THE RESPONSES OF SMALL OPEN ECONOMIES TO FOREIGN INTEREST RATE SHOCKS: CONSIDERING STRUCTURAL BREAK, NET EXTERNAL CREDIT, AND FINANCIAL INTEGRATION

by

YOUNG MOO CHO

B.A. in Economics, Yonsei University, Seoul, Korea, 1998

M.B.A. in Finance, Yonsei University, Seoul, Korea, 2000

M.A. in Economics, University of Colorado at Boulder, USA, 2010

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Department of Economics

2012

This thesis entitled:

The Responses of Small Open Economies to Foreign Interest Rate Shocks:
Considering Structural Break, Net External Credit, and Financial Integration

written by Young Moo Cho

has been approved for the Department of Economics

____

Professor Robert McNown, Chair

____

Professor Ufuk Devrim Demirel

Date :______________

The final copy of this thesis has been examined by the signatories, and
we find that both the content and the form meet acceptable presentation standards
of scholarly work in the above mentioned discipline.

Cho, Young Moo (Ph.D., Economics)
The Responses of Small Open Economies to Foreign Interest Rate Shocks: Considering Structural Break, Net External Credit, and Financial Integration
Thesis directed by Professor Robert McNown

This dissertation enhances our understanding of the effect of foreign interest rate shocks on small open economies. This dissertation investigates related issues such as the result of structural break unit root tests, the role of net external credit (or debt) and financial integration, and the difference in the response of a small open economy based on its categorization.

In chapter 2, this study compares various endogenous structural break unit root tests such as the ZA test, the LM test and the KP test. This study points out important drawbacks of the LM test that have been ignored, and also demonstrates practical problems of the KP test. The empirical result implies that the Asian financial crisis seems to be the most significant structural break in most macroeconomic variables of South Korea for the last 20 years. Meanwhile, it turns out that some macroeconomic variables of South Korea still remain nonstationary even after the consideration of a structural break.

In chapter 3, this study shows that the Korean economy after the Asian financial crisis demonstrates that, when a small open economy has sizable net external credit, foreign interest rate hikes may cause real expansion due to a positive wealth effect. In addition, the empirical result implies that enhanced financial integration of a small open economy enables foreign interest rate shocks to

explain a higher proportion of fluctuations in financial variables of the small open economy. Considering the co-movement of the foreign interest rate with the domestic interest rate of South Korea after the Asian financial crisis, enhanced financial integration seems to make the interest rate channel more important.

In chapter 4, this study suggests a new method to categorize small open countries based on net external credit (or debt) and financial integration level. This study shows how responses of developing countries to foreign interest rate shocks differ depending on their categorization. The empirical result based on the Panel VAR methodology shows that overall responses seem to be consistent with the theoretical model that is based on 3 transmission channels.

ACKNOWLEDGMENTS

I thank all of my committee members, Professor Robert McNown, Ufuk Devrim Demirel, Donald Waldman, Murat Iyigun, and Amy Liu for constructive comments and useful suggestions. In particular, I would like to express my highest gratitude to Professor Robert McNown, my main advisor. He has been the bright guiding light during my academic journey, providing vast knowledge, brilliant insight, and warm encouragement. I also would like to extend my gratitude to Professor Ufuk Devrim Demirel for his help and contribution especially on Chapter 3. To Professor James Markusen, Martin Boileau, Xiaodong Liu, and Tania Barham, I am grateful for their teaching and supporting me. Thanks, also, to Ms Patricia Holcomb for her excellent assistance in administrative procedure.

I must acknowledge the LG Economic Research Institute and the Korean government for giving me the chance to study abroad and financial support. Special thanks to Ph.D. Min Yong Shin, Professor Ungki Lim, Sammo Kang, and Jaymin Lee for generous helping me pursuing a Ph.D. Thanks to all Korean graduate students in the Economics department for their collaboration. Thanks, also, to all past and current colleagues in the LG Economic Research Institute for their lessons.

Finally, I would like to express my deepest gratitude to my parents for their love, encouragement, and dedication. I can say that I could finish this process thanks to the devotional assistance and understanding of my loving wife. Now and forever, my little children, Minseo, Sungbin, and Sungjae, will be the source of my power.

CONTENTS

TABLES

Table

FIGURES

Figure

CHAPTER I

INTRODUCTION

The effect of foreign interest rate shocks on small open economies has been an important issue in macroeconomic analysis. In particular, considering the influential role of the U.S. in the global financial market, the change of U.S. monetary policy or U.S. interest rates may substantially affect macroeconomic variables of small open economies. Canova (2005) finds that U.S. monetary policy shocks are more important than other U.S. shocks like supply shocks or real demand shocks in macroeconomic fluctuations of Latin American countries.

This dissertation investigates some important issues related to the study of interrelationships between the foreign interest rate and macroeconomic variables of small open economies. To be more specific, it seems that we need to consider the following issues to understand more precisely responses of small open economies to foreign interest rate shocks.

First, we need to check for the existence of a structural break in a macroeconomic variable and consider the effect of the structural break on the econometric analysis using time-series data. As shown by Perron (1989), the decision regarding the stationarity of a variable may change substantially depending on whether and how we consider a structural break in the unit root test. In addition, if we identify a common structural break point for most macroeconomic variables, this may imply that there could exist a structural break even in the interrelationship between macroeconomic variables.

By comparing 3 kinds of endogenous structural break unit root tests such as the Zivot and Andrews (1992) test (ZA test), the Lee and Strazicich (2004) test (LM test), and the Kim and Perron (2009) test (KP test), the chapter 2 of this dissertation answers the following questions: (1) Which endogenous structural break unit root test method will provide the most reliable result? (2) Which period will be selected as the most significant structural break of 5 major domestic macroeconomic variables of South Korea for the last 20 years? (3) How will the unit root test result of these variables change depending on whether and how we consider the structural break?

The time-series data of South Korea seems to provide a good chance to compare break point identifications and unit root test results of various unit root test methods. It has a strong candidate for a structural break, the Asian financial crisis in the late 1990s, based on the graphical illustration and preceding studies. Besides, even though preceding studies have analyzed macroeconomic variables of South Korea using old endogenous structural break unit root tests, results of these studies are not consistent.

In chapter 2, this study points out important biases of the LM test that have been overlooked in many preceding empirical papers. Specifically, the probability for the LM test to select a true break point is low when a variable is nonstationary while the power of the LM test is low when a variable is stationary. This study also points out important limitations of the KP test. If unit root test results of multiple test statistics are not consistent, it may be difficult for the KP test to make a clear decision about the stationarity of a variable.

The structural break point identification results of the above 3 endogenous structural break unit root tests imply that the Asian financial crisis in the late 1990s can be regarded as the most significant structural break in most macroeconomic variables of South Korea. The endogenous structural break unit root test results show that some domestic macroeconomic variables of South Korea remain nonstationary even after the consideration of a structural break in the unit root test.

Second, we need to consider the role of net external credit (or debt) and financial integration in the response of a small open economy to foreign interest rate shocks. Demirel (2009) analyzes the following three kinds of transmission channels through which foreign interest rate shocks are transmitted to a small open economy: (1) the portfolio reallocation effect, (2) the intertemporal substitution effect, and (3) the wealth effect. Based on these 3 channels, he finds that the effect of financial integration on responsiveness of a small open economy to foreign interest rate shocks changes depending on the size of external debt.

As an expansion of the above analysis, the chapter 3 of this dissertation answers the following questions by analyzing the economy of South Korea: (1) How will a small open economy respond to foreign interest rate shocks if the small open economy has sizable net external credit instead of net external debt? (2) How will the response of a small open economy to foreign interest rate shocks change depending on the level of financial integration?

It seems that the Korean economy can be an appropriate case for the above questions because of following characteristics: (1) as shown in chapter 2, the Korean economy has a strong candidate for the economic structural break, that is, the Asian financial crisis in the late 1990s; (2) the financial integration of South Korea was substantially enhanced through the Asian financial crisis; (3) South Korea had been a net debtor in the global financial market before the Asian financial crisis, but South Korea turned to be a net creditor right after the Asian financial crisis. Thus, by comparing the Korean economy before and after the Asian financial crisis, we may investigate the effect of enhanced financial integration and the change in the external debt position on the response to foreign interest rate shocks.

By applying the Perron and Yabu structural break test (Perron and Yabu, 2009) and the Quandt-Andrews structural break test (Andrews, 1993; Andrews 1994; Hansen, 1997), chapter 3 identifies the peak period of the Asian financial crisis as the most probable structural break of the Korean economy for the last 30 years. Based on this result, this study determines the pre-break period (1980 1Q ~ 1997 2Q) and the post-break period (1998 3Q ~ 2010 4Q). Since it turns out that there exists at least 1 cointegration relationship between nonstationary level variables in both sub-sample periods by applying the Johansen cointegration test (Johansen, 1988; Johansen 1995), this study uses the VAR (vector autoregression) model that estimates coefficients in equations by the OLS (ordinary least squares) method following Sims, Stock and Watson (1990).

The impulse response function analysis result in chapter 3 shows the evident difference between the pre-break period and the post-break period in the response of the Korean economy to foreign interest rate shocks. Foreign interest rate hike shocks cause real contraction, the fall of the domestic interest rate and the rise of the exchange rate before the Asian financial crisis when South Korea is a net external debtor with less integrated financial market. On the contrary, foreign interest rate hike shocks cause real expansion, the rise of the domestic interest rate and the fall of the exchange rate after the Asian financial crisis when South Korea becomes a net external creditor with more integrated financial market. In addition, the forecast error variance decomposition analysis result in chapter 3 shows that foreign interest rate shocks explain a higher proportion of variation in financial variables after the Asian financial crisis.

Third, we need to categorize small open economies to make more precise expectations regarding the response of a small open economy to foreign interest rate shocks. As shown in chapter 3, the effect of foreign interest rate shocks on a small open economy may differ substantially depending on the two criteria of net external credit (or debt) and the level of financial integration. This implies that the categorization result of a small open economy based on the above two criteria may provide useful information regarding how the small open economy will respond to foreign interest rate shocks.

To be more specific, the chapter 4 of this dissertation answers the following questions: (1) how can we categorize small open economies based on the two criteria of net external credit (or debt) and the level of financial integration? (2) How does the response to foreign interest rate shocks differ depending on a country's category?

In chapter 4, this study suggests a new method to categorize small open economies based on the above two criteria. This new categorization method provides advantages such as overcoming the problem of the lack of official foreign indebtedness data and capturing the intensity of financial restrictions. Based on this new categorization method, this study classifies (1) Malaysia, Thailand, and Russia into the high financial restriction-net external credit country type, (2) Norway and Switzerland into the low financial restriction-net external credit country type, (3) Peru, Canada, and New Zealand into the low financial restriction-net external debt country type, (4) Indonesia, Philippines, and Brazil into high financial restriction-net external debt country type.

By applying the panel VAR methodology suggested by Holtz-Eakin, Newey and Rosen (1988) and Love and Zicchino (2006), this study compares responses of 4 different types of small open economies to foreign interest rate shocks. Since all panel variables analyzed in this study turn out to be nonstationary by the Fisher-type panel unit root test, and also turn out to have no cointegration relationship by the Pedroni panel cointegration test, this study analyzes stationary first seasonal differenced variables.

The overall empirical result of chapter 4 seems to be consistent with the expectation based on the 3 kinds of transmission channels in Demirel (2009). The impulse response function analysis result shows that foreign interest rate hike shocks cause real expansion in countries with high financial restriction-net external credit while foreign interest rate hike shocks cause real contraction in countries with high financial restriction-net external debt. The empirical result also implies interest rate co-movement or coupling in monetary policy in countries with low financial restriction. This finding is also supported by the forecast error variance decomposition result that foreign interest rate shocks explain a higher fraction of the forecast error variance in domestic interest rate change in countries with low financial restriction rather than in countries with high financial restriction.

The rest of this dissertation is organized as follows. Chapter 2 investigates the issue regarding structural break point identification and endogenous structural break unit root tests of time-series data typically used in this study. Chapter 3 analyzes the issue regarding the role of foreign indebtedness and the level of financial integration of a small open economy in the effect of foreign interest rate shocks. Chapter 4 studies the issue regarding the categorization of small open economies based on two criteria of net external credit (or debt) and the level of financial integration and the difference in responses of small pen economies depending on categorization. Finally, chapter 5 offers concluding remarks.

CHAPTER II

STRUCTURAL BREAK UNIT ROOT TESTS OF SOUTH KOREA'S MACROECONOMIC VARIABLES

2.1. Introduction

It is well known that precise information regarding the stationarity of a variable is essential in the econometric analysis using time-series macroeconomic variables. If there exists a structural break in a variable, the unit root test result of the variable may change substantially depending on whether and how the structural break is considered in the unit root test. As the earliest and the most well known study, even though Nelson and Plosser (1982) insist that major U.S. macroeconomic variables seem to be nonstationary (without the consideration of a structural break), Perron (1989) shows that these variables are revealed to be stationary after considering the Great Depression as a structural break in the trend of a variable.

In addition, the consideration of a structural break may play an important role in the macroeconomic analysis as well as in the unit root test. More specifically, if a common structural break is identified for most macroeconomic variables, this may imply that there exists a structural break even in the interrelationship between these macroeconomic variables. If this is the case, to better understand interrelationship between macroeconomic variables, we may need to identify and consider the structural break not only in the univariate analysis but also in the multivariate analysis.

In this paper, I analyze the following 5 major macroeconomic variables of South Korea ranging from 1990 1Q to 2009 4Q: GDP, investment, inflation rate, exchange rate, and interest rate. At first, I apply the Ng and Perron (2001) test as the unit root test that does not allow for a structural break. After that, I apply the following three kinds of endogenous structural break unit root tests which determine a break point based on the data and execute a unit root test considering the identified break point: the Zivot and Andrews (1992) test (ZA test), the Lee and Strazicich (2004) test (LM test), and the Kim and Perron (2009) test (KP test). Based on the unit root test results of these methods, this paper answers the following questions: first, which period or which economic event will be selected as the most significant structural break of macroeconomic variables of South Korea for the last 20 years? Second, how will the unit root test result of these variables change depending on whether and how we consider the structural break? Third, considering the characteristic of each test method and the data analyzed in this paper, which test method will provide the most reliable result?

I think the time-series data of South Korea analyzed in this paper could provide a good chance to compare break point identifications and unit root test results of various unit root test methods due to the following reasons: first, macroeconomic variables of South Korea for the last 20 years seems to have a strong candidate for a structural break, that is, the Asian financial crisis in the late 1990s. In <Figure 2.1>, the shaded area in each graph represents the period from 1997 3Q to 1998 4Q, which is usually referred to as the peak of the Asian financial crisis. It seems that, for all 5 variables, the biggest fall or rise in the level or the most noticeable change in slope happened during this period. As well as this graphical illustration, there have been many studies that conclude that the Asian financial crisis substantially changed the economy of South Korea (Hong et al., 2004; Kim et al., 2006; Aizenman et al., 2007; Lee and Rhee, 2007; Kang and Sawada, 2008; Ra, 2008; Ang, 2010). Second, although there have been a few empirical papers that analyze macroeconomic variables of South Korea using relatively old endogenous structural break unit root tests, the results of these papers are not consistent. For example, Harvie and Pahlavani (2006) analyze 10 variables[1] ranging from 1980 1Q to 2005 1Q by applying the methodology of Perron (1997). They find that, under the Additive Outlier model (AO model) specification, all 10 variables are nonstationary and the Asian financial crisis is identified as a structural break for only 1 of 10 variables. They also find that, under the Innovational Outlier model (IO model) specification, 8 of 10 variables are nonstationary and the Asian financial crisis is identified as a structural break for 7 of 10 variables. Another paper (Harvie and Pahlavani, 2009) analyzes 6 variables[2] ranging from 1990 1Q to 2006 4Q by applying the ZA test. They find that only 2 of 6 variables are nonstationary and the Asian financial crisis is identified as a structural break for all 6 variables.[3]

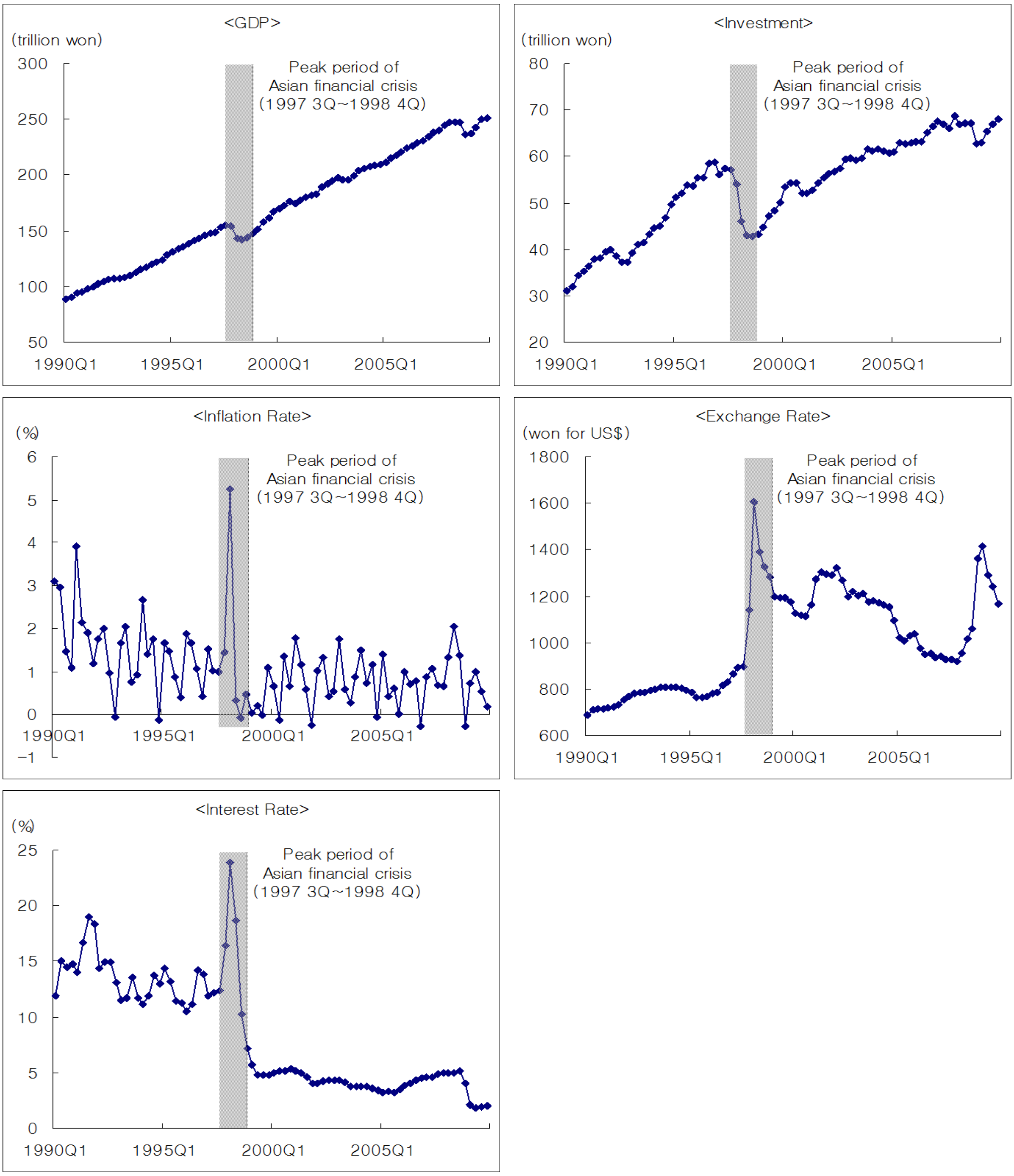
---

[1] The 10 variables are GDP, GNI, private consumption, government consumption, investment (gross fixed capital formation), total export, total import, CPI, money supply, and exchange rate.

[2] The 6 variables are GDP, exchange rate, broad money, currency in circulation, interest rate, and CPI.

[3] For the purpose of comparison with previous research, I tried to apply the methodology of this paper to the same variables analyzed in Harvie and Pahlavani (2009). Even though there are some differences between my result and their result based on the ZA test, probably due to the difference in the data analyzed, the overall empirical results of Harvie and Pahlavani turn out to be consistent with the empirical result of this paper.

<Figure 2.1> 5 macroeconomic variables of South Korea (1990 1Q~2009 4Q)



Note: GDP (national currency, billion won, real, seasonally adjusted), investment (Gross Fixed Capital Formation, national currency, billion won, real, seasonally adjusted), inflation rate (change rate of consumer price index from the previous quarter), exchange rate (nominal, national currency for US$, average of quarter) and interest rate (nominal, money market rate, average of quarter). The data used are obtained from the Bank of Korea (http://ecos.bok.or.kr/).

To get a more reliable conclusion about break point identification and the unit root test, I apply two recently proposed endogenous structural break unit root tests, that is, the LM test and the KP test. This paper is the first empirical trial that compares results of these two tests with old methods like the ZA test using identical time-series data. Even though the ZA test has been one of the most commonly used endogenous structural break unit root tests, it is prone to some important problems such as incorrect break point identification and spurious rejection[4] (Nunes et al., 1997; Lee and Strazicich, 2001). On the contrary, the LM test is known to be free from the spurious rejection problem of the ZA test due to the invariance property[5]. However, I point out in this paper some important biases of the LM test that have been overlooked. Based on the simulation result of Lee and Strazicich (2004), the paper that initially proposed the LM test, I find that the probability for the LM test to select a true break point is low when a variable is nonstationary. I also find that the power of the LM test is low when a variable is stationary. It is surprising that these characteristics of the LM test have been ignored in many empirical papers that use this methodology (Narayan and Kumar 2006; Lee and Chang, 2008; Narayan and Smyth, 2008; Madsen et al., 2008). Meanwhile, according to the simulation result of Kim and Perron (2009), the KP test seems to have many desirable properties such as correct size of the test[6] and high power of the test[7], and invariance to break parameters. However, I point out an important limitation of the KP test in this paper. Since the KP test uses multiple unit root test statistics, it may be difficult to make a clear decision about stationarity if unit root test results of multiple test statistics are not consistent.

[4] Incorrect rejection of the true unit root null hypothesis.
[5] The property that the asymptotic distribution of a unit root test statistic does not change depending on the existence, location, or magnitude of a structural break.
[6] The probability for a test to incorrectly reject true null hypothesis.
[7] The probability for a test to correctly reject false null hypothesis.

The empirical result of this paper suggests that the Asian financial crisis in the late 1990s can be regarded as the most significant structural break in most macroeconomic variables of South Korea for the last 20 years. This information regarding the structural break in the univariate analysis may provide useful intuition for the better multivariate analysis. To be more specific, the fact that the Asian financial crisis is identified as the structural break in most macroeconomic variables of South Korea implies that the Asian financial crisis may be a strong candidate for the structural break in the interrelationship between macroeconomic variables of South Korea. If this were true, it would be more appropriate in multivariate analysis to divide the sample period into two sub-sample periods, the pre-break period and the post-break period, and to compare the interrelationship between macroeconomic variables in the pre-break period and the post-break period.

Meanwhile, it turns out that some macroeconomic variables of South Korea remain nonstationary even after the consideration of a structural break in the unit root test. Considering drawbacks of the other endogenous structural break unit root tests such as the spurious rejection of the ZA test and the low power of the LM test, the unit root test result of the KP test seems to be the most reliable one. The unit root test result of the KP test suggests that GDP and the exchange rate are still nonstationary in spite of the consideration of a structural break while the stationarity of investment, the inflation rate and the interest rate are unclear due to the inconsistency in the unit root test results of multiple test statistics. This ambiguous conclusion regarding the stationarity of investment, the inflation rate and the interest rate demonstrates the practical problem that we may face in the application of the KP test.

The rest of this paper is organized as follows. In section 2.2, I explain the methodology used in this paper and related previous literature. In section 2.3, I present empirical results using macroeconomic variables of South Korea. Section 2.4 offers concluding remarks and an appendix provides some technical derivations.

