valid.

\(^{16}\) Since different interest rate measures are used for the models of 1990s and 2000s, we cannot judge in which period impulse responses persist longer.
[Figure 4] Impulse Response: 1991.1/4~1997.3/4

Real GDP

Interest rate

Monetary aggregate

Note: Each of shock 1, 2, 3 represents a shock from productivity, or aggregate demand, or price.
3. Robustness Check

Blanchard and Quah (1989)'s 2-variable model, its 3-variable extensions are also tested for robustness. These extensions are made by adding inflation($\Pi_t$) to the key variables of the real GDP growth($\Delta Y_t$) and the unemployment rate($U_t$). Matched with a larger set of the variables, the number of shocks increases from 2 to 3. Accordingly, three shocks are selected out of the following four- a demand shock($e^d_t$), a productivity shock($e^p_{1,t}$), a shock from financial innovation($e^f_{2,t}$), and an oil shock.
(\(e_{\text{null}}^s\)). Anyhow, instead of displaying the details, we simply note that they provide the similar qualitative results to those from the previous models.
V. Concluding Remarks

Defining growth to be accumulated responses of an economy to various shocks internal and external, our paper identifies diverse impacts that gave rise to the current status of the Korean economy, and differentiates relative contributions of those impacts. To that end, SVAR in presence of long run restrictions is applied to two economic models extended and modified from Stock and Watson (2002). Especially, these models are devised to reflect the recent changes in the determination of foreign exchange rate (from a fixed rate regime to a flexible rate one) as well as the monetary policy rule (from aggregate targeting to inflation targeting).

When organizing the assumed results in the form of impulse response and forecasting error variance decomposition, two common denominators are found as follows.

First, changes in the rate of economic growth are mainly attributable to the impact on productivity, and such trend has grown strong since the 2000s, which indicates that Korea’s economic growth since the 2000s has been closely associated with its potential growth rate.

Second, the magnitude or consistency of impact responses tends to have subsided since the 2000s. Given Korea’s high dependence on trade, it is possible that low interest rates, low inflation, steady growth, and the economic emergence of China as a world player have helped secure capital and demand for export and import, which therefore might reduced the impact of on the whole economy.

Despite the fact that a diverse mixture of model specifications and shock identifications has been tried for analysis, consistently are sustained these two findings\(^ {17) \). Therefore, it can be concluded that the decreased rate of economic growth of Korea since 2000 appears to be on the same track as the decrease in Korea’s potential growth rate.

Of course these two findings are consistent with the possibilities either that the inflation targeting rule and the flexible exchange rate system absorb shocks more before they reach the whole economy or that the size of shocks themselves has shrunken. Especially, compared with supply shocks, it seems that both the impact and the size of demand originated shocks have been diminished. In addition, the successful global co-ordination of the low interest rate regime led by FRB\(^ {18) \) (at least until mid 2000s) contributed to diminishing the magnitudes of external shocks to a small open economy like Korea.

\(^{17) \) These two patterns are also confirmed regardless of the number of lags included in the estimation of SVAR systems

\(^{18) \) Price competitiveness of Chinese manufacturing sectors could be identified as a prop for the low interest rate regime in early 2000s
Reference

(In Korean)
Kwon Sik Kim, 2005, "Impacts of Foreign Shocks on Domestic Macroeconomic Fluctuations", Policy References, no.05-06, KIEP.

(In English)
Hur, S., 2007, Measuring the effectiveness of fiscal policies in Korea, Ch. 3 in NBER-EASE series #16 ed. by T. Ito and A. Rose.