2.2. Methodology and related literature

In this paper, I analyze quarterly macroeconomic time-series data of South Korea ranging from 1990 Q1 to 2009 Q4. This data set consists of 5 variables such as gross domestic product (GDP: national currency, billion won, real, seasonally adjusted), gross fixed capital formation (investment: national currency, billion won, real, seasonally adjusted), inflation rate (change rate of consumer price index from the previous quarter), exchange rate (nominal, national currency for US$, average of quarter) and interest rate (nominal, money market rate, average of quarter). These data are obtained from the Bank of Korea (http://ecos.bok.or.kr/). For all variables, I use the level data with the exception that GDP, investment and exchange rate are in the natural log form.

GDP and the inflation rate are the macroeconomic variables most widely used, and investment has a close relationship with the growth potential of an economy. Exchange rate and interest rate represent the foreign currency market and the domestic money market, respectively. These domestic variables are usually used in many macroeconomic papers as the most relevant indicators of aggregate economic activity of a small open economy.

Unit root tests that do not allow for a break: ADF-type unit root tests

The ADF-type test is based on the following unit root test equation:

$$\Delta y_t = C + D\,t + A\,y_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta y_{t-j} + u_t \tag{2.1}$$

where y_t is the time t value of a macroeconomic variable tested, Δ means increment, u_t ~ i.i.d. N(0, σ^2), and k is a lag length of augmented terms to correct for auto-correlated errors. If there exists temporal dependence in the errors of the unit root test equation, it is impossible to properly estimate the unit root test statistic and its standard error. To correct for these auto-correlated errors, augmented terms, extra regressors of the differences of the dependent variables (y_{t-j}), are usually added to the unit root test equation. If A = 0, the unit root null hypothesis holds and y_t is nonstationary. On the contrary, if A < 0, the alternative hypothesis holds and y_t is stationary.

In this paper, I apply the Ng and Perron test as the ADF-type unit root test that does not allow for a structural break. Compared with other ADF-type unit root tests, two test statistics of the Ng and Perron test, MZa and MZt, are proved to have the better size and power of the test when implemented according to Ng and Perron's recommended procedure. I include both intercept and time trend in the test equation and choose the lag length based on the Modified Akaike Information Criterion.

Unit root tests that allow for a break: structural break unit root tests

(1) Exogenous structural break unit root tests

Nelson and Plosser (1982) conclude that major U.S. macroeconomic variables are nonstationary based on the ADF test. However, Perron (1989) shows that 11 of the 14 nonstationary variables examined in Nelson and Plosser (1982) turn out to be stationary by applying an alternative unit root test method that considers the Great Depression as a structural break. This implies that the ADF test often fails to correctly reject the unit root null hypothesis when the true data generating process of a variable is in fact stationary with a break. This finding gives rise to many succeeding studies regarding "structural break unit root tests". The methodology proposed by Perron (1989) is called "exogenous structural break unit root tests" since it assumes that a break point is known *a priori* and fixed exogenously without depending on data. This test allows the shift in the level and/or the slope under both the null and alternative hypothesis, and this test is known to have a good invariance property.

This pioneering methodology of Perron (1989) introduces following two kinds of models for a data generating process with a one-time change in a trend function: the "Additive Outlier model" (AO model) and the "Innovational Outlier model" (IO model). The AO model represents when the change to the new trend function occurs instantaneously. The IO model represents when the change to the new trend function is gradual. For each model, Perron (1989) specifies four different kinds of structures: a change in the level for a non-trending series (Model O); and for trending series, a change in the level (Model A), a change in the slope (Model B), and a change in both the level and the slope (Model C).

(2) Endogenous structural break unit root tests

The assumption of exogenous structural break unit root tests that a break point is known *a priori* has been controversial. In particular, Christiano (1992) asserts that this exogenously fixed break point assumption is inappropriate. In response to this criticism, many succeeding studies propose various "endogenous structural break unit root tests" that determine a break point based on data. Some of them assume only one break, whereas the others assume multiple breaks (Lumsdaine and Papell, 1997; Bai and Perron, 1998; 2003).

In this paper, I apply the following endogenous structural break unit root tests that assume only one break: the ZA test, the LM test, and the KP test. Compared with exogenous structural break unit root tests or endogenous structural break unit root tests that assume multiple structural breaks, I think these tests are more appropriate for key questions of this paper, that is, finding the most significant break point in a time-series and then checking the stationarity of the variable considering the identified break. For all these tests, I adopt Model C that allows for a change in both the level and the slope. Compared with other models that allow for only a change in the level or only a change in the slope, Model C is the least restrictive one. Since I try to answer key questions of this paper based on structural break points and unit root test results that these 3 test methods provide, it is essential to understand characteristics, in particular, advantages and disadvantages, of each test method.

<ZA test>

Zivot and Andrews (1992) extend the IO model of Perron (1989) to the case when the true break point is not known and the unit root test is executed based on the break point determined by the model. Their methodology allows the shift in the level and/or the slope not under the null hypothesis but only under the alternative hypothesis. Even though Zivot and Andrews (1992) do not mention evidently in their paper, it seems that they assume no break under the null hypothesis because of the "variance property". Perron and Vogelsang (1992) and Vogelsang and Perron (1998) reveal that, if a break is present under the null hypothesis and the break point is not known and should be searched for in the model, then the asymptotic distribution of the unit root test statistic varies depending on the location or magnitude of a break. This variance property may be cumbersome in applied works since it is necessary to simulate new critical values depending on break parameters (Lee and Strazicich, 2004).

To avoid this problematic feature, the ZA test assumes the following unit root null hypothesis:

$$y_t = \mu + y_{t-1} + e_t \tag{2.2}$$

where e_t is such that $\Delta e_t = C(L)\varepsilon_t$ where ε_t ~i.i.d. $(0, \sigma^2)$, $C(L) = \sum_{j=0}^{\infty} c_j L^j$ such that $\sum_{j=1}^{\infty} j\left|c_j\right| < \infty$, and $c_0 = 1$. The null hypothesis of the ZA test is that a series is integrated without a break. On the contrary, the alternative hypothesis of the ZA test is that a series is a trend-stationary process with a break occurring at an unknown point of time. Zivot and Andrews (1992) view the selection of the break point as the outcome of an estimation procedure designed to fit the series to the alternative hypothesis. Reflecting this view, the ZA test chooses the break point (T_B) that is the least favorable one for the null hypothesis over all possible break points. The range for possible break points is determined by [ε, 1-ε] T where ε is the pre-specified parameter and T is the total number of points. In this paper, the choice for ε is 0.25. The break fraction ($\lambda = T_B/T$) is chosen to minimize the one-sided *t*-statistic for testing $\alpha = 1$ in the following unit root test equation:

$$y_t = \mu + d_1 t + d_2 DU_t + d_3 DT_t + \alpha y_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta y_{t-j} + e_t \tag{2.3}$$

where $DU_t = 1$ for $t \geq T_B+1$, otherwise $DU_t = 0$; $DT_t = t - T_B$ for $t \geq T_B+1$, otherwise $DT_t = 0$.[8] In order to correct for auto-correlated errors, I determine the lag length of augmented terms (k) by the "general to specific procedure" proposed by Perron

[8] The unit root test equation of IO model-Model C in the exogenous break unit root test of Perron (1989) is as follows: $y_t = \alpha y_{t-1} + \mu + d_1 t + d_2 DU_t + d_3 DT_t + d_4 D(T_1)_t + \sum_{j=1}^{k} \gamma_j \Delta y_{t-j} + e_t$ where T_1 is a true break point and $D(T_1)_t=1$ for $t=T_1+1$, otherwise 0. Under the unit root null hypothesis, we expect $\alpha=1$, $d_1=0$, $d_3=0$, and d_4 is significantly different from 0. Under the alternative hypothesis, we expect $\alpha<1$, $d_1 \neq 0$, $d_3 \neq 0$, and d_4 is close to 0. Since the ZA test assumes no break under the null hypothesis, the equation (3) no longer needs the dummy variable $D(T_1)_t$.

(1989)[9]. Zivot and Andrews (1992) that propose the ZA test also adopts this lag length choice rule.

However, there are some important shortcomings of the ZA test that call for a careful interpretation when applying the ZA test. As explained above, the ZA test assumes no break under the unit root null hypothesis and derives its critical values accordingly. Then, the rejection of the null hypothesis in the ZA test implies that a series is not "nonstationary without a break". In other words, the rejection of the null hypothesis may imply that a series is "stationary (with or without a break)" or "nonstationary with a break". However, many empirical papers that applied the ZA test have concluded that the rejection of the null hypothesis of the ZA test implies that a series is "stationary".

In addition, Nunes et al. (1997) provide evidence that the assumption of no break under the null hypothesis in the ZA test causes the unit root test statistics to diverge. They mention that this divergence may cause the unit root test statistic to increase in absolute value, resulting in the incorrect rejection of the unit root null hypothesis (spurious rejection) when the true data generating process is a unit root process with a break. They also prove that this spurious rejection may occur more as the magnitude of a break increases (size distortion).

Moreover, Lee and Strazicich (2001) show that the ZA test tends to suggest the break point one-period prior to the true point (T_B-1) under both the null and the alternative hypothesis, and more so as the magnitude of a break increases. They find that the bias in estimating parameters in the unit root test equation is maximized at this incorrectly chosen break point (T_B-1). This bias causes the unit

[9] The general to specific procedure proposed by Perron (1989) takes the following procedure: begin with a maximum lag length k = 8. Examine if the last lag term is significantly different from zero at the 10% significance level. If it is insignificant, the last lag term is dropped and the model is re-estimated with one-less lag length. This procedure is repeated until the significant last lag term is found or k = 0.

root test statistic to diverge and may result in spurious rejection of the unit root null hypothesis.[10]

<LM test>

Lee and Strazicich (2004) propose an alternative endogenous structural break unit root test that does not lead to the above problems of the ZA test. Their testing methodology is the extension from the Lagrange Multiplier (LM) unit root test that is initially suggested by Schmidt and Phillips (1992).

The LM test considers the following data generating process:

$$\begin{aligned} y_t &= \delta' Z_t + X_t \\ X_t &= \beta X_{t-1} + \varepsilon_t \end{aligned} \tag{2.4}$$

where $\delta' = (\delta_1, \delta_2, \delta_3, \delta_4)$, $Z_t = [1, t, DU_t, DT_t]'$, and $\varepsilon_t \sim$ i.i.d. $(0, \sigma^2)$. The unit root null hypothesis is described by $\beta = 1$. The important advantage of using the above data generating process is that this parameterization allows for a trend with a break under both the null and the alternative. Based on the above data generating process, the following unit root test equation of the LM test is derived using the LM (score) principle[11]:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta \tilde{S}_{t-j} + u_t \tag{2.5}$$

where $\delta' = (\delta_2, \delta_3, \delta_4)$; $\Delta Z_t = [1, \Delta DU_t, \Delta DT_t]$; $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}$, $t = 2, \ldots, T$; $\tilde{\psi}_x = y_1 - Z_1\tilde{\delta}$; and $\tilde{\delta}$ are coefficients in the regression of Δy_t on ΔZ_t . $\Delta DU_t (= DU_t - DU_{t-1})$ corresponds to a one-time change in drift under the null

---

[10] Perron (1997) proposed an alternative endogenous break unit root test, which selects the break point where the absolute value of the *t*-statistics of the break dummy coefficient (d_1 in Model A, d_3 in Model C) is maximized. However, Lee and Strazicich (2001) showed that this methodology also has the same spurious rejection problem as the ZA test, caused by incorrect identification of a break point.

[11] The derivation of the unit root test equation of the LM test using the LM (score) principle is given in Appendix 1.

hypothesis and corresponds to a change in intercept under the alternative hypothesis. $\Delta DT_t\ (= DT_t - DT_{t-1})$ corresponds to a permanent change in drift under the null hypothesis and corresponds to a change in a trend under the alternative hypothesis. Intuitively, we can think of $\tilde{S}_t$ as the "residuals" given as the difference between the value of series (y_t) and the expected value from regression ($\tilde{\psi}_x + Z_t\tilde{\delta}$) with intercept $\tilde{\psi}_x$ and slope $\tilde{\delta}$. Thus, φ = 0 implies no linear relationship between the change of series in time t (Δy_t) and the residual in time t -1 ($\tilde{S}_{t-1}$), and no mean-reverting of y_t, and thus nonstationarity of y_t. Therefore, the unit root null hypothesis of the LM test is described by φ = 0. And the LM unit root test statistic is a t-statistic testing the null hypothesis φ = 0. Like the ZA test, the LM test also chooses the break point (T_B) with the minimum unit root test statistic over all possible break points, i.e., the least favorable one for the unit root null hypothesis. In order to correct for auto-correlated errors, I determine the lag length of augmented terms (*k*) by the "general to specific procedure" proposed by Perron (1989). Lee and Strazicich (2004) who propose the LM test also adopt this lag length choice rule. The range for possible break points is determined by [ε, 1-ε] T where ε is the pre-specified parameter and T is the total number of points. In this paper, the choice for ε is 0.25.

Lee and Strazicich (2004) show that the LM test has the advantage that the asymptotic distribution of the unit root test statistic is not affected by the existence, magnitude or location of the break under the null or the alternative hypothesis. This implies that the LM test may provide the same advantage of "invariance property" as the exogenous structural break unit root tests. Then, it is not necessary to get new critical values depending on the magnitude or location of the break. Lee and Strazicich (2004) also assert that the LM test is free from spurious rejection due to this invariance property.

However, in addition to the above advantages, this paper points out that the LM test has important disadvantages as well.. Although Lee and Strazicich (2004), who initially propose the LM test, focus on explaining advantages of the LM test, the simulation result contained in their paper shows important disadvantages of the LM test as well.

<Table 2.1> Simulation result given in Lee and Strazicich (2004)

Table 2. Rejection Rates and Frequency of Estimated Break Points

Test	δ_3	5% Rej.	Emp. Crit.	Frequency of Estimated Break Points in the Range						
				T_B-5 ~ T_B-2	T_B-1	T_B	T_B+1	T_B+2 ~ T_B+5	$T_B\pm$ 10	$T_B\pm$ 30
(a) Under the Null (β = 1)										
LM	0	.057	-3.62	.048	.015	.013	.010	.054	.259	.721
	4	.046	-3.53	.020	.006	.325	.005	.019	.446	.809
	6	.050	-3.56	.023	.013	.401	.009	.022	.519	.832
	8	.049	-3.56	.035	.019	.448	.018	.035	.598	.861
	10	.039	-3.48	.051	.031	.480	.029	.046	.682	.877
ZA	0	.060	-4.89	.048	.009	.013	.012	.049	.248	.726
	4	.081	-5.04	.099	.191	.003	.003	.019	.414	.801
	6	.169	-5.66	.108	.367	.003	.001	.009	.552	.859
	8	.325	-6.75	.085	.584	.002	.000	.002	.719	.918
	10	.506	-7.87	.064	.758	.005	.000	.000	.850	.963
(b) Under the Alternative (β = .8)										
LM	0	.710	-5.20	.057	.012	.014	.015	.062	.305	.745
	4	.581	-4.91	.040	.026	.553	.027	.048	.746	.907
	6	.537	-4.70	.041	.028	.737	.028	.047	.908	.962
	8	.492	-4.64	.041	.018	.834	.017	.036	.967	.982
	10	.454	-4.63	.026	.014	.898	.013	.024	.985	.991
ZA	0	.389	-5.77	.054	.015	.013	.015	.050	.276	.735
	4	.472	-6.15	.197	.493	.001	.001	.013	.778	.916
	6	.472	-6.15	.197	.493	.001	.001	.013	.778	.916
	8	.921	-8.48	.042	.949	.000	.000	.000	.996	.998
	10	.987	-9.94	.011	.988	.000	.000	.000	1.0	1.0

Note: All simulations were performed in samples of size T = 100.

Note: (1) δ_3 represents the magnitude of a break, (2) 5% Rej. represents rejection rate at the 5% significance level, (3) Emp. Crit. represents the 5% empirical critical values, (4) T_B represents a true break point.

<Table 2.1> is the simulation result given in Lee and Strazicich (2004). Under the unit root null hypothesis (when a series is nonstationary, i.e., in the panel (a) of <Table 2.1>), the disadvantage of the LM test is that the probability for the LM test to identify a true break point (T_B) is relatively low. The probability for the LM test to identify the true point is at most less than half (more accurately, 48%). Even the probability for the break point identified by the LM test to locate between 10-periods prior to the true point and 10-periods posterior to the true point ($T_B \pm 10$) is at most only 68.2%. On the other hand, even though the ZA test tends to suggest the break point at one-period prior to the true point (T_B-1), the probability for the ZA test identify that point (T_B-1) reaches up to 78.5% as the magnitude of a break (δ_3) increases.

In this case when a series is nonstationary, the advantage of the LM test is that the LM test provides a good size. The probability for the LM test to incorrectly reject the unit root null hypothesis (i.e., size of the test) stays around 5%, which is the pre-determined significance level of the test. On the contrary, the ZA test exposes evident spurious rejection. As the magnitude of a break increases, the size of the ZA test rises up to 50.6%, which is much greater than the 5% significance level of this test.

On the other hand, under the alternative hypothesis (when a series is stationary, i.e., panel (b) of <Table 2.1>), the disadvantage of the LM test is that the probability for the LM test to correctly reject the unit root null hypothesis (i.e., power of the test) decreases as the magnitude of the break increases. The power of the LM test is 0.71 when there is no break ($\delta_3 = 0$), but it falls down to 0.454 when there is a significant break ($\delta_3 = 10$). On the contrary, the power of the ZA test increases up to 0.987 as the magnitude of a break (δ_3) increases.

In this case when a series is stationary, the advantage of the LM test is that the probability for the LM test to choose a true break point increases as the magnitude of a break increases. The probability for the LM test to identify the true point amounts to at most 89.8%.

<KP test>

Kim and Perron (2009) propose another endogenous structural break unit root test, which is very similar to the exogenous structural break unit root test of Perron (1989). Their motivation is that the methodology of Perron (1989) has the most desirable properties such as allowing a break under both the null and the alternative hypothesis, invariance to break parameters, and high power of the test with the correct size. Reflecting this point of view, the KP test considers the same data generating processes used by Perron (1989), which consists of two kinds of models (the AO model and the IO model) with four kinds of structure (the Model O, Model A, Model B, and Model C). In this paper, I adopt the least restrictive model, Model C, which allows for a change in both the level and the slope. In other words, the KP test models that I apply in this paper are the "Model A3" and the "Model I3".[12]

Based on these data generating processes, the KP test considers the following unit root test equations that are the same ones as Perron (1989) except that the estimated break point ($T_B = \hat{\lambda}T$) is used instead of the true one ($T_1 = \lambda^c T$):

(for the Model A3)

$$\tilde{y}_t = \alpha\, \tilde{y}_{t-1} + \sum_{j=0}^{k} \omega_j\, D(T_B)_{t-j} + \sum_{j=1}^{k} d_j\, \Delta\tilde{y}_{t-j} + u_t \qquad (2.6)$$

[12] Kim and Perron (2009) use terms "Model A3" and "Model I3" to represent "Model AO-C" and "Model IO-C" of Perron (1989).

where $\tilde{y}_t$ is the detrended series by the regression $y_t = \mu + \beta t + \mu_b DU_t + \beta_b DT_t + \tilde{y}_t$; u_t is such that $\Delta u_t = C(L)e_t$ where e_t ~ i.i.d. $(0, \sigma^2)$ and $C(L) = \sum_{j=0}^{\infty} c_j L^j$ such that $\sum_{j=1}^{\infty} j|c_j| < \infty$ and $c_0 = 1$.

(for the Model I3)

$$y_t = \alpha\, y_{t-1} + \mu + \beta\, t + \mu_b DU_t + \beta_b DT_t + d\, D(T_B)_t + \sum_{j=1}^{k} d_j\, \Delta y_{t-j} + u_t \tag{2.7}$$

where $D(T_B)_t = 1$ for $t = T_B+1$, otherwise 0. The unit root test statistic is a t-statistic testing the null hypothesis $\alpha = 0$. For the KP test, I determine k by the (Modified) Akaike Information Criterion.

Regarding the method to identify a structural break point, Perron and Zhu (2005) proves that, when we use the estimate of the structural break point chosen by minimizing the sum of squared residuals, the estimate of the break point shows a good property, like consistency.[13] Based on their analysis, the KP test selects the break fraction for Model A3 ($\hat{\lambda}^{AO}$) and the break fraction for Model I3 ($\hat{\lambda}^{IO}$) by minimizing the sum of squared residuals from the following regression equation (2.8) and (2.9), respectively:

(for the Model A3)

$$y_t = z(T_B)'_t \phi + u_t = z'_{t,1}\phi_1 + z(T_B)'_{t,2}\phi_2 + u_t \tag{2.8}$$

where $z_{t,1} = (1, t)'$, $\phi_1 = (\mu, \beta)'$, $z(T_B)_{t,2} = (DU_t, DT_t)'$, $\phi_2 = (\mu_b, \beta_b)'$

[13] To identify an unknown break point, several methods have been used in the literature: for example, minimizing the value of the t-statistic on the unit root test coefficient, maximizing the absolute value of the t-statistic on the relevant break dummy, or minimizing the value of the t-statistic on the relevant break dummy. However, Kim and Perron (2009) points out that little is known about the consistency and the convergence rate of these estimates except the estimate chosen by minimizing the sum of squared residuals.

(for the Model I3)

$$y_t = z'_{t,1}\phi_1 + \sum_{i=0}^{k-1}\xi_i D(T_B+i)_t + z(T_B+k)'_{t,2}\zeta_2^* + u_t^s \tag{2.9}$$

where $\xi_i = \mu_b\sum_{j=0}^{i}\psi_j^* + \beta_b\sum_{j=0}^{i}\psi_j^*(i-j+1)$, $\quad \zeta_2^* = \zeta_2 + (\sum_{i=1}^{\infty}\psi_{k+i}^*)\phi_2$,

$\zeta_2' = (\mu_b\sum_{j=0}^{k}\psi_j^* + \beta_b\sum_{j=0}^{k-1}\psi_j^*(k-j),\ \beta_b\sum_{j=0}^{k}\psi_j^*)$, $\quad u_t^s = u_t - s_t$,

$s_t = \sum_{i=1}^{\infty}\psi_{k+i}^*\sum_{j=0}^{i-1} d(T_B+k+j)'_{t,2}\ \phi_2$

Equation (2.8) is the same as the data generating process for Model A3 of Perron (1989). Equation (2.9) is a more general representation of the data generating process for Model I3 since it allows breaks in the trend and the shock to the error to evolve in different ways.[14]

However, Kim and Perron (2009) find that, when we select the break point using $\hat{\lambda}^{AO}$ or $\hat{\lambda}^{IO}$, the distribution of the unit root test statistic does not converge so fast to the limit distribution of the exogenous structural break unit root test statistic of Perron (1989). As a method to increase the rate of convergence, the KP test proposes the modified unit root test statistic using a trimmed data set, i.e., eliminating some data points around the break point selected by $\hat{\lambda}^{AO}$ or $\hat{\lambda}^{IO}$.[15] Kim and Perron (2009) prove that limit distributions of these modified unit root test statistics are the same as the limit distribution of the unit root test statistic in Model A2 of Perron (1989). This implies that the KP test can use the same critical values for the exogenous structural break unit root test given in Perron (1989).

[14] In the original data generating process for the IO model proposed by Perron (1989), it is assumed that the economy responds to breaks in the trend in the same way as it reacts to the other shock to the error. The detailed derivation process of the equation (2.9) is given in Appendix 2.

[15] Kim and Perron (2009) mention that unit root test results are not sensitive to the choice of trimming window based on their simulation analysis. I eliminate four quarterly data points around the break point in this paper.

Another issue is that asymptotic advantages of the KP test described above do not hold when there is no break in a series. To deal with this problem, the KP test uses a pre-test proposed by Perron and Yabu (2009) to determine whether or not a break exists in the series. The most prominent advantage of this pre-test is that this pre-test is valid regardless of whether a time-series data is stationary or nonstationary. If the pre-test determines that there is no break, the KP test recommends applying a Dickey-Fuller type unit root test with no break dummy variables. If the pre-test determines that there is a break, the next procedure of the KP test may be applied. For the Perron and Yabu test, I determine lag length by the Akaike Information Criterion. The range for possible break points is determined by [ε, 1-ε] T where ε is the pre-specified parameter and T is the total number of points. In this paper, the choice for ε is 0.25.

By simulation analysis, Kim and Perron (2009) select a few unit root test statistics, which have good properties like correct size and high power. Thus, they show that these unit root test statistics chosen by the KP test procedure provide more reliable unit root test results than other unit root test statistics chosen by other commonly used endogenous structural break unit root tests. To be more specific, for the Model A3, the KP test recommends two kinds of unit root test statistics based on $\hat{\lambda}^{AO}$ ($t_\alpha(\hat{\lambda}^{AO})$) and trimmed data ($t_\alpha(\hat{\lambda}^{AO}_{tr})$). For the Model I3, the KP test recommends the unit root test statistic based on trimmed data ($t_\alpha(\hat{\lambda}^{IO}_{tr})$).

However, the fact that the KP test depends on these multiple unit root test statistics may reduce the usefulness of the KP test. If some test statistics imply that a series is stationary but the other test statistics imply that the series is nonstationary, it may be difficult to make a clear decision regarding the stationarity of the time-series data. In fact, Kim and Perron (2009) do not propose any definite decision-making rule for this case when unit root test results of multiple test statistics are not consistent. To be more specific, there is no definite decision rule about whether the AO model or the IO model is appropriate for a time-series data. Even though Perron (1989) defines that the AO model represents when the change to the new trend function occurs instantaneously and the IO model represents when the change to the new trend function is gradual, the distinction based on this guideline may be arbitrary.[16] Moreover, for Model A3, there is no definite decision rule about on which unit root test statistic we should put more weight between $t_{\alpha}(\hat{\lambda}^{AO})$ and $t_{\alpha}(\hat{\lambda}_{tr}^{AO})$ when unit root test results of these two test statistics are not consistent.

2.3. Empirical results

Structural break point identification

As explained before, endogenous structural break unit root tests identify a structural break point during the process of the unit root test. <Table 2.2> summarizes break points selected by three endogenous structural break unit root tests for the 5 macroeconomic variables of South Korea analyzed in this paper.

At first, <Table 2.3> shows the result of the Perron-Yabu test, the pre-test for the KP test to determine the existence of a structural break and identify the point of the structural break point. The null hypothesis that there exists no structural break is rejected for all 5 macroeconomic variables of South Korea. Considering the fact that the Perron-Yabu test is valid regardless of the stationarity of the variable (Perron and Yabu, 2009), this result implies that every macroeconomic variable analyzed in this paper has the significant structural break.

---

[16] In the exemplary empirical application of the KP test, Kim and Perron (2009) mention as follows: "Given the nature of these series, we considered the AO version of the test…" and "Given the gradual nature of the change in the trend, we used Model I3…"

<Table 2.2> Summary of structural break point identification

Variable	ZA test	LM test	KP test (Model A3)	KP test (Model I3)
GDP	1997 2Q	1994 4Q	1997 3Q	1997 4Q
investment	1997 3Q	1997 4Q	1997 4Q	1997 2Q
inflation rate	1994 4Q	1998 1Q	1998 1Q	1997 3Q
exchange rate	1997 3Q	1997 4Q	1997 3Q	1997 3Q
interest rate	1999 1Q	1998 3Q	1998 3Q	1997 4Q

Note: ZA test, LM test, and KP test represent the Zivot and Andrews (1992) test, the Lee and Strazicich (2004) test, and the Kim and Perron (2009) test respectively.

<Table 2.3> Result of the Perron and Yabu test (Pre-test for the KP test)

Variable	Break point identified (T_B)	Test statistic
GDP	1997 3Q	19.94 ***
investment	1997 4Q	13.08 ***
inflation rate	1998 1Q	4.51 **
exchange rate	1997 3Q	11.31 ***
interest rate	1998 3Q	9.32 ***

Note: (1) The test is based on a model that allows for both a shift in intercept and a change in trend slope; (2) The lag length is chosen based on the Akaike Information Criterion; (3) *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level.

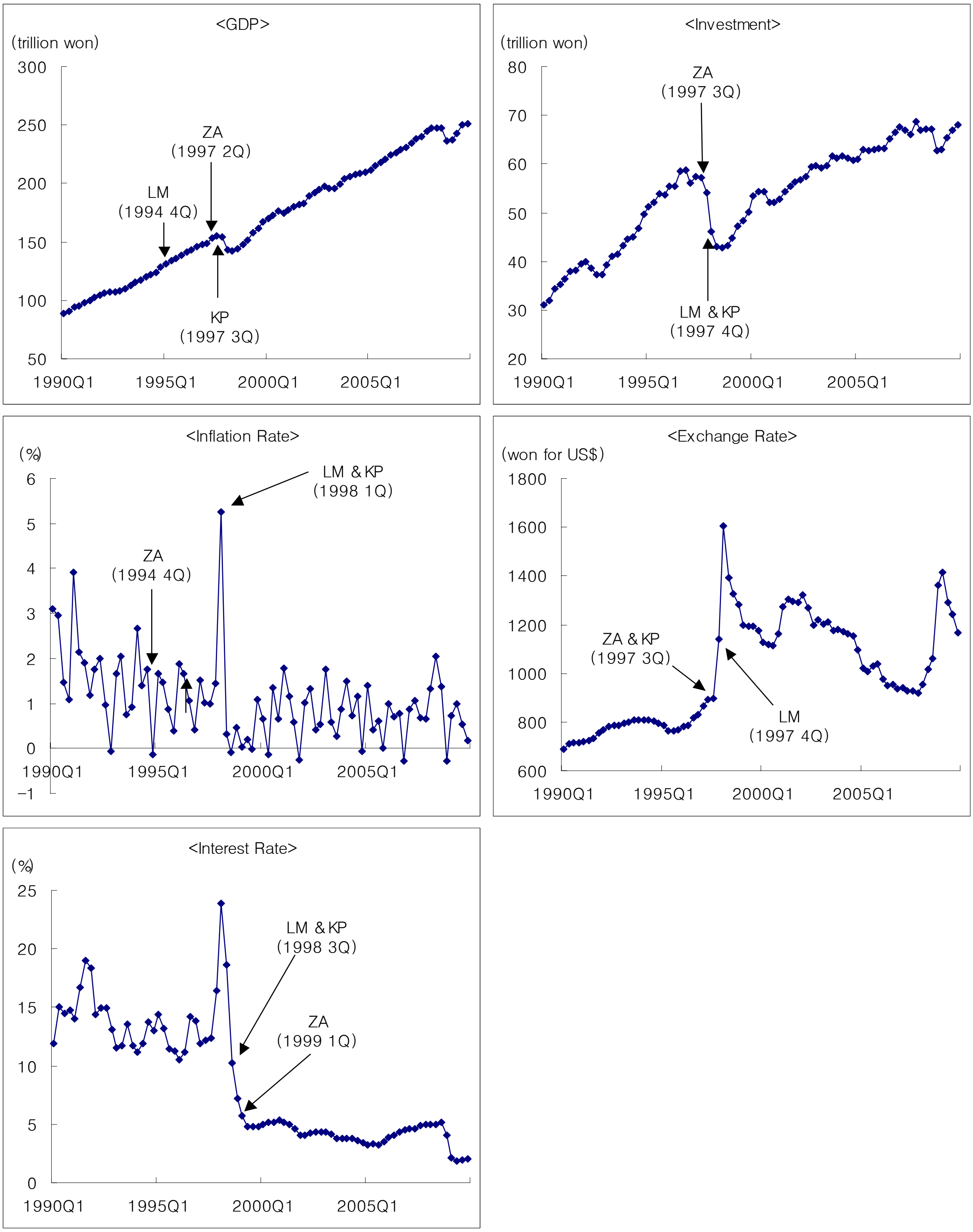
Regarding the point of the structural break, the structural break point identified by the KP test may change depending on whether we assume the A3 model or the I3 model. However, the empirical result of this paper shows that every structural break point identified by the A3 model is the same as the structural break point identified by the Perron-Yabu test. More interestingly, it turns out that all of these structural break points fall into the Asian financial crisis period ranging from 1997 to 1998. Considering the fact that the break point estimate identified by the KP test is consistent (Perron and Zhu, 2005), this result implies that the Asian financial crisis is a strong candidate for the structural break of major macroeconomic variables of South Korea.

This implication from the structural break point identification by the KP test (or the Perron and Yabu test) seems to be supported by the real time-series data. As shown in <Figure 2.2>, the structural break point chosen by the KP test seems to correspond well to the most prominent fluctuation in each macroeconomic variable of South Korea for the last 20 years, which also coincide with the Asian financial crisis in the late 1990s. In fact, the annualized growth rate of GDP from the previous quarter dropped from 12.1% in 1997 2Q to -25.1% in 1998 1Q. While bankruptcies of conglomerates such as Hanbo (ranking 14th, January 1997), Jinro (ranking 19th, April 1997), Kia (ranking 8th, July 1997) and others continued, loan withdrawal of domestic financial institutions, caused by credit crunch in the international financial market, aggravated financial risk of most Korean companies. The increase of risk aversion resulted in the decrease of corporate investment and the annualized growth rate of investment from the previous quarter dropped by -47.3% in 1998 1Q. This shrink of investment reduced the long-run growth potential of Korean economy (Hong et al., 2004). The average annual GDP growth rate dropped from 8% in the pre-crisis period to 4% in the post-crisis period excluding high growth rates right after the crisis caused by the base effect. Due to sudden the foreign currency outflow and the decrease of international reserves, the Korean won, the domestic currency of South Korea, depreciated by 40.8% in 1998 1Q from the previous quarter, causing the growth rate of CPI from the previous quarter to climb up to 5.3% in 1998 1Q. Under the structural adjustment program of IMF starting from December 1997, the monetary authority of South Korea raised its policy interest rate to depress foreign currency outflows and increase international reserves. The call rate between financial intermediaries increased by 7.5%p in 1998

1Q. During this turmoil, the monetary authority of South Korea changed its monetary policy framework from monetary targeting to inflation targeting at the end of 1997.

For many variables, structural break points identified by the LM test and the ZA test turn out to be identical or very close to the structural break point identified by the KP test. However, for some variables, the LM test and the ZA test suggest a point that is far from the structural break point chosen by the KP test. In the case of GDP, the KP test chooses 1997 3Q and the ZA test chooses 1997 2Q, but the LM test chooses 1994 4Q as the structural break point. In the case of the inflation rate, the KP test and the LM test choose 1998 1Q, but the ZA test chooses 1994 4Q as the structural break point. As shown in <Figure 2.2>, 1994 4Q does not seemingly look like the most significant break in the level and/or the slope of both GDP and the inflation rate.

<Figure 2.2> Break points identified by endogenous structural break unit root tests



Note: ZA, LM, and KP represent the break points identified by the Zivot and Andrews (1992) test, the Lee and Strazicich (2004) test, and the Kim and Perron (2009) test, respectively. The structural break point of the KP test is the structural break point identified by the Perron and Yabu (2009) test, the pre-test to determine the existence of a structural break and identify the point of the structural break point.

These unlikely structural break points suggested by the LM test and the ZA test seem to demonstrate the shortcoming of these two endogenous structural break unit root tests in the identification of a structural break. As pointed out before, the probability for the LM test to identify a true break point is relatively low if the variable is nonstationary (Lee and Strazicich, 2004). It is also revealed that the ZA test tends to suggest an incorrect break point like the one at one-period prior to the true one (Lee and Strazicich, 2001). [17] It is notable that the break point chosen by the ZA test is one-period prior to the break point chosen by the KP test in the case of GDP and investment. Therefore, considering these drawbacks of the LM test and the ZA test in the identification of a structural break, it seems that the structural break point identified by the KP test (or the Perron and Yabu test) is the most reliable one.

Unit root test results

At first, <Table 2.4> shows the unit root test result of the Ng-Perron test, the ADF-type unit root test that does not allow for a structural break. It fails to reject the unit root null hypothesis for all 5 macroeconomic variables of South Korea based on both test statistics MZ_a and test statistic MZ_t. This means that, when we do not consider a break in the level and/or the slope of a variable in the unit root test, the Ng-Perron test implies that the macroeconomic variables of South Korea are nonstationary.

[17] Harvey et al. (2001) recommends the method of moving the estimated break point of the ZA test one-period forward to get the more reliable estimate of a true break point.

<Table 2.4> Unit root test result of the Ng-Perron test

Variable	Test statistic MZa		Test statistic MZt	
	Lag length	Test statistic	Lag length	Test statistic
GDP	1	-7.64	1	-1.79
investment	1	-9.90	1	-2.18
inflation rate	3	-0.85	3	-0.65
exchange rate	2	-8.11	2	-2.00
interest rate	2	-13.37	2	-2.56

Note: (1) gross domestic product (GDP: national currency, billion won, real, seasonally adjusted), gross fixed capital formation (investment: national currency, billion won, real, seasonally adjusted), inflation rate (change rate of consumer price index from the previous quarter), exchange rate (nominal, national currency for US$, average of quarter) and interest rate (nominal, money market rate, average of quarter); (2) Data obtained from the Bank of Korea (http://ecos.bok.or.kr/); (3) For all variables, the level data is used with the exception that GDP, investment and exchange rate are in the natural log form; (4) data range: 1990 1Q ~ 2009 4Q; (5) Both intercept and time trend are included in the test equation; (6) The lag length is chosen based on the Modified Akaike Information Criterion; (7) *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level.

As shown in <Table 2.5>, the ZA test rejects the unit root null hypothesis for 4 of 5 macroeconomic variables of South Korea. The unit root test t-statistic of the ZA test is greater than the critical value at the 1% significance level for variables other than GDP. However, we need to be more careful in the interpretation of this result. As mentioned before, the rejection of the null hypothesis of the ZA test implies that the series tested is "nonstationary with a break" or "stationary (with or without a break)" since the null hypothesis of the ZA test is that a series is nonstationary without a break. In particular, Nunes et al. (1997) prove that the unit root test statistic of the ZA test diverges and this increase in the absolute value of the test statistic may lead to the incorrect rejection of the unit root null hypothesis (spurious rejection). Moreover, Lee and Strazicich (2001) show that the probability of this spurious rejection increases as the magnitude of a break increases (size distortion) and an incorrect break point is identified. Based on the structural break point identification result of this paper, macroeconomic variables of South Korea for the last 20 years seem to have an evident and strong candidate for the structural break. In addition, the ZA test seems to identify the unlikely break point for some variables like the inflation rate. Thus, it seems that the unit root test result of the ZA test is not free from the spurious rejection problem and it may be misleading to conclude that the variables such as investment, the inflation rate, the exchange rate and the interest rate become stationary after the consideration of a structural break, solely based on the rejection of the unit root null hypothesis in the ZA test.

<Table 2.5> Unit root test result of the ZA test

Variable	Lag length (k)	Break point identified (T_B)	Test statistic
GDP	1	1997 2Q	-3.72
investment	5	1997 3Q	-6.31 ***
inflation rate	1	1994 4Q	-7.67 ***
exchange rate	3	1997 3Q	-5.65 ***
interest rate	1	1999 1Q	-6.04 ***

Note: (1) The unit root test is based on a structural break model that allows for both a shift in intercept and a change in trend slope; (2) In the ZA test, the lag length is determined by a "general to specific procedure" proposed by Ng and Perron (1995); (3) *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level; (4) The critical value at the 1% significance level, the 5% significance level, and the 10% significance level are -5.57, -5.08, and -4.82, respectively.

Meanwhile, <Table 2.6> presents the unit root test result of the LM test. The LM test rejects the unit root null hypothesis for the inflation rate and the interest rate. Based on the advantages and disadvantages of the LM test mentioned before, it is proved that, when a variable is stationary, the power of the LM test decreases as the magnitude of a break increases. This means that the probability for the LM test to correctly reject the unit root null hypothesis is not high when the magnitude of a break is sizable. This implies that, when a variable is in fact stationary and there exists a significant structural break, the LM test may fail to reject a false unit root null hypothesis. Thus, it may be misleading to conclude that the variables such as GDP, investment and the exchange rate are nonstationary even after the consideration of a structural break solely based on the non-rejection of the unit root null hypothesis in the LM test.

<Table 2.6> Unit root test result of the LM test

Variable	Lag length (*k*)	Break point identified (T_B)	Test statistic
GDP	1	1994 4Q	-3.52
investment	3	1997 4Q	-3.70
inflation rate	7	1998 1Q	-4.82 **
exchange rate	3	1997 4Q	-3.48
interest rate	1	1998 3Q	-5.84 ***

Note: (1) The unit root test is based on a structural break model that allows for both a shift in intercept and a change in trend slope; (2) In the LM test, the lag length is determined by a "general to specific procedure" proposed by Ng and Perron (1995; (3) *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level; (4) The critical value in the LM test depends on the total number of sample (T) and the break fraction (T_B/T). Regarding the specific critical values of the LM test, refer to Lee and Strazicich (2004).

Lastly, the unit root test result of the KP test is given in <Table 2.7>. Compared with other endogenous structural break unit root tests, it is proved that the KP test has the most desirable properties such as invariance to break parameters, high power of the test with the correct size and consistent structural break point identification. As shown in <Table 2.3>, the Perron-Yabu test supports that there exists a structural break for all 5 macroeconomic variables of South Korea. This result of the pre-test implies that structural break unit root tests like the KP test are more appropriate rather than the ADF-type unit root tests that do not consider a structural break. Since the KP test assumes two kinds of data generating processes, i.e., the AO model and the IO model, and this paper adopts

Model C that allows for a change in both the level and the slope, the KP test in this paper uses the following 3 kinds of unit root test statistics for each variable: $t_\alpha(\hat{\lambda}^{AO})$ and $t_\alpha(\hat{\lambda}_{tr}^{AO})$ for the Model A3, $t_\alpha(\hat{\lambda}_{tr}^{IO})$ for the Model I3. For GDP and the exchange rate, all three test statistics fail to reject the unit root null hypothesis. For investment, the inflation rate and the interest rate, one or two test statistics reject the unit root null hypothesis, but the other test statistics fail to reject. As pointed out before, in this case when the unit root test results of multiple test statistics of the KP test are not consistent, it is difficult to make a definite decision regarding the stationarity of the variable. Thus, the unit root test result of the KP test suggests that GDP and the exchange rate are nonstationary while the stationarity of investment, the inflation rate and the interest rate is ambiguous.

<Table 2.7> Unit root test results of the KP test

Variables	Model used	Break point	Lag length	Statistic used	Test statistic
GDP	A3	1997 3Q	3	$t_{\alpha}(\hat{\lambda}^{AO})$	-3.79
				$t_{\alpha}(\hat{\lambda}_{tr}^{AO})$	-1.63
	I3	1997 4Q	3	$t_{\alpha}(\hat{\lambda}_{tr}^{IO})$	-3.29
investment	A3	1997 4Q	1	$t_{\alpha}(\hat{\lambda}^{AO})$	-1.99
				$t_{\alpha}(\hat{\lambda}_{tr}^{AO})$	-3.18
	I3	1997 2Q	3	$t_{\alpha}(\hat{\lambda}_{tr}^{IO})$	-5.53 ***
inflation rate	A3	1998 1Q	5	$t_{\alpha}(\hat{\lambda}^{AO})$	-3.70
				$t_{\alpha}(\hat{\lambda}_{tr}^{AO})$	-3.63 *
	I3	1997 3Q	2	$t_{\alpha}(\hat{\lambda}_{tr}^{IO})$	-7.62 ***
exchange rate	A3	1997 3Q	1	$t_{\alpha}(\hat{\lambda}^{AO})$	-2.97
				$t_{\alpha}(\hat{\lambda}_{tr}^{AO})$	-2.09
	I3	1997 3Q	5	$t_{\alpha}(\hat{\lambda}_{tr}^{IO})$	-3.52
interest rate	A3	1998 3Q	4	$t_{\alpha}(\hat{\lambda}^{AO})$	-3.06
				$t_{\alpha}(\hat{\lambda}_{tr}^{AO})$	-1.90
	I3	1997 4Q	6	$t_{\alpha}(\hat{\lambda}_{tr}^{IO})$	-6.85 ***

Note: (1) The unit root test is based on a structural break model that allows for both a shift in intercept and a change in trend slope; (2) Model "A3" and "I3" represent "Model AO-C" and "Model IO-C" of Perron (1989) respectively; (3) The lag length is determined by the (Modified) Akaike Information Criterion; (4) The KP test selects the estimate of the break fraction (λ^{AO} and λ^{IO}) by minimizing the sum of squared residuals from the appropriate regression equation; (5) For the Model A3, the KP test uses two unit root test statistics based on whether the estimate of the break fraction (λ^{AO}) or the estimate of the break fraction using a trimmed data (λ_{tr}^{AO}). For the Model I3, the KP test uses the root test statistic based on the estimate of the break fraction using a trimmed data (λ_{tr}^{IO}); (6) *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level; (7) The critical value in the KP test depends on the total number of samples (T) and the break fraction (T_B/T). Regarding the specific critical values of the KP test, refer to Kim and Perron (2009).

As summarized in <Table 2.8>, the empirical results of this paper show that whether and how we consider a structural break in the unit root test may change the unit root test result of major macroeconomic variables of South Korea. When we ignore the existence of a structural break, all 5 macroeconomic variables analyzed in this paper are nonstationary based on the Ng-Perron test. Even though the ZA test suggests that 4 of 5 variables become stationary and the LM test suggests that 3 of 5 variables remain nonstationary after the consideration of a structural break, we need to be more careful in the interpretation of these unit root test results because of the spurious rejection of the ZA test and the low power of the LM test. Based on the KP test with the most desirable properties, GDP and the exchange rate are still nonstationary even after the consideration of a structural break, whereas the stationarity of the other variables is unclear due to the inconsistency in unit root test results of multiple test statistics.

<Table 2.8> Summary of unit root test results

Variable	Ng-Perron test	ZA test	LM test	KP test
GDP	nonstationary	nonstationary	nonstationary	nonstationary
investment	nonstationary	stationary	nonstationary	ambiguous
inflation rate	nonstationary	stationary	stationary	ambiguous
exchange rate	nonstationary	stationary	nonstationary	nonstationary
interest rate	nonstationary	stationary	stationary	ambiguous

Note: (1) "Nonstationary" means that the unit root null hypothesis is not rejected while "stationary" means that the unit root null hypothesis is rejected at least the 10% significance level; (2) In the KP test, "ambiguous" means that at least one of three test statistics reject the unit root null hypothesis but the other test statistics fail to reject.

4. Conclusion

The empirical results of this paper analyzing 5 major macroeconomic variables of South Korea for the last 20 years suggest the following important implications.

First, the Perron-Yabu test, the pre-test for the KP test, to check the existence of a structural break suggests that there exists a structural break for all 5 macroeconomic variables of South Korea. Considering the fact that the Perron-Yabu test is valid regardless of whether a variable is stationary or nonstationary, this result implies that, to determine the stationarity of a variable, it is more appropriate to apply the endogenous structural break unit root test instead of the ADF-type unit root test that do not allow for a structural break.

Second, the Asian financial crisis in the late 1990s seems to be the most significant structural break of most macroeconomic variables of South Korea for the last 20 years. Even though this is the result from the univariate analysis, this may provide useful and practical intuition for the multivariate analysis of the South Korean economy. If the Asian financial crisis is identified as the structural break even in the multivariate analysis, then we may consider dividing the sample period into two sup-sample periods of before and after the Asian financial crisis, and comparing the interrelationship between macroeconomic variables before and after the Asian financial crisis.

Third, the structural break point identification and the unit root test result may change substantially depending on the choice of endogenous structural break unit root test. Thus, to find a structural break point more correctly and determine the stationarity of a variable more precisely, it is essential to understand characteristics of the endogenous structural break unit root test used. Compared with the ZA test and the LM test, the KP test seems to provide the most reliable structural break point and root test result. In particular, this paper points out that the LM test has important weak points such as the low probability to identify a true break point when a variable is nonstationary and the low power of the test when a variable is stationary.

Four, even though the KP test has the most desirable properties as the endogenous structural break unit root test, the unit root test result of this paper demonstrates the practical problem in the application of the KP test. That is the fact that there is no clear decision rule in the case when unit root test results of multiple test statistics of the KP test are not consistent. Thus, for the KP test to be more applicable, further study is required to answer the following questions: between the AO model and the IO model, which data-generating process is more appropriate for a variable? In the case when the AO model is chosen, which test statistic is more reliable among the test statistic based on the original data and the test statistic based on the trimmed data? This may be the reasonable next research issue.

CHAPTER III

THE EFFECT OF NET EXTERNAL CREDIT AND FINANCIAL INTEGRATION ON THE RESPONSE TO FOREIGN INTEREST RATE SHOCKS: BEFORE AND AFTER THE STRUCTURAL BREAK OF SOUTH KOREA

3.1. Introduction

In the macroeconomic analysis about a small open economy, how foreign financial shocks affect the small open economy has been studied in many research papers. In particular, Demirel (2009) finds that the effect of financial integration on the responsiveness of a small open economy to foreign interest rate shocks changes depending on the size of external debt. Using Turkey data, he shows that financial integration alleviates macroeconomic volatility under higher levels of external debt, but amplifies macroeconomic volatility under lower levels of external debt.

Then, how will responses of macroeconomic variables of a small open economy to foreign interest rate shocks change if the small open economy has sizable net external credit instead of net external debt? How will responses of the small open economy to foreign interest rate shocks change depending on the level of financial integration? This paper answers these questions.

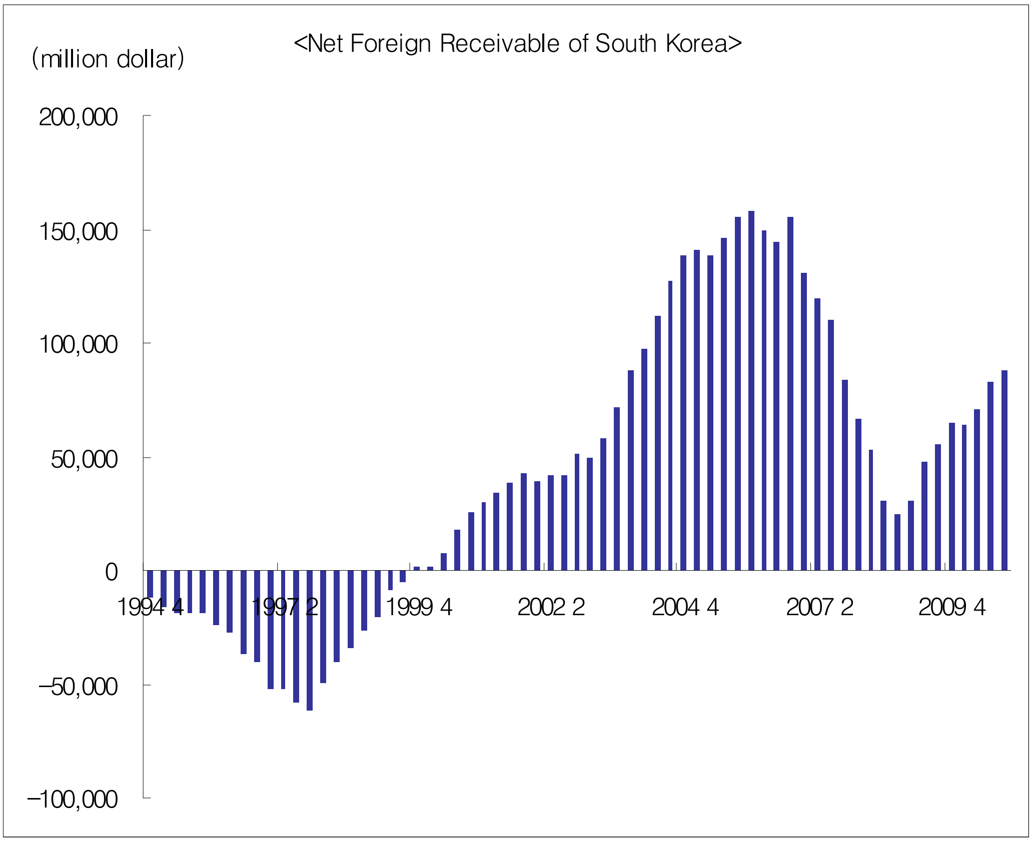
To answer these questions, this paper analyzes 6 domestic macroeconomic variables of South Korea (GDP, consumption, investment, inflation rate, the interest rate and the exchange rate) and the foreign interest rate (US 3-month treasury bills rate) for the last 30 years. These 6 domestic variables are usually used in many macroeconomic papers to reflect the overall situation of a small open economy. I believe that the Korean economy during this period is an appropriate case for my research questions because of the following characteristics.

First, the Korean economy has a strong candidate for the economic structural break, that is, the Asian financial crisis in the late 1990s. There have been many studies that conclude that the Asian financial crisis substantially changed the Korean economy in many aspects (Hong et al., 2004; Kim et al., 2006; Aizenman et al., 2007; Lee and Rhee, 2007; Kang and Sawada, 2008; Ra, 2008; Ang, 2010). Particularly, after experiencing a severe credit crunch and painful restructuring, most South Korea companies became much more risk-averse, and corporate investment substantially decreased, which is believed to have reduce the long-run economic growth potential of South Korea.

Second, South Korea's financial openness and integration with global financial market was substantially progressed through the Asian financial crisis. After the joining the OECD (Organization for Economic Cooperation and Development) at the end of 1996, the limit on daily exchange rate change was removed at the end of 1997. Foreigners' investment into the Korean stock/bond market and the real asset market was fully liberalized in April 1998 and June 1998, respectively. The long-term borrowing and bond issuance of Korean companies in foreign capital market was also liberalized in July 1998.

Third, even though South Korea had been a net debtor in the international capital market before the Asian financial crisis, South Korea became a net creditor with a sizable amount of net foreign credit right after the Asian financial crisis. As shown in <Figure 3.1>, South Korea had net external debt of 61 billion dollars in the end of 1997, but South Korea had net external credit of 138 billion dollars in the end of 2004.

<Figure 3.1> The net external credit (debt) position of South Korea



Note: Each bar represents net foreign receivable, which is calculated by foreign receivable minus foreign debt. Thus, negative value means that South Korea is net debtor in the international capital market, and positive value means that South Korea is net creditor in international capital market. The data used are obtained from the Bank of Korea (http://ecos.bok.or.kr/).

Therefore, by comparing the Korean economy before and after the Asian financial crisis, it is expected that we may investigate the effect of enhanced financial integration and the change in the external debt position on the interrelationship between macroeconomic variables.

Methodologically, this paper identifies the structural break point of the Korean economy by applying the following two structural break tests: the Perron and Yabu test (Perron and Yabu, 2009) as a univariate test method and the Quandt-Andrews test (Andrews, 1993; Andrews 1994; Hansen, 1997) as a multivariate test method. Based on these two structural break tests, the peak period of the Asian financial crisis in the late 1990s is identified as the most probable structural break of the Korean economy for the last 30 years. Considering this result, I split the total sample period (1980 1Q ~ 2010 4Q) into the following two sub-sample periods: the pre-break period (1980 1Q ~ 1997 2Q) and the post-break period (1998 3Q ~ 2010 4Q).

Even though all 7 variables in both sub-sample periods turn out to be nonstationary based on the Ng and Perron unit root test (Ng and Perron, 2001), I find that there exists at least 1 cointegration equation in both sub-sample periods by applying the Johansen cointegration test (Johansen, 1988; Johansen 1995). In addition to this, since this paper analyzes level data without differencing or filtering, I use the VAR (vector auto regression) model that estimates the coefficients in equations by the OLS (ordinary least squares) method to investigate the interrelationship between variables. According to Sims, Stock and Watson (1990), as long as the model is correctly specified, the OLS estimator is consistent regardless of the stationarity of variables. Moreover, they prove that, if the cointegrated VAR model is estimated on the untransformed data, common hypothesis tests of linear restrictions are valid.

Empirical result of this paper shows that there is a substantial difference in responses of domestic macroeconomic variables of South Korea to foreign interest rate shocks between the pre-break period and the post-break period. Foreign interest rate hikes cause real contraction, the fall of the domestic interest rate and the rise of the exchange rate before the Asian financial crisis. However, foreign interest rate hikes cause real expansion, the rise of the domestic interest rate and the fall of the exchange rate after the Asian financial crisis. It is also revealed that foreign interest rate shocks explain a higher proportion of variation in the interest rate, the exchange rate and consumption of South Korea after the Asian financial crisis.

Regarding the effect of financial integration of a small open economy, the empirical result of this paper implies that, as the enhanced financial integration causes co-movement between the foreign interest rate and the domestic interest rate, the interest rate channel becomes more important in the transmission of foreign interest rate shocks. Regarding the effect of net external credit of a small open economy, the Korean economy after the Asian financial crisis shows that, in the case of foreign interest rate hike shocks, the positive wealth effect from net external credit may outweigh the negative portfolio reallocation effect and the negative intertemporal substitution effect, which results in real expansion.

The rest of this paper is organized as follows. Section 3.2 introduces related theories and previous research papers. Section 3.3 explains methodology adopted in this paper such as variables and data, the structural break identification and sub-sample groups, the VAR model specification and the ordering for the Cholesky decomposition. Section 3.4 provides the empirical results such as the impulse response function analysis and the forecast error variance decomposition analysis. Finally, section 3.5 offers concluding remarks.

3.2. Related theories and previous research papers

The following two theoretical models provide the basic framework to explain the mechanism by which U.S. monetary policy shocks, which are represented by foreign interest rate shocks, are transmitted to a foreign small open economy: the traditional Mundell–Flemming–Dornbusch (MFD) model and the intertemporal model.

The MFD model predicts that U.S. monetary tightening causes appreciation of the U.S. dollar and improvement of the U.S. terms of trade, which deteriorates the U.S. balance of trade as a result of the expenditure-switching effect. In this way, U.S. monetary tightening may improve the balance of trade of a foreign small open economy that trades with U.S., which increases the output of the small open economy.

On the other hand, the MFD model also expects that U.S. monetary tightening decreases U.S. domestic income as well as U.S. demand for imported goods, which improves the U.S. balance of trade as a result of the income absorption effect. In this way, U.S. monetary tightening may worsen the balance of trade of a foreign small open economy that trades with U.S., which decreases the output of the small open economy.

In contrast, the intertemporal model emphasizes the forward-looking intertemporal decision behavior of economic agents, providing a different framework (Svensson and Van Wijnbergen, 1989; Obstfeld and Rogoff, 1995). The intertemporal model predicts that U.S. monetary tightening decreases the income of U.S. households, but the decrease of U.S. consumption may be smaller than the decrease of U.S. income due to consumption smoothing, which decreases U.S. savings. In this case, if U.S. investment decreases substantially, responding to the rise of the U.S. interest rate, this may offset the decrease of U.S. savings, and the U.S. balance of trade does not worsen. However, if U.S. investment does not decrease enough, the decrease of U.S. savings worsens the U.S. balance of trade. In this way, U.S. monetary tightening may improve the balance of trade of a foreign small open economy that trades with U.S., which increases the output of the small open economy.

On the other hand, the intertemporal model also expects that U.S. monetary tightening raises the international interest rate, which decreases the world demand for consumption and investment in both the U.S. and non-U.S. countries. As a result, both exports and imports of both the U.S. and non-U.S. countries may decrease at the same time. In this case, depending on the extent to which the exports and imports of a small open economy decrease, the balance of trade and output of the small open economy may either increase or decrease.

Empirical results of previous studies regarding the effect of U.S. monetary policy shocks are not consistent. Kim (2001) analyzes the effect on non-U.S. G-7 countries by applying a structural VAR model, and concludes that the spillover effects of U.S. monetary policy shocks on developed countries do not seem to be sizable. Mackowiak (2007) finds that external shocks play an important role in macroeconomic fluctuations of emerging countries, including East Asian countries, but U.S. monetary policy shocks are not important relative to other kinds of external shocks. However, he points out that U.S. monetary shocks affect the domestic interest rate and the exchange rate of a small open economy quickly and strongly. On the contrary, Canova (2005) finds that, in macroeconomic fluctuations of Latin America countries, U.S. monetary policy shocks are more important than other U.S. shocks like supply shocks or real demand shocks.

Regarding channels through which U.S. monetary policy shocks are transmitted, Canova (2005) finds that the financial market, especially the interest rate channel, plays a more important role than the balance of trade in the transmission of U.S. monetary shocks. On the other hand, Uribe and Yue (2006) show that the country-spread, the spread that emerging countries face in the international capital market, is important in the transmission of foreign interest rate shocks. Demirel (2009) analyzes following 3 transmission channels through which foreign interest rate shocks are transmitted to a small open economy: the portfolio reallocation effect, the intertemporal substitution effect and the wealth effect. For example, foreign interest rate hikes increase the opportunity cost of domestic investment of a small open country, which causes the reallocation of resources from domestic investment to foreign investment (the portfolio reallocation effect). Moreover, the higher level of the foreign interest rate also raises the opportunity cost of current consumption of the small open economy, which reduces current consumption and increases current savings, in other words, future consumption (the intertemporal substitution effect). If the small open economy has net external debt, foreign interest rate hikes increase interest payments for the external debt, which decreases aggregate demand (the wealth effect). As a result, foreign interest rate hike shocks cause real contraction.

In this context, there has been much research regarding the effect of financial integration on the transmission of U.S. monetary policy shocks. Heathcote and Perri (2002) show that enhanced financial openness reduces the volatility of macroeconomic variables. They consider the financial autarky model, an economy in which there is no market for international asset trade, and compare this financial autarky model with other two models: an economy that has only one bond and an economy that has complete asset markets. They find that, when households cannot borrow and lend internationally, productivity shocks generate higher volatility in the terms of trade. Canova (2005) mentions that the importance of the financial market channel depends on the level of financial integration. He also finds that, even though there are differences in the timing and magnitude of responses between countries with a floating exchange rate and countries with a non-floating exchange rate, the transmission mechanism and pattern of propagation is similar between two groups. Buch et al. (2005) prove that the relationship between financial openness and business cycle volatility has been unstable over time. Their empirical result indicates that the impact of the interest rate is increased while the impact of government spending is reduced.

Lastly, Demirel (2009) analyzes the effect of external debt of a small open economy on impulse responses to foreign interest rate shocks. He shows that financial integration under bigger external debt mutes real contraction while financial integration under smaller external debt magnifies real contraction. As mentioned above, foreign interest rate hike shocks cause real contraction due to the portfolio reallocation effect, the intertemporal substitution effect and the negative wealth effect. In this case, the enhanced financial integration enables households to smooth consumption more effectively by lowering the portfolio adjustment cost. On the other hand, the enhanced financial integration strengthens the portfolio reallocation effect and intertemporal substitution effect. Thus, in higher levels of external debt, enhanced financial integration may mitigate the real contraction by substantial consumption smoothing. However, in lower levels of external debt, enhanced financial integration may intensify real contraction by the dominant portfolio reallocation effect and intertemporal substitution effect.

3.3. Methodology

Variables and data

This paper investigates the Korean economy for the last 30 years ranging from 1980 1Q to 2010 4Q. I analyze the interrelationship between the foreign interest rate (US 3-month treasury bills rate, nominal, average of quarter) and the following 6 domestic macroeconomic variables of South Korea: GDP (national currency, billion won, real, seasonally adjusted), consumption (national currency, billion won, real, seasonally adjusted), investment (gross fixed capital formation, national currency, billion won, real, seasonally adjusted), the inflation rate (consumer price index basis, percent change from the previous quarter), the exchange rate (nominal, national currency for US$, average of quarter) and the interest rate (nominal, money market rate, average of quarter).

These 6 domestic variables are usually used in many macroeconomic papers as the most relevant indicators of a small open economy. Demirel (2009) analyzes the 5 domestic macroeconomic variables of Turkey, excluding consumption.[18] These quarterly data are obtained from the IFS database and the Bank of Korea (http://ecos.bok.or.kr/). For all variables, I use the level data without differencing or filtering with the exception that GDP, consumption, investment, and exchange rate are in the natural log form.

Structural break identification and sub-sample groups

When the interrelationship between macroeconomic variables is not stable, it may be more appropriate to find a structural break point, and to split a total sample period into a pre-break period and a post-break period, and to compare the change in the interrelationship between macroeconomic variables. If we ignore the instability of the interrelationship between variables and estimate coefficients of economic system equations using the total sample period, the result may be incorrect and misleading.

To identify the most significant structural break point, in this paper I apply the Perron and Yabu test (Perron and Yabu, 2009) to 6 univariate domestic macroeconomic time-series variables. In addition, I also apply the Quandt-Andrews test (Andrews, 1993; Andrews 1994; Hansen, 1997) to 6 multivariate autoregressive equations representing 6 domestic macroeconomic variables analyzed in this paper.

---

[18] Demirel (2009) uses the real exchange rate, but this paper uses the nominal exchange rate for the following reasons. First, the exchange rate we can see and use easily in our common life is not the real exchange rate but the nominal exchange rate. Thus, it seems that the result and implication regarding the nominal exchange rate may provide more practical information to us. Second, the Bank of Korea, which announces official exchange rate time series data, provides only the nominal exchange rate. Even though the IFS database provides the real effective exchange rate time series data of South Korea, it starts only from 1984 1Q. Third, I perform the same analysis applying the same methodology explained in this paper except that I use the real effective exchange rate instead of the nominal exchange rate. However, the overall result of the impulse response function analysis is not consistent with any theoretical model.
Demirel (2009) also includes the country interest rate of Turkey as an additional domestic macroeconomic variable. The country interest rate in his paper refers to the interest rate that a country faces in the international capital market. It is calculated as the summation of US treasury bills rate and the J.P. Morgan EMBI+ Turkey spread. This paper does not include the country interest rate since there exists no corresponding country interest rate of South Korea. J.P. Morgan does not announce the J.P. Morgan EMBI+ South Korea but rather only the J.P. Morgan EMBI+ Asia, which is too comprehensive as a spread to reflect the situation of South Korea.

The Perron and Yabu test determines whether a structural break exists or not in univariate time-series data and recommends the break point based on the quasi-GLS approach.[19] The most prominent advantage of this test is that its result is valid regardless of whether the univariate time-series data is stationary or nonstationary. I perform the Perron and Yabu test using the model that allows for a change in both the level and the slope of a univariate time-series data since this is the least restrictive model. I apply the trimming of the first 25% and the last 25% of the total observations.

The Quandt-Andrews test performs structural stability tests for a specified multivariate equation. This test executes the standard Wald test of the restriction that all coefficients of the equation are the same in all sub-samples, and the selected break date is the one that corresponds to the maximum (sup) Wald F-statistic computed under the restriction. I perform the Quandt-Andrews test using the VAR (4) specification in which each domestic macroeconomic variable is regressed by 6 domestic macroeconomic variables and foreign interest rate with 4-period lags. I determine this lag length based on the same VAR model specification process that is explained in the following section. I use the model that includes only a constant without a time-trend term, and I apply the trimming of the first 25% and the last 25% of the total observations.[20]

As shown in <Table 3.1>, both the Perron and Yabu test and the Quandt-Andrews test reject the null hypothesis that there exists no structural break in the trimmed data at the 1% significance level for all 6 domestic macroeconomic variables of South Korea. It is notable that the period ranging from 1997 3Q to 1998

[19] Kim and Perron (2009) use the Perron and Yabu test as a pre-test to check for the existence of a structural break in their endogenous structural break unit root test methodology.

[20] It has been proven that the distribution of the structural break test statistic becomes degenerate as the structural break point approaches the beginning or the end of the sample. To avoid this problem, it is generally suggested that some end points of the total observations not be included in the testing procedure. In the test for the stability of autoregressive parameters in the VAR system, Demirel (2009) applies the same trimming of the first 25% and the last 25% of the total observations.

2Q, the year that is usually referred to as the peak of the Asian financial crisis, is identified as the structural break point for 3 of 6 variables by the Perron and Yabu test and for 4 of 6 variables by the Quandt-Andrews test. Thus, two structural break tests suggest that the Asian financial crisis is the strongest candidate for the structural break of the Korean economy for the last 30 years.

<Table 3.1> Structural break test result and break points identified

Variable	Perron and Yabu test		Quandt-Andrews test	
	Test statistic	Break point	Test statistic	Break point
GDP	21.50 ***	1994 1Q	87.42 ***	1998 2Q
consumption	74.23 ***	1997 3Q	180.21 ***	1998 2Q
investment	12.16 ***	1997 3Q	91.45 ***	1996 1Q
inflation rate	14.19 ***	1987 3Q	97.92 ***	1989 2Q
exchange rate	17.90 ***	1997 3Q	145.77 ***	1997 4Q
interest rate	11.68 ***	1988 4Q	67.61 ***	1997 4Q

Note: *** represents significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level

Based on this structural break identification result, I choose the period ranging from 1980 1Q to 1997 2Q as the pre-break period, and the period ranging from 1998 3Q to 2010 4Q as the post-break period. As a robustness test, I perform the same following analysis using various selections of the pre-break period and the post-break period around the Asian financial crisis. Even though there are small differences in the magnitudes of responses, the overall direction of the impulse responses of domestic macroeconomic variables of South Korea to the foreign interest shock turn out to be similar to the results based on the above selection of sub-sample periods.

VAR model specification

As the first step for model specification, I check the stationarity of variables analyzed in this paper. I apply the Ng and Perron unit root test (Ng and Perron, 2001) to the pre-break period data and the post-break period data, respectively. Two test statistics of the Ng and Perron unit root test, MZa and MZt, are shown to have the better size and power properties when implemented according to Ng and Perron's recommended procedure. I include both intercept and time trend in the test equation and choose the lag length based on the Modified Akaike Information Criterion (AIC) lag selection criterion.

<Table 3.2> Ng and Perron unit root test result

Variable	Pre-break period		Post-break period	
	Test statistic MZa	Test statistic MZt	Test statistic MZa	Test statistic MZt
foreign interest rate	-13.57	-2.55	-10.17	-2.25
GDP	-4.01	-1.31	-2.59	-1.01
consumption	-3.81	-1.37	-5.68	-1.60
investment	-4.06	-1.40	-3.34	-1.21
inflation rate	-0.94	-0.60	-0.61	-0.54
exchange rate	-7.10	-1.88	-12.35	-2.47
interest rate	-3.48	-1.28	-2.80	-1.16

Note: *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, * represents the null is rejected at the 10% significance level.

As shown in <Table 3.2>, the Ng and Perron unit root test fails to reject the unit root null hypothesis in all 7 variables: the 6 domestic macroeconomic variables of South Korea and the foreign interest rate, for both MZa and MZt test statistics.

This implies that both the pre-break period data and the post-break period data consist of nonstationary variables.

Even though all variables in the system are nonstationary, this paper investigates the interrelationship between 6 domestic macroeconomic variables of South Korea and the foreign interest rate using the VAR model that estimates coefficients in equations based on the OLS method. According to Sims, Stock and Watson (1990), as long as the model is correctly specified, the OLS estimator is consistent regardless of whether the VAR contains a nonstationary variable or not. In addition, they also prove that, if the cointegrated VAR model is estimated on the original (untransformed) data, common hypothesis tests of linear restrictions performed in the VAR are valid. This implies that the OLS estimator of the VAR model would be consistent and other hypothesis test analyses provided by the VAR model would be valid if I specify the VAR model correctly and there exists any cointegration relationship between variables since this paper analyzes level data without differencing or filtering.

For the correct VAR model specification, I consider both the LR (likelihood ratio) test result and the correlogram for the residual series in determining adequate lag length. The LR test suggests 2-period lags and 4-period lags as the smallest lag length for the pre-break period and the post-break period respectively. In the estimation of the VAR model that uses these lag lengths, there exists no correlation coefficient that falls outside of the 2-standard deviation confidence band in the correlogram. Thus, I adopt 2-period lags for the pre-break period and 4-period lags for the post-break period.

As a result, the VAR model used in this paper has the following specification:

$$D_t = \alpha + \sum_{i=1}^{j} \beta_i V_{t-i} + \varepsilon_t$$

The 6×1 vector D_t contains the 6 domestic macroeconomic variables of South Korea at time t. The 6×1 vector α contains constants of 6 equations that correspond to 6 domestic macroeconomic variables of South Korea. The 6×7 matrix β_i denotes the coefficient matrix corresponding to V_{t-i}, where j=2 in the pre-break period and j=4 in the post-break period. The 7×1 vector V_t denotes $[fir_t, D_t]'$, where fir_t denotes the foreign interest rate of time t. The 6×1 vector ε_t contains 6 error terms that correspond to the 6 domestic macroeconomic variables of South Korea at time t, which is understood as a linear combination of orthogonal structural disturbances of V_t.

Based on this VAR model, I check if there exists a cointegration relationship between variables by applying the Johansen cointegration test (Johansen, 1988; Johansen 1995) to the pre-break period and to the post-break period, respectively. I adopt the model that includes both an intercept and a linear time trend in the equation for the level data and only an intercept in the cointegrating equation. Based on the lag length determined above, I include 1-period lags and 3-period lags of the first differenced terms in the cointegration test equation for the pre-break period and the post-break period, respectively. As shown in <Table 3.3>, the Johansen cointegration test suggests that there exists at least 1 cointegration equation in the pre-break period and 5 cointegration equations in the post-break period at the 5% significance level.

<Table 3.3> Johansen cointegration test result

<Pre-break period>

Trace test			Max-eigen value test		
Hypothesized No. of CE(s)	Eigen value	Trace Statistic	Hypothesized No. of CE(s)	Eigen value	Max-Eigen Statistic
None ***	0.530	148.47	None **	0.530	51.31
At most 1 **	0.401	97.16	1	0.401	34.86
At most 2	0.358	62.30	2	0.358	30.08
At most 3	0.157	32.22	3	0.157	11.62
At most 4	0.139	20.60	4	0.139	10.20
At most 5	0.126	10.40	5	0.126	9.14

<Post-break period>

Trace test			Max-eigen value test		
Hypothesized No. of CE(s)	Eigen value	Trace Statistic	Hypothesized No. of CE(s)	Eigen value	Max-Eigen Statistic
None ***	0.891	309.71	None ***	0.891	110.98
At most 1 ***	0.749	198.73	1 ***	0.749	69.15
At most 2 ***	0.646	129.58	2 ***	0.646	51.85
At most 3 ***	0.510	77.72	3 ***	0.510	35.67
At most 4 ***	0.443	42.05	4 ***	0.443	29.27
At most 5	0.201	12.78	5	0.201	11.20

Note: *** represents the null is rejected at the 1% significance level, ** represents the null is rejected at the 5% significance level, and * represents the null is rejected at the 10% significance level.

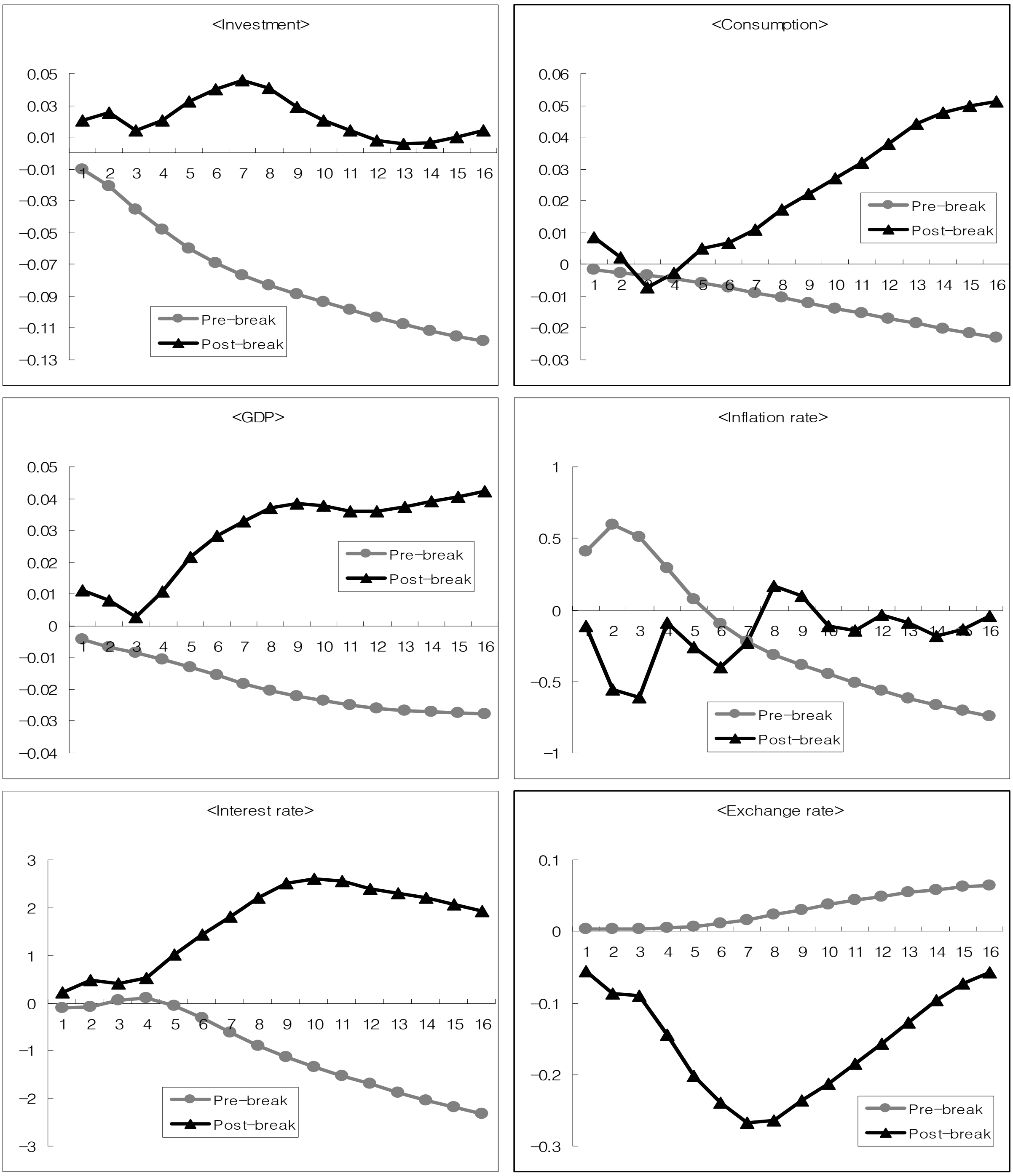
In the VAR model analysis, to identify the recursive structure of an economic model, parameters in the structural-form equations should be recovered from estimated parameters in the reduced-form equations. This paper imposes restrictions on contemporaneous parameters in the structural-form equations by applying Cholesky decomposition of the reduced-form residuals. In determining the order of variables, this paper applies the common rule of placing contemporaneously exogenous variables first. Since this paper analyzes small open economies, this paper allows for contemporaneous effects of the foreign interest rate on domestic macroeconomic variables of a small open economy, but rules out contemporaneous effects of domestic macroeconomic variables of a small open economy on the foreign interest rate. Thus, this paper puts the foreign interest rate before domestic macroeconomic variables of a small open economy in the ordering.

4. Empirical results

Impulse response function analysis

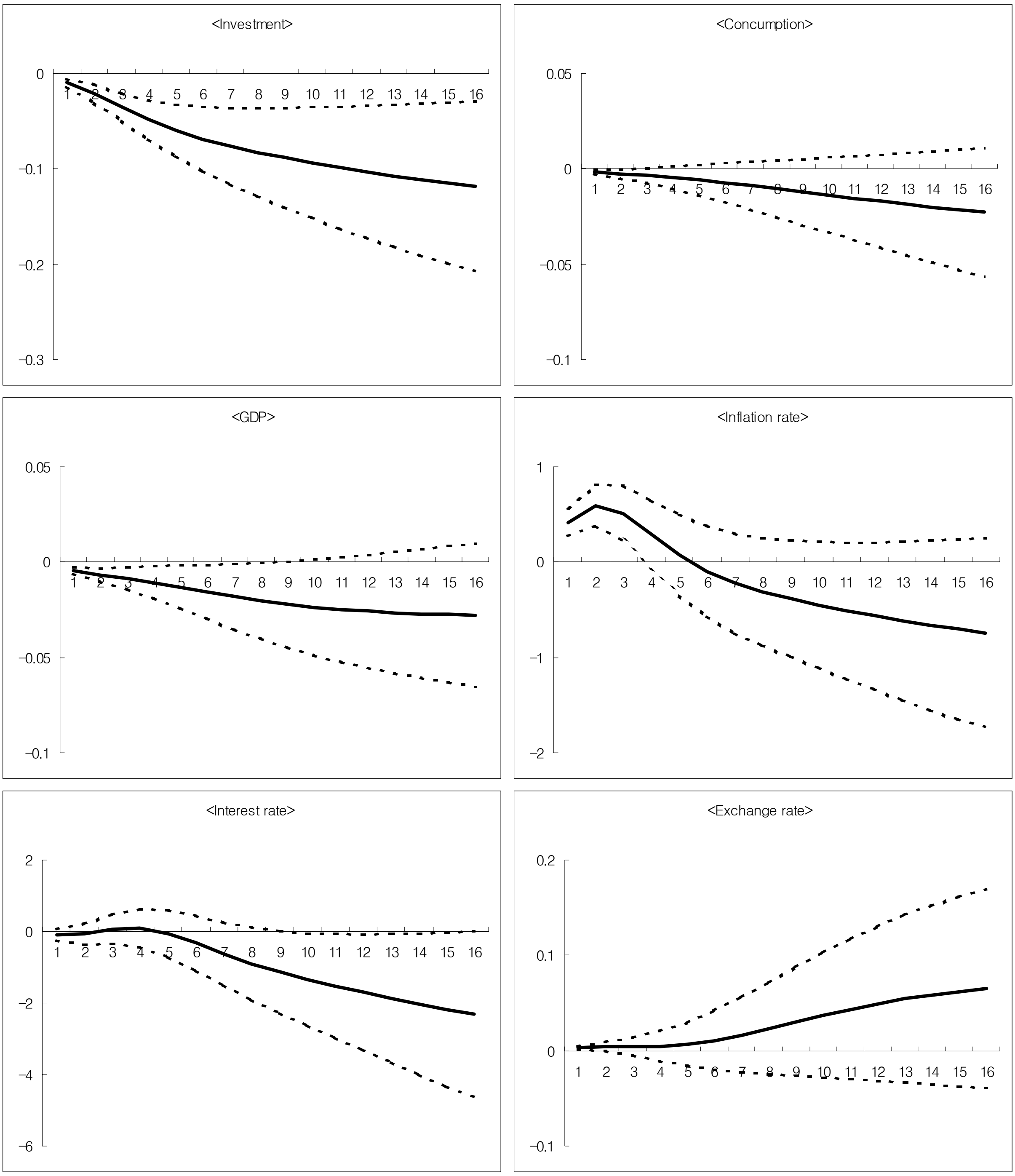
<Figure 3.2> through <Figure 3.4> present the accumulated impulse responses of 6 domestic macroeconomic variables of South Korea over 16 quarters (4 years) responding to the shock of a 1% point increase in the foreign interest rate. It is more general to provide impulse responses to 1-standard deviation shocks of a variable. However, in this paper, 1-standard deviation shock of the foreign interest rate is 0.81% point in the pre-break period and 0.31% point in the post-break period. Thus, if I present the impulse responses to 1-standard deviation shock of the foreign interest rate, impulse responses in each sub-sample period will represent impulse responses to different magnitudes of foreign interest rate shocks. For the convenient comparison between the pre-break period and the post-break period, I provide accumulated impulse responses responding to the shock of a 1% point increase of the foreign interest rate in this paper. <Figure 3.2> compares the accumulated impulse responses in the pre-break period and the accumulated impulses responses in the post-break period in the same graph. <Figure 3.3> and <Figure 3.4> show the accumulated impulse responses as a solid line and 1-standard deviation error bands as dashed lines in the pre-break period and the post-break period respectively.

<Figure 3.2> Accumulated impulse responses to foreign interest rate hike shocks



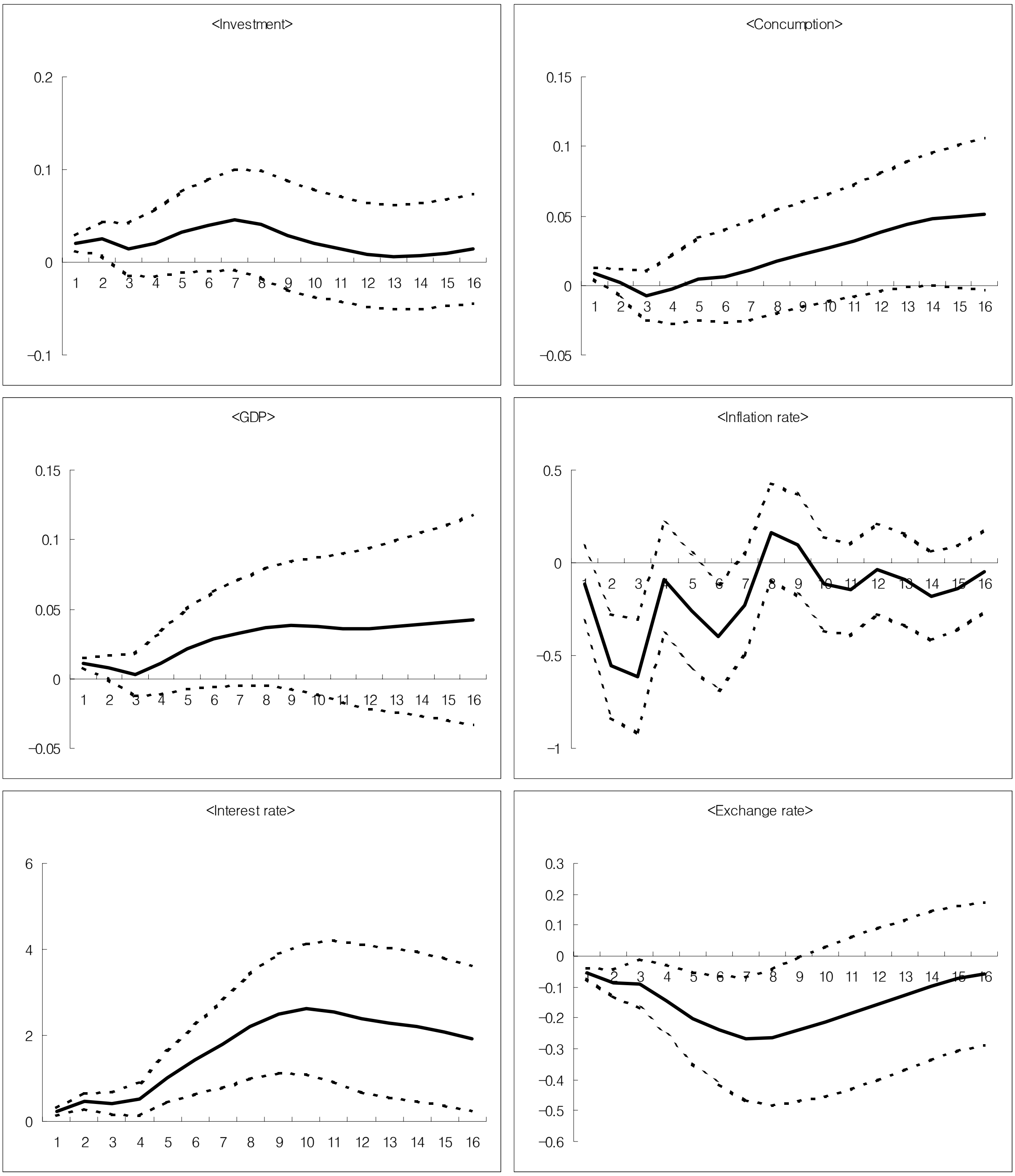
Note: (1) All variables are level data with the exception that GDP, consumption, investment and the exchange rate are in the natural log form; (2) Accumulated impulse responses to the shock of a 1% point increase of the foreign interest rate; (3) Horizontal line represents 16 quarters (4 years) from the shock.

<Figure 3.3> Accumulated impulse responses in the pre-break period



Note: (1) All variables are level data with the exception that GDP, consumption, investment and the exchange rate are in the natural log form; (2) Accumulated impulse responses to the shock of a 1% point increase of the foreign interest rate; (3) Dotted lines represents ±1-standard deviation error bands; (4) Horizontal line represents 16 quarters (4 years) from the shock.

<Figure 3.4> Accumulated impulse responses in the post-break period



Note: (1) All variables are level data with the exception that GDP, consumption, investment and the exchange rate are in the natural log form; (2) Accumulated impulse responses to the shock of a 1% point increase of the foreign interest rate; (3) Dotted lines represents ±1-standard deviation error bands; (4) Horizontal line represents 16 quarters (4 years) from the shock.

As shown in <Figure 3.2>, it is evident that there are substantial differences between the pre-break period and the post-break period in the responses of domestic variables of South Korea to foreign interest rate shocks. Before the Asian financial crisis, US treasury bill rate hikes cause real contraction (decrease of investment, consumption and GDP), the fall of the inflation rate (in spit of its rise in the short run), the fall of the domestic interest rate (in spit of its rise in the short run) and the rise of the exchange rate. In contrast after the Asian financial crisis, US treasury bill rate hikes cause real expansion (increase of investment, consumption and GDP), the fall of the inflation rate, the rise of the domestic interest rate and the fall of the exchange rate.[21]

Based on the theoretical model of Demirel (2009), it seems that the enhanced financial integration and the change in the external debt position of South Korea may explain these differences between the pre-break period and the post-break period. Thus one needs to remember the fact that the financial market openness of South Korea was substantially increased through the Asian financial crisis, and that South Korea dramatically changed from a net debtor to a net creditor in the international capital market right after the Asian financial crisis.

As shown in <Figure 3.3>, an empirical result of this paper implies that, when a small open economy is less integrated with the international financial market and has sizable net external debt like South Korea before the Asian financial crisis, foreign interest rate hikes cause real contraction. The low levels of financial integration may mitigate the negative effects of foreign interest rate hikes on investment and consumption by the portfolio reallocation effect and the

[21] Based on the analysis of Latin America countries, Canova (2005) shows that tightening U.S. monetary shocks cause significant rise of the domestic interest rate that is accompanied by domestic currency depreciation, inflation, improvement in the balance of trade, increases of aggregate demand and substantial output increases. However, this result is based on the rise of the domestic interest rate higher than the rise of the foreign interest rate as well as capital inflow. In addition, all Latin America countries have sizable net external debt instead of net external credit unlike South Korea after the Asian financial crisis.

intertemporal substitution effect. However, when the foreign interest rate rises, sizable net external debt causes a substantial negative wealth effect. Therefore, negative effects from the portfolio reallocation effect, the intertemporal substitution effect and the wealth effect all result in real contraction.

Factor prices rise due to domestic investment decrease, and foreign import goods prices also rise due to the expected rise of the exchange rate. As a result, the inflation rate may rise in the short run. However, factor demand decreases as a result of real contraction and labor supply increases as a result of the intertemporal substitution effect and the negative wealth effect, which lowers factor prices and domestic goods prices. Therefore, the inflation rate eventually falls.

This non-monotonic impulse response of the inflation rate has a close relationship with the non-monotonic impulse response of the domestic interest rate. The domestic interest rate analyzed in this paper is the short-term money market rate that has a very close relationship with the monetary policy determined by the monetary authority of South Korea.[22] In the short run, the monetary authority may raise the domestic interest rate as a response to the rising inflation rate. However, the monetary authority may eventually lower the domestic interest rate as a response to real contraction and the falling inflation rate. Finally, due to this real contraction and the falling domestic interest rate, the nominal exchange rate rises.

Meanwhile, as shown in <Figure 3.4>, another empirical result of this paper also implies that, when a small open economy is more integrated with the international financial market and it has sizable net external credit instead of net external debt, like South Korea after the Asian financial crisis, foreign interest rate hikes may cause real expansion. The higher levels of financial integration may

[22] In the monetary market in South Korea, this short-term money market rate is called "over-night call rate between financial intermediaries". Under the inflation targeting monetary policy system, the Bank of Korea, the monetary authority of South Korea, uses the over-night call rate between financial intermediaries as its operating target and announces its target level of the over-night call rate between financial intermediaries every month.

strengthen the negative effects of a foreign interest rate hike on investment and consumption by the portfolio reallocation effect and the intertemporal substitution effect since enhanced financial integration lowers portfolio adjustment costs that is related with the portfolio reallocation effect and the intertemporal substitution effect. However, when the foreign interest rate rises, sizable net external credit causes the substantial positive wealth effect. The economy of South Korea after the Asian financial crisis demonstrates that the positive wealth effect may dominate the negative effects from the portfolio reallocation effect and the intertemporal substitution effect in foreign interest rate hikes.

Considering the fact that outstanding external debt or credit determines the size of the wealth effect, it seems that the rapid and dramatic change in the external debt position of South Korea after the Asian financial crisis causes the increase of investment, consumption and GDP responding to foreign interest rate hikes.[23] In fact, South Korea had net external debt of 61 billion dollars in the end of 1997, but the net external credit of South Korea increased up to 138 billion dollars by the end of 2004. This amount of the net external credit is about 20% of the GDP of South Korea in 2004.

From the perspective of the intertemporal model that emphasizes the forward-looking intertemporal decision making of economic agents, this wealth

---

[23] The magnitude of the positive wealth effect caused by foreign interest rate hike may change depending on many factors such as the composition of foreign receivables and liabilities, the terms and conditions regarding interest payments and the currency used for the denomination of securities or deposits. In the case of South Korea, the monetary authority has net foreign external credit while the other sectors such as the government and financial institutions have net foreign external debt. However, accessibility to the detailed data regarding international foreign reserves is very limited. In fact, monetary authorities of most countries are very careful in reporting the detailed composition of its international foreign reserves since it may have a substantial effect on its foreign currency market and other financial markets. Nonetheless, it is highly likely that the international foreign reserves of South Korea will be affected by the change in the foreign international interest rate. According to the Bank of Korea, securities and deposits account for about 98% of its international foreign reserves as of October 2011. It is known that monetary authorities of most countries hold their international foreign reserves in the form of government bonds of major countries such as U.S., Japan and EU as a stable investment. Even though this paper uses the US 3-month treasury bill rate as the foreign interest rate, other foreign international interest rates including the LIBOR (London Inter Bank Offered Rates) show very similar movements to that of US interest rates. Thus, this implies that foreign interest rate hike shocks will have a positive wealth effect on the international foreign reserves of South Korea. The effects on the private sector include indirect ones like the reduction of tax burdens.

effect caused by the foreign interest rate hikes increases current savings as well as current consumption since this wealth effect is not a permanent wealth increase but a temporary wealth increase. In this case, if the financial market of the small open economy is perfectly integrated with the international financial market, then the increase of current savings may not increase domestic investment at all. Due to the rise in the real foreign interest rate, the increasing current savings will be invested in foreign bonds instead of domestic investment. On the contrary, if the financial market of the small open economy is not integrated with the international financial market, then the increase of current savings may increase domestic investment through the fall of the long-term real domestic interest rate. However, in the more realistic case of the partially integrated financial market like South Korea, the investment increase effect will disappear as time goes by since the investment in foreign bonds will increase gradually. The accumulated impulse response of investment of South Korea to foreign interest rate hikes in the post-break period seems to be consistent with this expectation. Investment increases significantly in the short run, but gradually returns to the initial level.

In addition to the increase of investment, the labor supply also increases through the intertemporal substitution effect. As a result, factor prices fall, which lowers the inflation rate. On the other hand, factor demand increases due to real expansion, which may increase inflationary pressure. Reflecting these conflicting factors, the empirical result of this paper shows that the inflation rate falls in the short run but returns to the initial level eventually.

The rise of the domestic interest rate may represent the tightening of monetary policy in response to real expansion. At the same time, it may be the reaction of the monetary authority of South Korea to prevent a sharp capital outflow that may be caused by foreign interest rate hikes. During the Asian financial crisis, South Korea experienced a rapid capital outflow and a sharp reduction in its international foreign reserves, which aggravated a financial turmoil and caused a painful economic recession. Moreover, the openness of the domestic financial market and the integration with the global financial market of South Korea was substantially enhanced through the Asian financial crisis. As a result, it is believed that the stabilization of financial markets became more important in the monetary policy of South Korea after the Asian financial crisis.[24] Thus, the rise of the domestic interest rate after foreign interest rate hikes can be characterized as an "interest rate co-movement". Due to real expansion and the rise of the domestic interest rate, nominal exchange rate falls.[25]

Forecast error variance decomposition analysis

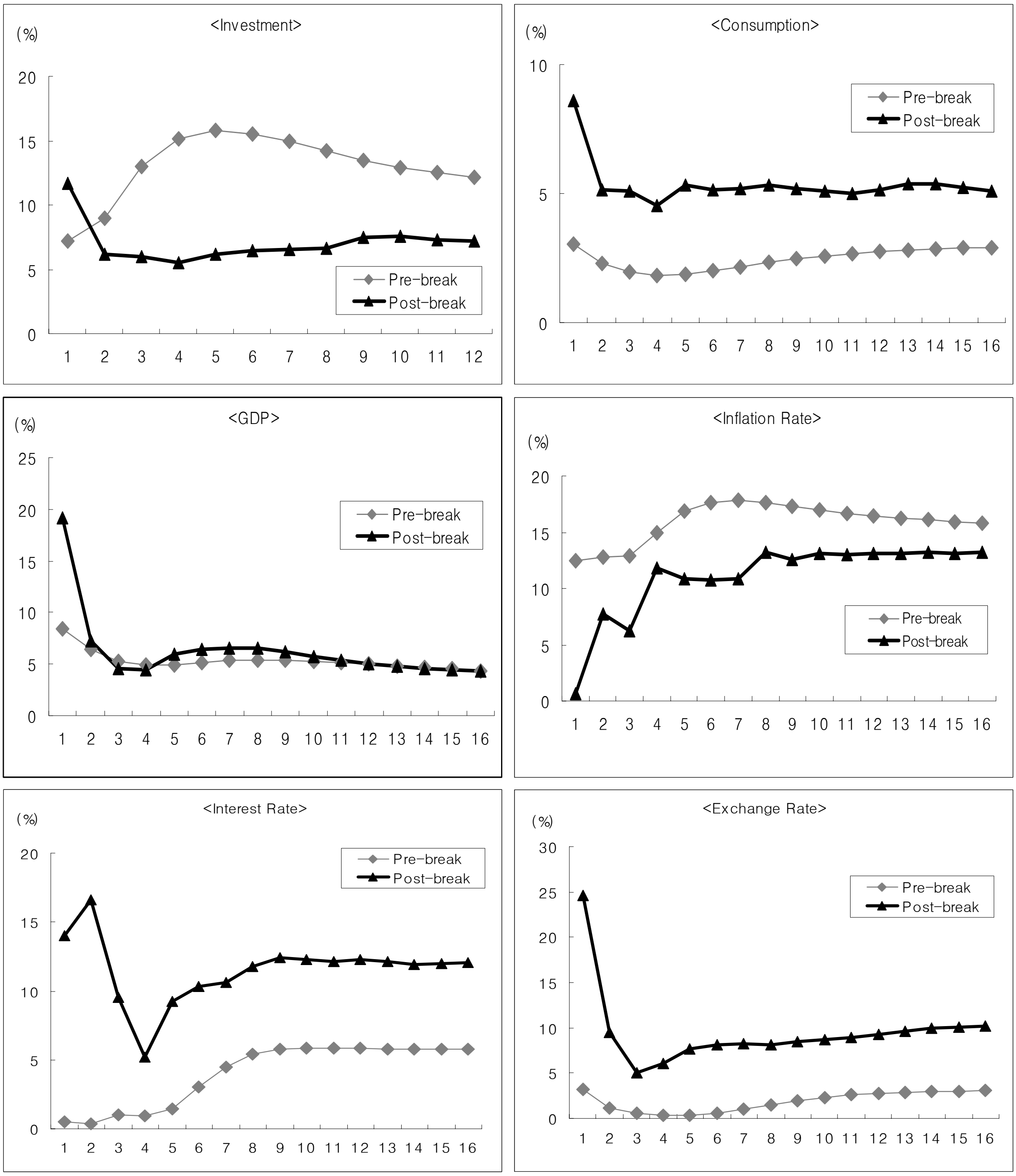
To scale the contribution of foreign interest rate shocks to the variation of domestic macroeconomic variables of South Korea, I compare the forecast error variance decomposition result between the pre-break period and the post-break period. <Figure 3.5> shows the percentage of n-quarter-ahead forecast error variance that is explained by foreign interest rate shocks for 6 domestic macroeconomic variables.

---

[24] Ra (2007; 2008) studies the international foreign reserve holding behavior of countries that experienced the Asian financial crisis. He highlights that South Korea shows the most evident change in international foreign reserve holding behavior responding to financial market volatility.

[25] Considering the fact that both the inflation rate and the nominal exchange rate fall, the domestic currency of South Korea may depreciate in terms of the real exchange rate if the inflation rate falls more than the nominal exchange rate. In this case, the depreciation of domestic currency in terms of the real exchange rate may improve the balance of trade of South Korea, which may be another reason for the real expansion of South Korea after foreign interest rate hike shocks in the post-break period.

<Figure 3.5> Forecast Error Variances explained by the foreign interest rate



Note: (1) Percentage of n-quarter-ahead forecast error variances explained by foreign interest rate shocks; (2) Horizontal line represents 16 quarters (4 years) from the shock.

At first, for financial macroeconomic variables of South Korea such as the interest rate and the exchange rate, the proportion that foreign interest rate shocks can explain consistently increases after the Asian financial crisis. In the pre-break period, US treasury bill rate shocks can explain a maximum of 5.9% of the forecast error variance in the interest rate and 3.2% of the forecast error variance in the exchange rate for 4 years after the shock. However, in the post-break period, US treasury bill rate shocks can explain a maximum of 16.6% of the forecast error variance in the domestic interest rate and 24.7% of the forecast error variance in the exchange rate for 3-years after the shock. This result seems to be consistent with the fact that the integration with the international financial market of South Korea was noticeably increased after the Asian financial crisis.

The fact that the influence of foreign interest rate shocks on the exchange rate increases in the post-break period may seem to be inconsistent with the fact that the exchange rate falls after the foreign interest rate hike shock in the post-break period since the MFD model predicts that U.S. monetary tightening (the rise of the foreign interest rate) causes the appreciation of the U.S. dollar (the depreciation of the domestic currency of a small open economy that trades with the U.S.). However, it seems that previous research of Canova (2005) and Grilli and Roubini (1995) can explain this seemingly inconsistent fact.

According to Canova (2005), in less developed countries with low levels of financial integration, external shocks were transmitted through a real exchange rate adjustment or a change in the balance of trade. However, for the past decades, many less developed countries experienced notable progress in financial integration with the global financial market, which changed the transmission channels of foreign economic shocks. He finds that the interest rate channel amplifies responses of domestic macroeconomic variables to U.S. monetary shocks while the role of the trade channel is negligible. As already mentioned above, responding to foreign interest rate hike shocks, the domestic interest rate of South Korea falls before the Asian financial crisis, but rises after the Asian crisis. This "interest rate co-movement" or "coupling in monetary policy", strengthened by the progress in financial integration, seems to have an important and substantial effect on the change in the transmission mechanism of foreign interest rate shocks.

With respect to this point, Grilli and Roubini (1995) mention that the monetary policy of non-U.S., G-7 countries strongly follows that of the U.S. based on the idea that the U.S. is the "leader country" that determines overall monetary policy for the G-7 area. If this applies to even a small open economy like South Korea, impulse responses of domestic macroeconomic variables other than the domestic interest rate may reflect not only the effect of foreign interest rate shocks but also the effect of domestic interest rate shocks that follow foreign interest rate shocks. Grilli and Roubini (1995) also show that, after controlling for US interest rate hike shocks and inflation, domestic interest rate hike shocks cause persistent domestic currency appreciation in most G-7 countries.

As mentioned above, after the Asian financial crisis, it seems that the interest rate channel is intensified and the co-movement between the domestic interest rate and the foreign interest rate is strengthened as the result of enhanced financial integration. Therefore, even though the result of the forecast error variance decomposition analysis suggests that the influence of foreign interest rate shocks on the exchange rate increases, the rise of the domestic interest rate that follows the rise of the foreign interest rate may explain the fall of the exchange rate shown in the impulse response function analysis.

Meanwhile, for consumption, the proportion that foreign interest rate shocks can explain consistently increases after the Asian financial crisis. This result seems to be consistent with the fact that South Korea changed from net foreign debtor to net foreign creditor right after the Asian financial crisis and holds sizable net foreign credit and has substantial positive wealth effect to foreign interest rate hike shocks.

For investment, the proportion that foreign interest rate shocks can explain increases in the short run but decreases gradually when we compare before versus after the Asian financial crisis. In 1 quarter after the shock, foreign interest rate shocks explain 7.2% of forecast error variances in investment before the Asian financial crisis and 11.7% of forecast error variances in investment after the Asian financial crisis. However, 2 quarters after the shock, the proportion after the Asian financial crisis is lower than the proportion before the Asian financial crisis. This result seems to be consistent with the finding in the impulse response function analysis that investment increases significantly in the short run but returns to the initial level gradually responding to foreign interest rate hike shocks after the Asian financial crisis.

Reflecting these results regarding consumption and investment, the proportion of the change in GDP that foreign interest rate shocks can explain turns out to increase only in the short run when we compare before versus after the Asian financial crisis. Lastly, for the inflation rate, the proportion that foreign interest rate shocks can explain decreases consistently after the Asian financial crisis.

5. Conclusion

The Korean economy for the last 30 years is an appropriate case to study the change in the response of a small open economy to foreign interest rate shocks as well as the change on the influence of foreign interest rate shocks on the variance of domestic macroeconomic variables of the small open economy. South Korea has a strong candidate for the economic structural break: the Asian financial crisis in the late 1990s. In addition, the financial integration of South Korea was substantially enhanced through the Asian financial crisis, and South Korea changed from a net external debtor to a net external creditor in the international capital market right after the Asian financial crisis.

Based on Sims, Stock and Watson (1990), this paper analyzes the interrelationship between 6 domestic macroeconomic variables of South Korea and the foreign interest rate using the VAR model that estimates coefficients in equations by the OLS method since this paper analyzes level data and it turns out that there exist cointegrating relationships between variables.

The impulse response function analysis shows that responses of domestic macroeconomic variables of South Korea to foreign interest rate shocks substantially change after the Asian financial crisis. Foreign interest rate hikes cause real contraction: the fall of the domestic interest rate and the rise of the exchange rate before the Asian financial crisis. On the contrary, foreign interest rate hikes cause real expansion: the rise of the domestic interest rate and the fall of the exchange rate after the Asian financial crisis. Meanwhile, the forecast error variance decomposition analysis shows that foreign interest rate shocks explain a higher proportion of fluctuations in the interest rate, the exchange rate and consumption of South Korea after the Asian financial crisis. These results imply that the level of financial integration and the external debt position of a small open economy substantially affect responses of domestic macroeconomic variables of the small open economy to foreign interest rate shocks.

Regarding the effect of financial integration, the empirical result of this paper seems to support the argument of Canova (2005) and Grilli and Roubini (1995). Considering the co-movement of the foreign interest rate and the domestic interest rate after the Asian financial crisis, it seems that the monetary authority of South Korea, in making its monetary policy decision, puts more weight on factors such as the change in U.S. monetary policy, the interest rate differential and the international financial market condition. In this case, the effect of foreign interest rate shocks may be strengthened by the co-moving domestic interest rate of South Korea. Therefore, it seems that the interest rate channel becomes more important in the transmission of foreign interest rate shocks after the Asian financial crisis through which financial integration was substantially enhanced.

Regarding the effect of external debt, this paper provides an interesting empirical result for the situation when a small open economy has sizable net external credit instead of net external debt. The result of the impulse response function analysis shows that foreign interest rate hikes cause the real expansion of the Korean economy after the Asian financial crisis. It seems that 3 transmission channels of foreign interest rate shocks, which are analyzed in Demirel (2009), may explain this result. Since the size of outstanding external debt or credit determines the size of the wealth effect, when a small open economy has sizable net external credit like South Korea after the Asian financial crisis, the positive wealth effect may outweigh the negative portfolio reallocation effect and the negative intertemporal substitution effect of foreign interest rate hikes.

On the other hand, we need to admit that another macroeconomic theory also might explain the empirical result of this paper. For example, the intertemporal model can explain the real expansion of a small open economy after foreign interest rate hikes without accompanying the depreciation of the domestic currency of the small open economy. To be more specific, U.S. monetary tightening decreases U.S. household income. However, the decrease of U.S. consumption may be smaller than the decrease of U.S. household income because U.S. households try to smooth their consumption based on a forward-looking intertemporal decision. If U.S. investment does not decrease enough in spite of the rise of the U.S. interest rate, then the decrease of U.S. savings worsens the U.S. balance of trade. In this case, U.S. monetary tightening may improve the balance of trade of the foreign small open economy that trades with the U.S., which increases the output of the foreign small open economy.

Therefore, this implies that, to find a more appropriate theoretical model that explains the economy of South Korea before and after the Asian financial crisis, we may need to consider additional macroeconomic variables such as the balance of trade, exports, imports and capital flows. Lastly, another direction for future study related to this topic may be to analyze other small open economies that have different combinations of financial integration levels and external debt positions.

CHAPTER IV

THE CATEGORIZATION OF SMALL OPEN ECONOMIES AND THE RESPONSE TO FOREIGN INTEREST RATE SHOCKS: BASED ON NET EXTERNAL CREDIT AND FINANCIAL INTEGRATION

4.1. Introduction

Effects of foreign interest rate shocks have been an important issue in the study of a small open economy. In particular, many studies pay attention to the role of the external credit (or debt) and the international financial integration in transmission channels through which foreign interest rate shocks are transmitted to a small open economy. Based on an analysis using the data of Turkey, Demirel (2009) finds that financial integration under bigger external debt mutes real contraction from foreign interest rate hike shocks while financial integration under smaller external debt magnifies real contraction from foreign interest rate hike shocks. By comparing the economy of South Korea before and after the Asian financial crisis, Cho (2011) shows that foreign interest rate hike shocks cause the real contraction of a small open economy with sizable net external debt and low financial integration, but foreign interest rate hike shocks cause the real expansion of a small open economy with sizable net external credit and enhanced financial integration.

Then, how can we categorize many small open economies based on two criteria of net external credit (or debt) and the level of financial integration? How does the response to foreign interest rate shocks differ depending on a country's category? This paper answers these two key questions.

For the systematic classification of many small open economies, this paper suggests a new method to categorize small open economies based on the following two criteria: (1) the size of net external credit (or debt), (2) the level of financial restriction. Even though most small open economies do not report official data of external credit and debt, this categorization method overcomes the problem of the lack of official data by introducing a reliable proxy number for net external credit (or debt). Even though nearly all existing *de jure* capital control indices represent only the existence of a financial restriction, this categorization method captures the intensity of financial restrictions of a small open economy by using the new financial restriction data set by the IMF.

Based on this new categorization method, this paper classifies (1) Malaysia, Thailand, and Russia into the high financial restriction-net external credit country type, (2) Norway and Switzerland into the low financial restriction-net external credit country type, (3) Peru, Canada, and New Zealand into the low financial restriction-net external debt country type, (4) Indonesia, Philippines, and Brazil into high financial restriction-net external debt country type.

To understand responses of small open economies to foreign interest rate shocks, this paper analyzes the interrelationship between the foreign interest rate (US 3-month treasury bills rate) and 5 domestic macroeconomic variables (investment, consumption, the consumer price index (CPI), the interest rate, and the exchange rate) of the above countries during 1995 1Q to 2010 4Q.

This paper uses the panel VAR (vector autoregression) methodology suggested by Holtz-Eakin, Newey and Rosen (1988) and Love and Zicchino (2006) to find common characteristics of countries in each category. This technique is the combination of the VAR approach and the panel approach that allows for unobserved individual heterogeneity. Since all 6 variables turn out to be nonstationary by the Fisher-type panel unit root test, and also turn out to have no cointegration relationship by the Pedroni panel cointegration test, this paper analyzes stationary first seasonal differenced variables.

The overall empirical result of this paper seems to be consistent with the expectation of the theoretical model that is based on 3 transmission channels such as (1) the portfolio reallocation effect, (2) the intertemporal substitution effect, and (3) the wealth effect. According to this model, high financial restriction mitigates the negative portfolio reallocation effect and the negative intertemporal substitution effect of foreign interest rate hike shocks. In addition, high financial restriction intensifies the positive wealth effect of foreign interest rate hike shocks in countries with net external credit as well as the negative wealth effect of foreign interest rate hike shocks in countries with net external debt. Consistent with this expectation, the result of impulse response function analysis of this paper shows that foreign interest rate hike shocks cause "real expansion" in countries with high financial restriction-net external credit while foreign interest rate hike shocks cause "real contraction" in countries with high financial restriction-net external debt.

This paper also finds that, in countries with low financial restriction, foreign interest rate hike shocks cause a significant rise in the domestic interest rate change, which implies "interest rate co-movement" or "coupling in monetary policy". This strong linkage between the foreign interest rate and the domestic interest rate in countries with low financial restriction is also supported by the forecast error variance decomposition result, which shows that foreign interest rate shocks explain a higher fraction of the forecast error variance in the domestic interest rate change in countries with low financial restriction rather than in countries with high financial restriction.

Therefore, this paper verifies that the effects of foreign interest rate shocks on small open economies may differ substantially depending on (1) whether the country is a net creditor or a net borrower in the global financial market, (2) how the domestic financial market of the country is integrated with the global financial market. This paper also suggests the new useful categorization methodology of small open economies based on above two criteria. Using this categorization and the panel VAR model, this paper provides responses to foreign interest rate hike shocks of many small open economies with various combinations of net external credit (or debt) and financial integration.

The rest of this paper is organized as follows. Section 4.2 introduces related theories and previous research. Section 4.3 suggests the new categorization method of small open economies. Section 4.4 explains the empirical methodology adopted in this paper such as the panel unit root test, the panel cointegration test, and the panel VAR model. Section 4.5 provides empirical results on the impulse response function analysis and the forecast error variance decomposition analysis. Finally, section 6 offers concluding remarks.

4.2. Related theories and previous research

Following two traditional theoretical models provide the basic framework to explain the mechanism by which U.S. monetary shocks are transmitted to a foreign small open economy: (1) the traditional Mundell–Flemming–Dornbusch (MFD) model, (2) the intertemporal model. In particular, the intertemporal model emphasizes the forward-looking intertemporal decision behavior of economic agents (Svensson and Van Wijnbergen, 1989; Obstfeld and Rogoff, 1995).

Based on the MFD model, U.S. monetary tightening, which is represented by foreign interest rate hike shocks, causes US dollar appreciation and the improvement of the U.S. terms of trade, which deteriorates the U.S. balance of trade (the expenditure switching effect). In this case, U.S. monetary tightening improves the balance of trade of a foreign small open economy that trades with the U.S., which increases the output of the small open economy. On the other hand, based on the MFD model, U.S. monetary tightening decreases U.S. domestic income as well as U.S. demands for import goods, which improves the U.S. balance of trade (the income absorption effect). In this case, U.S. monetary tightening worsens the balance of trade of a foreign small open economy that trades with the U.S., which decreases the output of the small open economy. Thus, under the MFD model, the output of a small open economy may either increase or decrease in response to foreign interest rate hike shocks.

Based on the intertemporal model, U.S. monetary tightening decreases the income of U.S. households, but the decrease of U.S. consumption may be smaller than the decrease of U.S. income (consumption smoothing), which decreases U.S. saving. If U.S. investment decreases substantially in response to the rise of the U.S. interest rate, this may offset the decrease of U.S. savings, and the U.S. balance of trade may not worsen. However, if U.S. investment does not decrease enough in response to the rise of the U.S. interest rate, the decrease of U.S. saving may worsen the U.S. balance of trade. Thus, under the intertemporal model, U.S. monetary tightening may either improve or deteriorate the balance of trade of a foreign small open economy that trades with U.S., which may increase or decrease the output of the small open economy.[26]

As explained above, the traditional theoretical models do not seem to provide a clear conclusion regarding the effect of U.S. monetary shocks on a small open economy. Even though results of empirical studies are more important in this case, empirical results of previous studies do not seem to be consistent. Kim (2001) concludes that the spillover effect of U.S. monetary policy shocks on developed countries do not seem to be sizable by analyzing effects on the non-U.S. G-7

[26] Another mechanism that is based on the intertemporal model focuses on the relationship between U.S. monetary policy and the international interest rate. Under this mechanism, U.S. monetary tightening raises the international interest rate, which decreases the world demand for consumption and investment in both the U.S. and non-U.S. countries. As a result, both exports and imports of both the U.S. and non-U.S. countries decrease at the same time. In this case, depending on the extent to which the exports and imports of a small open economy decreases, the balance of trade and output of the small open economy may either increase or decrease. Thus, even under this mechanism, the output of a small open economy may either increase or decrease in response to foreign interest rate hike shocks.

countries. Mackowiak (2007) finds that external shocks play an important role in macroeconomic fluctuations of emerging countries. However, he points out that U.S. monetary policy shocks are not important relative to other kinds of external shocks. On the contrary, Canova (2005) finds that, in macroeconomic fluctuations of Latin American countries, U.S. monetary policy shocks are more important than other U.S. shocks such as supply shocks or demand shocks.[27]

Regarding channels through which U.S. monetary policy shocks are transmitted, Demirel (2009) analyzes the following 3 transmission channels through which foreign interest rate shocks are transmitted to a small open economy: (1) the portfolio reallocation effect, (2) the intertemporal substitution effect, and (3) the wealth effect. For example, foreign interest rate hikes increase the opportunity cost of domestic investment of a small open country, which causes the reallocation of resources from domestic investment to foreign investment (the negative portfolio reallocation effect). In addition, the higher level of the foreign interest rate also raises the opportunity cost of current consumption of the small open economy, which reduces current consumption and increases current savings, in other words, future consumption (the negative intertemporal substitution effect). If the small open economy has net external debt, foreign interest rate hikes increase interest payments for the external debt. In this case, foreign interest rate hike shocks decrease aggregate demand (the negative wealth effect), and cause real contraction.

With respect to above channels, many studies emphasize the role of the level of financial integration of a small open economy. Canova (2005) mentions that the importance of the financial market channel depends on the level of financial

[27] Sousa and Zaghini (2008) investigate the international transmission of monetary shocks focusing on the effect of global foreign liquidity aggregate in the euro area. Based on the structural VAR analysis, they find that a positive shock in global foreign liquidity aggregate causes the permanent increase in the euro area money aggregate and the price level, the temporary increase in output, and the temporary appreciation of the euro.

integration. Heathcote and Perri (2002) show that enhanced financial openness reduces the volatility of macroeconomic variables. They find that, when households cannot borrow and lend internationally, productivity shocks generate higher volatility in the terms of trade. Kose, Prasad and Terrones (2003) show that benefits of financial integration such as improved risk sharing and consumption smoothing appear to accrue beyond a certain threshold level of financial integration. Ehrmann and Fratzscher (2009) find that the level of international financial integration of a country plays an important role in the transmission of US monetary policy shocks by analyzing equity markets of 50 countries. In particular, they show that a country's global integration with the world, rather than a country's bilateral integration with the U.S., is a key determinant.

Regarding the effect of external debt of a small open economy on impulse responses to foreign interest rate shocks, Demirel (2009) shows that financial integration under bigger external debt mutes real contraction while financial integration under smaller external debt magnifies real contraction. Considering the 3 transmission channels, foreign interest rate hike shocks cause real contraction due to the negative portfolio reallocation effect, the negative intertemporal substitution effect and the negative wealth effect. In this case, enhanced financial integration enables households to smooth consumption more effectively by lowering the portfolio adjustment cost. On the other hand, enhanced financial integration strengthens the negative portfolio reallocation effect and the negative intertemporal substitution effect. Thus, at higher levels of external debt, enhanced financial integration may mitigate real contraction by substantial consumption smoothing. On the contrary, at lower levels of external debt, enhanced financial integration may intensify real contraction by the dominant negative portfolio reallocation effect and the dominant negative intertemporal substitution effect.

Cho (2011) investigates the case of a small open economy with net external credit and enhanced financial integration by analyzing the economy of South Korea after the Asian financial crisis. The empirical result shows that, when a small open economy has sizable net external credit, foreign interest rate hikes may cause real expansion due to the dominant positive wealth effect. In addition, it turns out that enhanced financial integration of a small open economy enables foreign interest rate shocks to explain a higher proportion of fluctuations in financial variables of the small open economy.

4.3. Categorization of small open economies

As mentioned above, two factors, the size of net external credit (or debt) and the level of financial integration of a small open economy, seem to play an important role in the response of the small open economy to foreign interest rate shocks. Thus, this paper categorizes small open economies based on following two criteria: (1) the size of net external credit (or debt), (2) the level of financial integration.

An important issue in the measurement of net external credit (or debt) is that most economies do not report official data of external credit and debt. To overcome this problem, this paper uses the proxy number for net external credit (or debt) that is calculated using the IIP (International Investment Position) database of the IMF. This database provides a country's stock of external assets and liabilities on an annual frequency from 2001 to 2010. The proxy for net external credit (or debt) is calculated as follows:

Proxy for Foreign Receivable
= IIP Total Foreign Assets
- IIP Direct Investment Abroad, Assets
- IIP Portfolio Investment in Equity Securities, Assets (3.1)

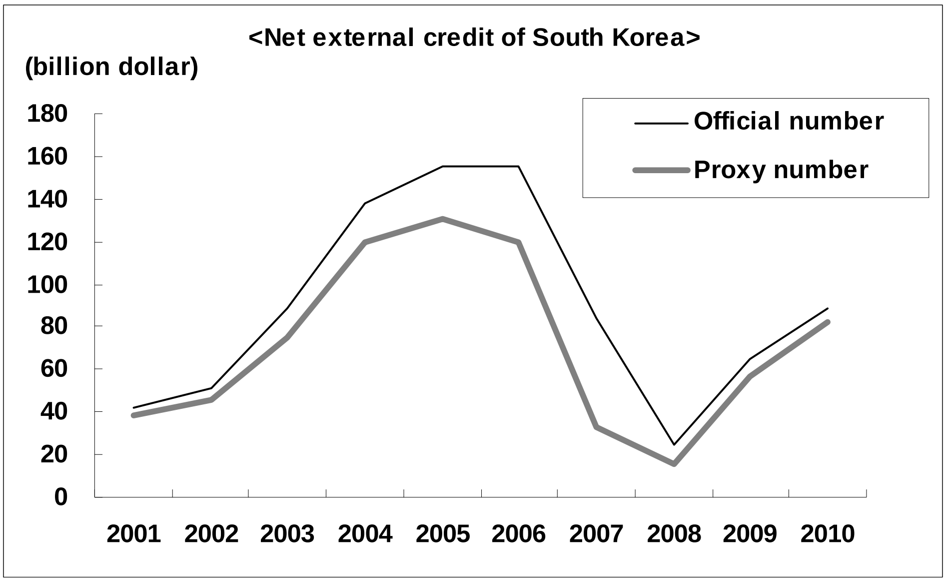
Proxy for Foreign Debt
= IIP Total Foreign Liabilities
- IIP Direct Investment in Reporting Economy, Liabilities
- IIP Portfolio Investment in Equity Securities, Liabilities (3.2)

Proxy for Net Foreign Credit (or Debt)
= Proxy for Foreign Receivable - Proxy for Foreign Debt (3.3)

The reason to pay a special attention to the size of net external credit (or debt) of a country is that it plays an important role in transmission channels of foreign interest rate shocks. If a country has sizable net external credit, foreign interest rate hike shocks may cause the positive wealth effect from the increase of interest revenue. In contrast, if a country has sizable net external debt, foreign interest rate hike shocks may cause the negative wealth effect from the increase of interest payment. This implies that, to make the more reasonable proxy for foreign receivable (or foreign debt) from total foreign assets (or total foreign liabilities), we need to exclude direct investment and portfolio investment in equity securities, which are assets (or liabilities) that do not change responding to the change of foreign interest rate.

To check how the proxy for net foreign credit (or debt) approximates the real net foreign credit (or debt), this paper compares the proxy number with the official number using the data of South Korea. The proxy for net foreign credit of South Korea in <Figure 4.1> is the result of the calculation explained above. Meanwhile, the official net foreign credit number of South Korea in <Figure 4.1> is the number officially reported by the Bank of Korea, the central bank of South Korea. <Figure 4.1> shows that the proxy number approximates the real number closely over 10 years ranging from 2001 to 2010. The correlation coefficient between the proxy number and the official number is 0.948. Thus, this result illustrates the validity of the proxy for net external credit (or debt) proposed in this paper.

<Figure 4.1> Official vs. Proxy number for net external credit of South Korea



Note: (1) The official net external credit is the number that is reported by the Bank of Korea (http://ecos.bok.or.kr/); (2) The proxy for net external credit is the number that is calculated using the IIP (International Investment Position) by the IMF; (3) Proxy for Net Foreign Credit = (IIP Total Foreign Assets - IIP Direct Investment Abroad, Assets - IIP Portfolio Investment in Equity Securities, Assets) - (IIP Total Foreign Liabilities - IIP Direct Investment In Reporting Economy, Liabilities - IIP Portfolio Investment in Equity Securities, Liabilities).

Regarding the measurement of the extent to which a country's financial integration with the global economy, most researchers have used the following three measurement ways (Rogoff, Kose, Prasad and Wei, 2004). The first way is based on *de jure* restrictions on capital account transactions. Since capital account liberalization is an important precursor to financial integration, many empirical studies have used binary indicators provided by the IMF based on the official restrictions on capital flows.[28] Even though this indicator shows directly the existence of a capital control, it does not capture the intensity of that capital control. The second way is based on *de facto* capital flows across national borders. It uses either the ratio of gross capital inflows and outflows to GDP or the ratio of gross stocks of foreign assets and liabilities to GDP. The stock data may be a better indicator than the flow data due to less volatility from year to year. Lane and Milesi-Ferretti (2001) and Kose, Prasad and Taylor (2011) use this stock data in their study. The third way is based on various interest parity conditions (Frankel, 1992). However, this way may be difficult to apply for a long time period and a large number of countries.

To get a more reliable measurement of international financial integration that covers many small open economies, this paper uses "A new data set" that is recently constructed by the IMF (Martin Schindler, 2009). This data set contains measures of restrictions on cross-border financial transactions for 91 countries on an annual frequency from 1995 to 2005. It is mainly based on *de jure* restrictions on capital account transactions that are contained in the AREAER by the IMF. Even though it is based on the same source as existing indices, the indices in "A new data set" differ in how, and to what extent, they extract the information provided in the AREAER. It covers almost every category of assets and liabilities of global cross-border holdings such as equity, bond, money market, financial credit and direct investment. The level "0" represents no financial restrictions (perfect financial integration) and the level "1" represents the highest financial restrictions (perfect

[28] According to Martin Schindler (2009), nearly all existing *de jure* capital control indices have relied on information contained in the AREAER (Annual Report on Exchange Arrangements and Exchange Restrictions) by the IMF. Until 1995, the AREAER summarized a country's restrictions on capital flows using a binary dummy variable (0 or 1) that represents only the existence of a restriction. Since 1995, the AREAER started providing detailed information on restrictions on capital flow in many subcategories.

financial separation). Thus, the value between 0 and 1 of each country captures the intensity of financial restrictions.[29]

In the application of the size of net external credit (or debt) and the level of financial integration to categorize small open economies, this paper uses the following two measures for each country: (1) the average of the ratio of the proxy for net external credit (or debt) to nominal GDP from 2001 to 2010 (hereafter, the average net external credit ratio), (2) the average of the measure of restrictions on overall cross-border financial transactions based on "A new data set" by the IMF from 1995 to 2005 (hereafter, the average financial restriction level).

Based on these two criteria, this paper categorizes small open economies into the following four categories: [30]

(Type 1) high financial restriction-net external credit

: the average financial restriction level > 0.4 and

the average net external credit ratio > 10%

(Type 2) low financial restriction-net external credit

: the average financial restriction level < 0.1 and

the average net external credit ratio > 10%

(Type 3) low financial restriction-net external debt

: the average financial restriction level < 0.1 and

the average net external credit ratio < -10%

[29] Even though I tried to expand the length of data set over 2005, it was impossible since the AREAER by the IMF is not an open source to public.

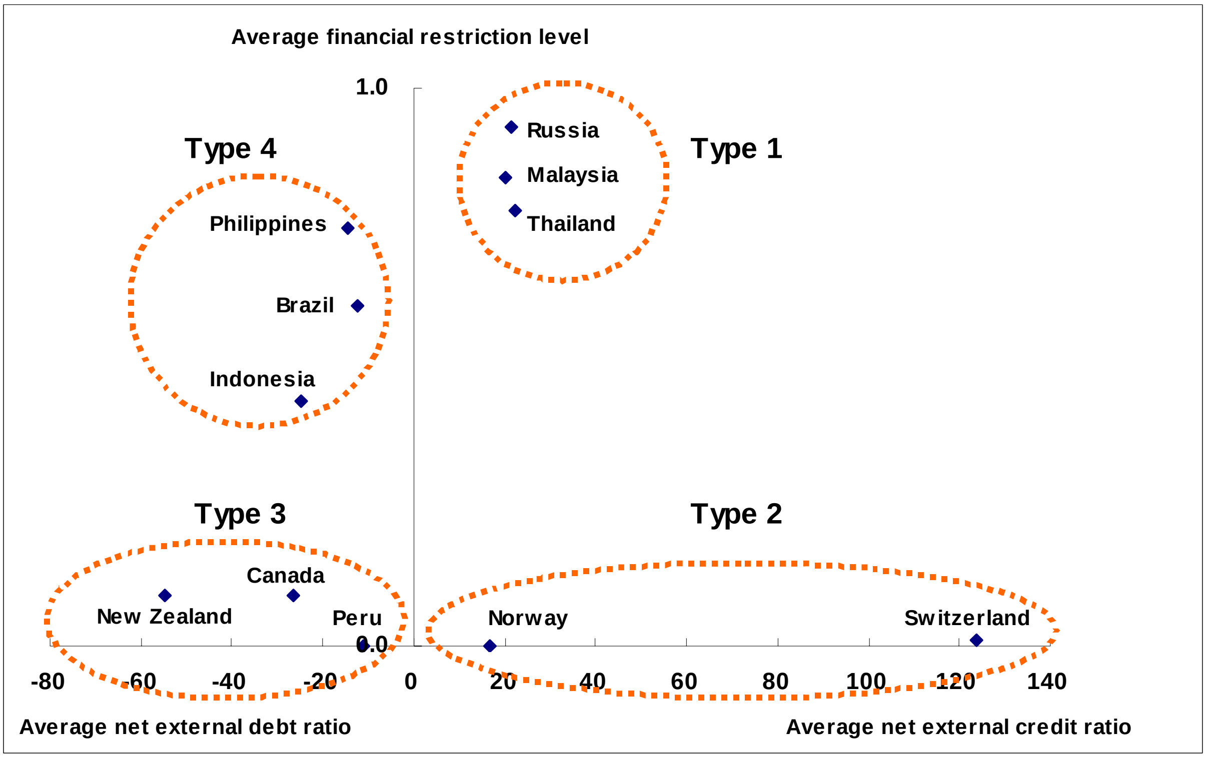
[30] To identify evident characteristics of each category, this chapter 4 applies threshold values in its categorization of small open economies. These threshold values are 0.4 and 0.1 for the average financial restriction level, and 10% and -10% for the average net external credit ratio. These threshold values were selected by considering the overall distribution of both the average financial restriction levels and the average net external credit ratios of small open economies analyzed in this study. As a kind of robustness check, this study performed the same analysis by applying different threshold values in its categorization. It turns out that empirical results when applying different threshold values are very similar to empirical results explained in chapter 4. The more detail explanation and result regarding this robustness check is given in Appendix 3.

(Type 4) high financial restriction-net external debt

: the average financial restriction level > 0.4 and

the average net external credit ratio < -10%

<Figure 4.2> Categorization of small open economies based on two criteria



Note: (1) The average net external credit ratio represents the average of the ratio of the proxy for net external credit (or debt) to nominal GDP from 2001 to 2010; (2) The average financial restriction level represents the average of the measure of restrictions on overall cross-border financial transactions based on "A new data set" by the IMF from 1995 to 2005; (3) Type 1 represents high financial restriction-net external credit countries; Type 2 represents low financial restriction-net external credit countries; Type 3 represents low financial restriction-net external debt countries; Type 4 represents high financial restriction-net external debt countries.

This paper analyzes small open economies that satisfy all of following three conditions: (1) a country that is included in "A new data set" by the IMF, (2) a country other than large economies such as the US, EU, China, Japan, and Great Britain, (3) a country that reports quarterly data of 5 domestic macroeconomic variables that are analyzed in this paper. As shown in <Figure 4.2>, the following countries that satisfy all of above three conditions are included in four categories:

(Type 1) high financial restriction-net external credit

: Malaysia, Thailand, Russia

(Type 2) low financial restriction-net external credit

: Norway, Switzerland

(Type 3) low financial restriction-net external debt

: Peru, Canada, New Zealand

(Type 4) high financial restriction-net external debt

: Indonesia, Philippines, Brazil

4.4. Methodology

Panel unit root test and Panel cointegration test

This section of the paper analyzes small open economies that are categorized into four types explained above. Considering the period that is used for the calculation of the average net external credit ratio and the average financial restriction level, this paper analyzes quarterly data ranging from 1995 1Q to 2010 4Q.[31] To investigate the responses of countries in each type to foreign interest rate shocks, this paper analyzes the foreign interest rate (US 3-month treasury bills rate, nominal, average of quarter) and the following 5 domestic macroeconomic variables for each country in each category: investment (gross fixed capital

[31] Both Russia in type 1 and Brazil in type 4 report the national account data such as investment and consumption from 1995 1Q. Thus, the first seasonal differenced data of Russia and Brazil start from 1996 1Q. Indonesia in type 4 reports the national account data such as investment and consumption from 1997 1Q. Thus, the first seasonal differenced data of Indonesia starts from 1998 1Q.

formation, national currency, real), consumption (private final consumption expenditure, national currency, real), CPI (consumer price index, all items), the interest rate (nominal, money market rate or discount rate, average of quarter), the exchange rate (nominal, national currency per US$, average of quarter). These domestic variables are usually used in many macroeconomic papers as the most relevant indicators of a small open economy. These quarterly data are obtained from the IMF database (http://elibrary-data.imf.org/DataExplorer.aspx).

To investigate the characteristics of variables analyzed in this paper, this paper applies panel techniques such as the panel unit root test and the panel cointegration test to the pooling data, which is the combined data of individual countries contained in each type.

At first, this paper checks the stationarity of variables in each type by applying the Fisher-type panel unit root test that is proposed by Maddala and Wu (1999). This panel unit root test combines the *p*-values from the individual PP (Phillips-Perron) unit root tests, and the test statistic follows the asymptotic chi-square distribution. In this panel unit root test, the null hypothesis is that the variable tested is nonstationary for all cross sections in the panel data. The alternative hypothesis is that the variable tested is stationary for at least one cross section in the panel data. <Table 4.1> shows the Fisher-type panel unit root test results of 6 variables analyzed in this paper for each type. When testing variables using the level data, the Fisher-type panel unit root test fails to reject the unit root null hypothesis for 3 of 6 variables for type 1 and type 2 countries, all 6 variables for type 3 countries, and 4 of 6 variables for type 4 countries. Thus, this panel unit root test result of the level data implies that, in all 4 types of countries, some level variables are nonstationary for all cross section in the panel data.

<Table 4.1> Fisher-type panel unit root test result

<Type 1 countries>

Variable	Level data		Differenced data	
	Test statistic	*p*-value	Test statistic	*p*-value
Foreign interest rate	3.769	0.708	17.803 ***	0.007
Investment	35.675 ***	0.000	18.853 ***	0.004
Consumption	19.282 ***	0.004	20.755 ***	0.002
CPI	4.128	0.659	21.493 ***	0.002
Interest rate	47.295 ***	0.000	44.371 ***	0.000
Exchange rate	0.961	0.987	17.874 ***	0.007

<Type 2 countries>

Variable	Level data		Differenced data	
	Test statistic	*p*-value	Test statistic	*p*-value
Foreign interest rate	2.513	0.547	11.869 **	0.018
Investment	9.058 *	0.060	14.779 ***	0.005
Consumption	21.695 ***	0.000	20.357 ***	0.000
CPI	13.459 ***	0.009	20.394 ***	0.000
Interest rate	4.769	0.312	13.299 ***	0.010
Exchange rate	1.250	0.870	14.759 ***	0.005

<Type 3 countries>

Variable	Level data		Differenced data	
	Test statistic	*p*-value	Test statistic	*p*-value
Foreign interest rate	3.769	0.708	17.803 ***	0.007
Investment	1.409	0.965	24.711 ***	0.000
Consumption	10.158	0.118	20.629 ***	0.002
CPI	8.291	0.218	19.905 ***	0.003
Interest rate	7.180	0.305	30.323 ***	0.000
Exchange rate	1.381	0.967	14.966 **	0.021

<Type 4 countries>

Variable	Level data		Differenced data	
	Test statistic	p-value	Test statistic	p-value
Foreign interest rate	3.769	0.708	17.803 ***	0.007
Investment	4.705	0.582	22.482 ***	0.001
Consumption	22.951 ***	0.001	34.284 ***	0.000
CPI	4.222	0.647	29.982 ***	0.000
Interest rate	16.363 **	0.012	70.101 ***	0.000
Exchange rate	1.867	0.932	35.158 ***	0.000

Note: (1) Fisher-type test using PP (Phillips-Perron) test proposed by Maddala and Wu (1999); (2) Type 1 countries represent high financial restriction-net external credit countries such as Malaysia, Thailand, and Russia; Type 2 countries represent low financial restriction-net external credit countries such as Norway and Switzerland; Type 3 countries represent low financial restriction-net external debt countries such as Peru, Canada and New Zealand; Type 4 countries represent high financial restriction-net external debt countries such as Indonesia, Philippines and Brazil; (3) In levels: foreign interest rate (US 3-month treasury bills rate, nominal, average of quarter), investment (gross fixed capital formation, national currency, real), consumption (private final consumption expenditure, national currency, real), CPI (consumer price index, all items), interest rate (nominal, money market rate or discount rate, average of quarter), exchange rate (nominal, national currency per US$, average of quarter); (4) In differences: first seasonal difference representing percent changes over corresponding period of the previous year for investment, consumption, CPI and exchange rate or percent point changes over corresponding period of the previous year for foreign interest rate and interest rate; (5) Both individual intercepts and individual linear trends are included in test equations for level data and individual intercepts are included in test equations for differenced data. (6) *** represents significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level.

To make all variables stationary, this paper applies the first seasonal difference since it seems that some quarterly national account variables such as investment and consumption have evident seasonality. As a result of the first seasonal difference transformation, the differenced data of investment, consumption, CPI and the exchange rate represent percent changes of investment, consumption, CPI and the exchange rate over the corresponding quarter of the previous year (hereafter, YoY: Year-over-Year). Meanwhile, as a result of the first seasonal difference transformation, the differenced data of the foreign interest rate and the domestic interest rate represent percent point changes of the foreign interest rate and the interest rate over the corresponding quarter of the previous year (YoY).[32] <Table 4.1> shows that, when testing variables using the differenced data, the Fisher-type panel unit root test rejects the unit root null hypothesis in all 6 variables for all 4 types of countries at the 1% significance level.

To check if there exists a cointegration relationship between untransformed levels of variables, this paper applies the Pedroni panel cointegration test that is proposed by Pedroni (1999, 2004). This panel cointegration test is based on the Engle-Granger (1987) cointegration test that examines the residuals of the regression performed using nonstationary variables. According to Engle-Granger (1987), if the variables are cointegrated, then the residuals should be stationary. On the contrary, if the variables are not cointegrated, then the residuals should be nonstationary. Pedroni proposes multiple panel cointegration test statistics that have various properties such as different size and power of the test depending on the number of cross sections and the length of the time series. While the null hypothesis is that there exists no cointegration relationship between variables, this test provides results based on the following two alternative hypotheses: (1) the homogeneous alternative hypothesis that assumes the common AR coefficient in the unit root test equation for the residuals (within-dimension test), (2) the heterogeneous alternative hypothesis that allows for the individual AR coefficient in the unit root test equation for the residuals (between-dimension test). In the equation to calculate the residuals, this paper includes both individual intercepts and individual linear trends, and the lag length is selected based on the Modified Akaike Information Criteria (MAIC).

[32] Even though variables other than national account variables do not seem to have evident seasonality, this paper applies the first seasonal difference to all variables for the consistency in the interpretation of transformed data. For example, the first seasonal differenced investment means the change rate of investment YoY, and the first seasonal differenced CPI means the inflation rate YoY. Similarly, the first seasonal differenced foreign interest rate means the change of foreign interest rate YoY.

<Table 4.2> Pedroni panel cointegration test result

<Type 1 countries>

Test statistics	Within-dimension test		Between-dimension test
	Unweighted	Weighted	Unweighted
Panel v-statistic	-0.97	-0.97	N/A
Panel rho-statistic	2.20	2.20	2.89
Panel PP-statistic	2.47	2.47	3.22
Panel ADF-statistic	2.78	2.77	3.44

<Type 2 countries>

Test statistics	Within-dimension test		Between-dimension test
	Unweighted	Weighted	Unweighted
Panel v-statistic	0.15	0.08	N/A
Panel rho-statistic	0.67	0.74	1.18
Panel PP-statistic	0.10	0.18	0.50
Panel ADF-statistic	1.21	1.30	1.75

<Type 3 countries>

Test statistics	Within-dimension test		Between-dimension test
	Unweighted	Weighted	Unweighted
Panel v-statistic	-0.20	-0.10	N/A
Panel rho-statistic	1.58	1.52	2.09
Panel PP-statistic	1.42	1.34	1.85
Panel ADF-statistic	2.11	1.99	2.54

<Type 4 countries>

Test statistics	Within-dimension test		Between-dimension test
	Unweighted	Weighted	Unweighted
Panel v-statistic	-0.82	-0.76	N/A
Panel rho-statistic	1.33	1.23	1.50
Panel PP-statistic	0.99	0.85	1.20
Panel ADF-statistic	2.96	2.86	3.46

Note: (1) Pedroni panel cointegration test proposed by Pedroni (1999, 2004); (2) Type 1 countries represent high financial restriction-net external credit countries such as Malaysia, Thailand, and Russia; Type 2 countries represent low financial restriction-net external credit countries such as Norway and Switzerland; Type 3 countries represent low financial restriction-net external debt countries such as Peru, Canada and New Zealand; Type 4 countries represent high financial restriction-net external debt countries such as Indonesia, Philippines and Brazil; (3) The null hypothesis is that there exists no cointegration relationship between variables; (4) The within-dimension test is based on the homogeneous alternative hypothesis that assumes the common AR coefficient in the unit root test equation for the residuals; (5) The between-dimension test is based on the heterogeneous alternative hypothesis that allows for the individual AR coefficient in the unit root test equation for the residuals; (6) The weighted test statistics are calculated with weighting component statistics by the cross-section specific long-run conditional variances. The unweighted test statistics are calculated without this weighting; (7) The equation to calculate the residuals includes both individual intercepts and individual linear trends, and the lag length is selected based on the Modified Akaike Information Criteria (MAIC); (8) *** represents significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level.

<Table 4.2> shows the Pedroni panel cointegration test results for 4 types of countries. Depending on the test statistic, the alternative hypothesis and whether weighted or unweighted,[33] a total of 11 cointegration test statistics are produced. As shown in <Table 4.2>, the Pedroni panel cointegration test fails to reject the null hypothesis of no cointegration in all 11 test statistics for all 4 types of countries. This implies that there seems to exist no long-run relationship between 6 variables in the pooling data. This result suggests that the transformed stationary data should be used for the following VAR analysis.

[33] Pedroni (1999) proposes the weighted test statistics that are calculated with weighting component statistics by the cross-section specific long-run conditional variances. Pedroni (2004) proposes the unweighted test statistics that are calculated without weighting used in Pedroni (1999). Based on Monte Carlo simulation results, Pedroni (2004) shows that the unweighted test statistics consistently outperform the weighted test statistics in terms of the small sample size properties.

Panel VAR model

This paper uses the panel VAR model suggested by Holtz-Eakin, Newey and Rosen (1988) and Love and Zicchino (2006). This technique is the combination of the VAR approach and the panel approach that allows for unobserved individual heterogeneity.

The VAR model used in this paper is based on the following reduced form:

$$Y_{it} = \Gamma(L)Y_{it} + f_i + e_{it} \tag{4.4}$$

where Y_{it} is a vector of six stationary variables of country i at period t, $\Gamma(L)$ is a matrix polynomial in the lag operator with $\Gamma(L) = \Gamma_1 L^1 + \Gamma_2 L^2 + \cdots + \Gamma_P L^P$ and P is a lag length, f_i is a vector of fixed effects of country i that represents country specific heterogeneity, and e_{it} is a vector of idiosyncratic errors. Thus, Y_{it} consists of the following six variables: percent changes of investment, consumption, CPI and the exchange rate over corresponding period of the previous year, percent point changes of the foreign interest rate and the interest rate over corresponding period of the previous year. Considering the lag length selection test result and the correlogram for the residual series, this paper uses 2 lags for the type 1 countries and 1 lag for the other type's countries.

The important issue in estimating this model is that fixed effects are correlated with regressors since regressors in this model are lags of dependent variables. Arellano and Bover (1995) show that the mean-differencing procedure used in the common panel approach to remove fixed effects produces biased coefficients in the panel VAR model. Following Love and Zicchino (2006), this paper uses the forward mean-differencing procedure proposed by Arellano and Bover (1995). This procedure transforms variables by removing the mean of all future observations available at each period. To be more specific, let $\overline{y}_{it} = \sum_{s=t+1}^{T_i} y_{is}/(T_i - t)$

denote the forward mean of y_{it}, a variable in the vector Y_{it}, where T_i represents the last period of observations available for country i. Let $\bar{\varepsilon}_{it}$ denote the same forward mean of ε_{it}, an element in the vector e_{it}. Thus, we get following transformed variables:

$$\tilde{y}_{it} = \delta_{it}(y_{it} - \bar{y}_{it}) \tag{4.5}$$

and

$$\tilde{\varepsilon}_{it} = \delta_{it}(\varepsilon_{it} - \bar{\varepsilon}_{it}) \tag{4.6}$$

where $\delta_{it} = \sqrt{(T_i - t)/(T_i - t + 1)}$. Since fixed effects are eliminated by this forward mean-differencing procedure, the final transformed model is given by:

$$\tilde{Y}_{it} = \Gamma(L)\tilde{Y}_{it} + \tilde{e}_{it} \tag{4.7}$$

In equation (4.4), we can assume the following orthogonality between lagged regressors and errors:

$$E[Y_{is}e_{it}] = 0, \quad (s < t) \tag{4.8}$$

Arellano and Bover (1995) prove that the forward mean-differencing procedure preserves the orthogonality between untransformed lagged regressors and transformed variables. Thus, we can also assume the following orthogonality between untransformed lagged regressors and transformed errors:

$$E[Y_{is}\tilde{e}_{it}] = 0, \quad (s < t) \tag{4.9}$$

This implies that the untransformed lagged regressors can be used as instruments. This paper uses the panel GMM (generalized method of moments) estimator based on the moment conditions (4.9). By stacking all T observations in equation (4.7), we can get the following for country i:

$$\tilde{Y}_i = \Gamma(L)\tilde{Y}_i + \tilde{e}_i \tag{4.10}$$

where $\tilde{Y}_i$ and $\tilde{e}_i$ are T x 6 matrices. Let X_i denote the T x (6 x P) regressor matrix that consists of lagged $\tilde{Y}_i$ s, and let Z_i denote the T x (6 x P) instrument matrix that consists of lagged Y_i s. Then, the panel GMM estimator is as follows:

$$\hat{\beta}_{PGMM} = [X'Z W_N Z'X]^{-1} X'Z W_N Z'Y \tag{4.11}$$

where $Y' = [\tilde{Y}_1 \ldots \tilde{Y}_N]$, $X' = [X_1' \ldots X_N']$, $Z' = [Z_1' \ldots Z_N']$ and W_N denotes a weighting matrix. This estimator is asymptotically normal with the following estimated asymptotic variance matrix:

$$\hat{V}[\hat{\beta}_{PGMM}] = [X'Z W_N Z'X]^{-1} X'Z W_N (N\hat{S}) W_N Z'X [X'Z W_N Z'X]^{-1} \tag{4.12}$$

where $\hat{S}$ is a consistent estimate of

$$S = \text{plim } (1/\text{N}) \sum_{\text{i}=1}^{\text{N}} Z_i' \tilde{e}_i \tilde{e}_i' Z_i \tag{4.13}$$

A White-type robust estimate of S is

$$\hat{S} = (1/\text{N}) \sum_{\text{i}=1}^{\text{N}} Z_i' \hat{e}_i \hat{e}_i' Z_i \tag{4.14}$$

where the estimated residual $\hat{e}_i = \tilde{Y}_i - X_i\hat{\beta}$, and $\hat{\beta}$ is calculated by 2SLS (two stage least squares). Since the most efficient GMM estimator uses weighting matrix $W_N = \hat{S}^{-1}$, using $\hat{S}$ in (4.14) yields the two-step GMM estimator

$$\hat{\beta}_{2SGMM} = [X'Z \hat{S}^{-1} Z'X]^{-1} X'Z \hat{S}^{-1} Z'Y \tag{4.15}$$

with the following simplified asymptotic variance matrix:

$$\hat{V}[\hat{\beta}_{2SGMM}] = [X'Z (N\hat{S})^{-1} Z'X]^{-1} \tag{4.16}$$

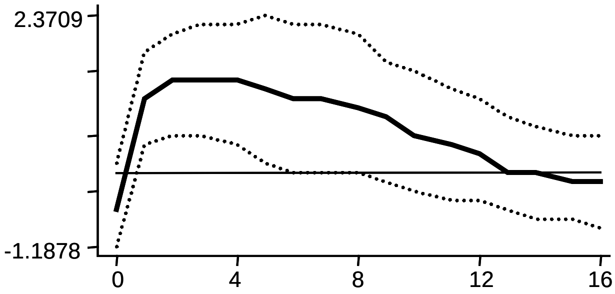
Since the number of regressors (transformed lagged regressors) equals the number of instruments (untransformed lagged regressors), this model is just-identified. In the just-identified case, the panel GMM estimator simplifies to the IV (instrumental variable) estimator for any weighting matrix (Cameron and Trivedi, 2005). This implies that the panel GMM is numerically equivalent to the equation-by-equation 2SLS (Love and Zicchino, 2006).

In the VAR model analysis, to identify the recursive structure of an economic model, parameters in the structural-form equations should be recovered from estimated parameters in the reduced-form equations. This paper imposes restrictions on contemporaneous parameters in the structural-form equations by applying Cholesky decomposition of the reduced-form residuals. In determining the order of variables, this paper applies the common rule to place contemporaneously exogenous variables first. Since this paper analyzes small open economies, this paper allows for contemporaneous effects of the foreign interest rate on domestic macroeconomic variables of a small open economy, but rules out contemporaneous effects of domestic macroeconomic variables of a small open economy on the foreign interest rate. Thus, the ordering of this paper puts the foreign interest rate before domestic macroeconomic variables of a small open economy.

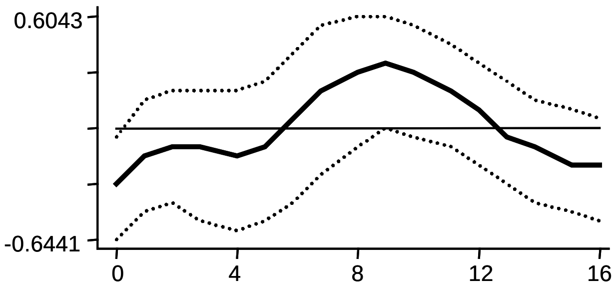
4.5. Empirical results

In the panel VAR model, this paper analyzes the following first seasonal differenced variables: (1) percent point change of the foreign interest rate YoY (hereafter, foreign interest rate change), (2) percent change rate of investment YoY (investment change), (3) percent change rate of consumption YoY (consumption change), (4) inflation rate YoY (inflation rate), (5) percent point change of the interest rate YoY (interest rate change), (6) percent change rate of the exchange rate YoY (exchange rate change).

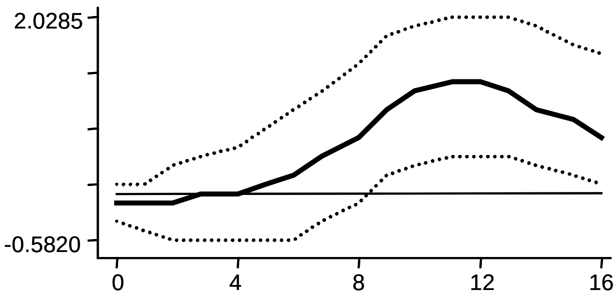
<Figure 4.3> Impulse responses of Type 1 countries



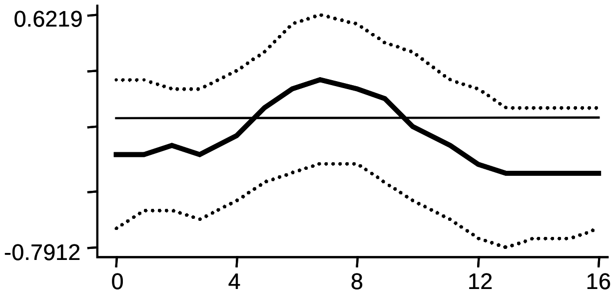
Response of investment to foreign interest rate shock



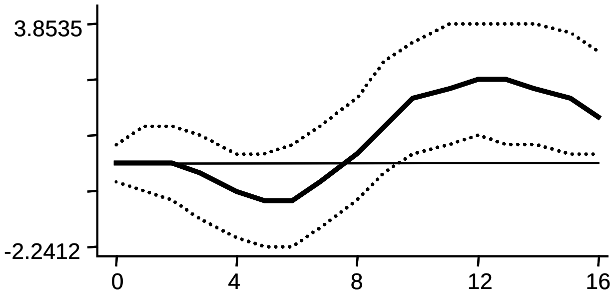
Response of consumption to foreign interest rate shock



Response of inflation rate to foreign interest rate shock



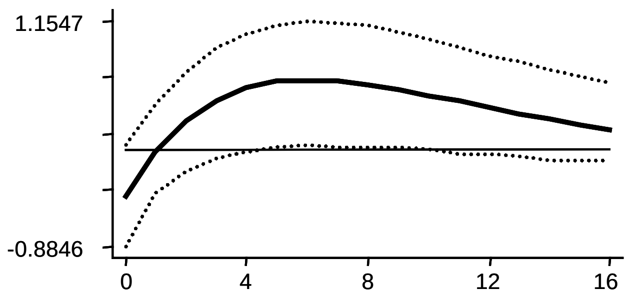
Response of interest rate to foreign interest rate shock



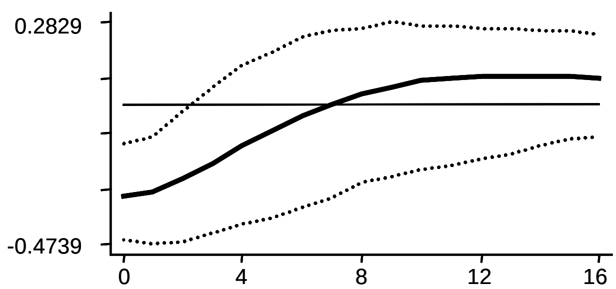
Response of exchange rate to foreign interest rate shock

Note: (1) Type 1 countries represent high financial restriction-net external credit countries such as Malaysia, Thailand, and Russia; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) In the data analyzed in this paper, the 1-standard deviation shock of foreign interest rate change represents the change of foreign interest rate by 1.5%p; (5) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (6) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

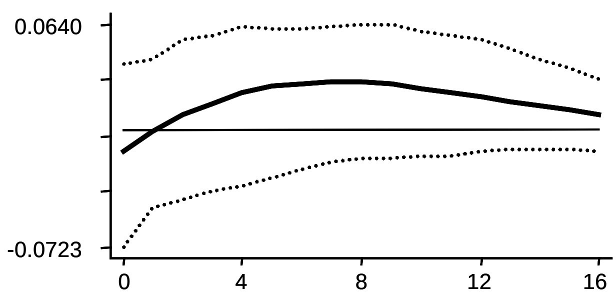
<Figure 4.4> Impulse responses of Type 2 countries



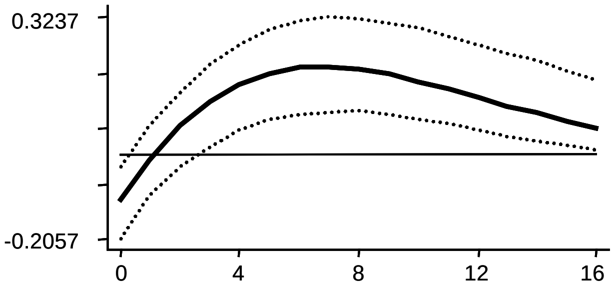
Response of investment to foreign interest rate shock



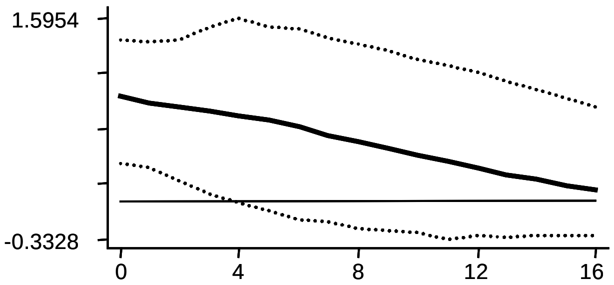
Response of consumption to foreign interest rate shock



Response of inflation rate to foreign interest rate shock



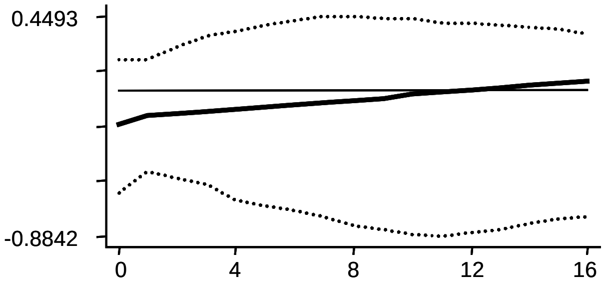
Response of interest rate to foreign interest rate shock



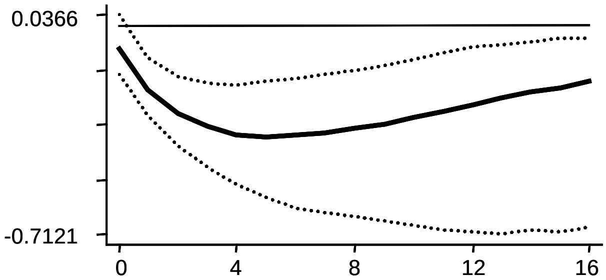
Response of exchange rate to foreign interest rate shock

Note: (1) Type 2 countries represent low financial restriction-net external credit countries such as Norway and Switzerland; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) In the data analyzed in this paper, the 1-standard deviation shock of foreign interest rate change represents the change of foreign interest rate by 1.5%p; (5) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (6) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

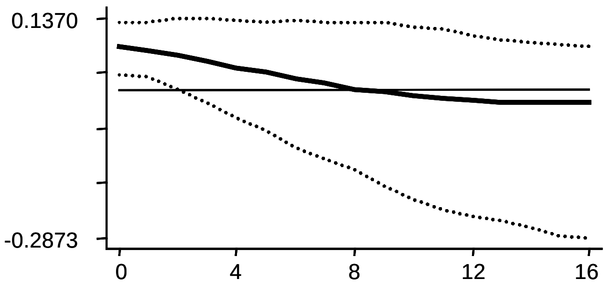
<Figure 4.5> Impulse responses of Type 3 countries



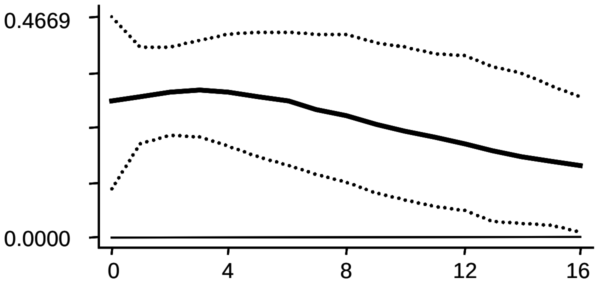
Response of investment to foreign interest rate shock



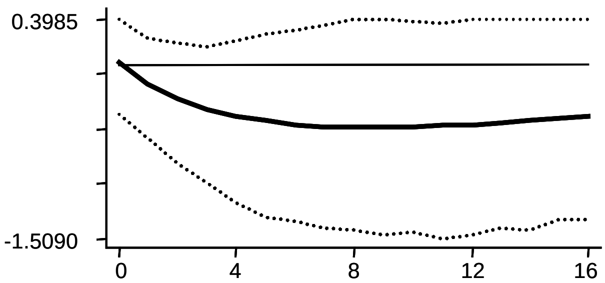
Response of consumption to foreign interest rate shock



Response of inflation rate to foreign interest rate shock



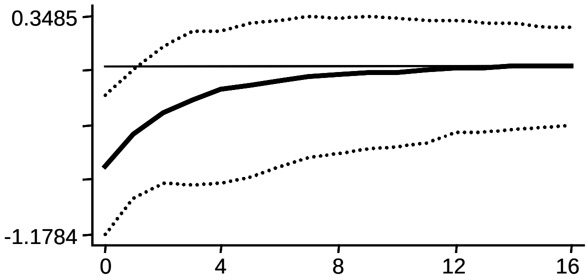
Response of interest rate to foreign interest rate shock



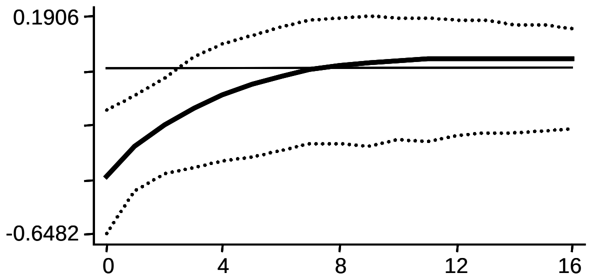
Response of exchange rate to foreign interest rate shock

Note: (1) Type 3 countries represent low financial restriction-net external debt countries such as Peru, Canada and New Zealand; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) In the data analyzed in this paper, the 1-standard deviation shock of foreign interest rate change represents the change of foreign interest rate by 1.5%p; (5) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (6) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

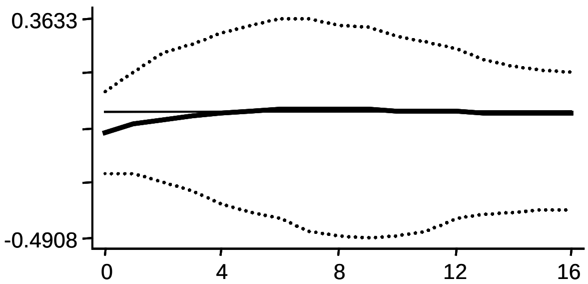
<Figure 4.6> Impulse responses of Type 4 countries



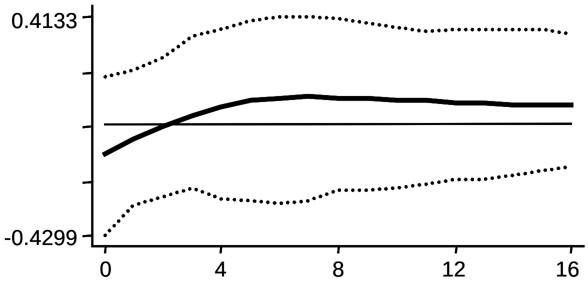
Response of investment to foreign interest rate shock



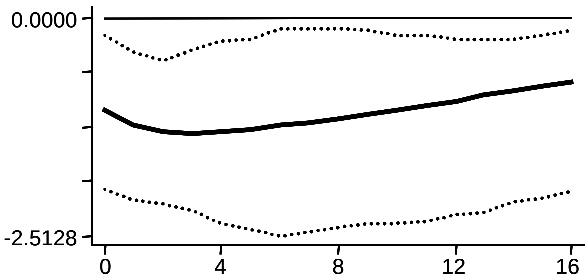
Response of consumption to foreign interest rate shock



Response of inflation rate to foreign interest rate shock



Response of interest rate to foreign interest rate shock



Response of exchange rate to foreign interest rate shock

Note: (1) Type 4 countries represent high financial restriction-net external debt countries such as Indonesia, Philippines and Brazil; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) In the data analyzed in this paper, the 1-standard deviation shock of foreign interest rate change represents the change of foreign interest rate by 1.5%p; (5) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (6) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

<Figure 4.3> through <Figure 4.6> present results of the impulse response function analysis of type 1 through type 4 countries, respectively. Bold solid lines represent impulse responses of 5 domestic macroeconomic variables of each type to 1-standard deviation shocks of foreign interest rate change.[34] Dotted lines represent ±1-standard deviation error bands calculated based on the Monte-Carlo method with 500 repetitions. Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

<Figure 4.3> shows impulse responses of type 1 countries that represent high financial restriction-net external credit countries such as Malaysia, Thailand, and Russia. Immediately following foreign interest rate hike shocks, investment change and consumption change fall instantly due to the negative portfolio reallocation effect and the negative intertemporal substitution effect. However, those responses are not significant due to high financial restriction that mutes the negative portfolio reallocation effect and the negative intertemporal substitution effect. After a few quarters, the positive wealth effect from net external credit dominates the negative portfolio reallocation effect and the negative intertemporal substitution effect. From the perspective of the intertemporal model, this positive wealth effect increases current savings as well as current consumption since the increasing interest revenue from foreign interest rate hike shocks is not permanent but temporary. Because of high financial restriction, the increase of savings increases domestic investment, which is supported by the significant rise of investment change in <Figure 4.3>. If a small open economy has a domestic financial market that is perfectly integrated with the international financial market, the increase of current saving may not increase domestic investment at all. Instead, the increasing current saving will be invested in foreign bonds instead of domestic investment due to the

[34] In the data analyzed in this paper, the 1-standard deviation shock of foreign interest rate change represents the change of foreign interest rate by 1.5%p.

rise in the foreign interest rate. Thus, foreign interest rate hike shocks may cause "real expansion" in type 1 countries with high financial restriction-net external credit due to the positive wealth effect. It is notable that the domestic interest rate does not show a significant rise in spite of foreign interest rate hike shocks. This seems to reflect the weak linkage between foreign interest rate changes and domestic interest rate changes, which stem from the high financial restriction of type 1 countries.

<Figure 4.4> shows impulse responses of type 2 countries that represent low financial restriction-net external credit countries such as Norway and Switzerland. Immediately following foreign interest rate hike shocks, investment change and consumption change fall due to the negative portfolio reallocation effect and the negative intertemporal substitution effect. Even though it lasts for a very short time, it turns out that consumption change falls significantly in spite of the expected positive wealth effect from net external credit. Considering low financial restriction, it seems that most of increasing interest revenue from foreign interest rate hike shocks is not consumed or invested domestically but is rather invested in foreign financial assets such as bonds or deposits. Thus, the domestic financial market that is highly integrated with the global financial market strengthens the negative portfolio reallocation effect and the negative intertemporal substitution effect, but weakens the positive wealth effect in type 2 countries. It is notable that the interest rate change rises significantly in response to foreign interest rate hike shocks. This implies that there exists an "interest rate co-movement" between the foreign interest rate and the domestic interest rate under enhanced financial integration. Reflecting the domestic financial market that is highly integrated with the global financial market, domestic currency depreciates significantly in response to foreign interest rate shocks, but this depreciation of the domestic currency disappears as the domestic interest rate change rises.

<Figure 4.5> shows impulse responses of type 3 countries that represent low financial restriction-net external debt countries such as Peru, Canada and New Zealand. Under foreign interest rate hike shocks on type 3 countries, the low financial restriction may have two conflicting effects. The low financial restriction may intensify the negative portfolio reallocation effect and the negative intertemporal substitution effect because it becomes easier to invest or save in foreign financial assets, rather than invest or consume domestically, by lowering the portfolio adjustment cost. On the other hand, the low financial restriction may mitigate the negative wealth effect from net external debt because it becomes easier to smooth consumption effectively by borrowing from foreign lenders with lower cost. The empirical result of this paper shows that, responding to foreign interest rate hike shocks, consumption change falls significantly due to the negative intertemporal substitution effect and the negative wealth effect. Even though investment change also falls slightly due to the negative portfolio reallocation effect, it is not significant. In particular, it is notable that both the inflation rate and the interest rate change rise significantly immediately following the foreign interest rate hike shocks. The foreign interest rate (US 3-month treasury bills rate) and the domestic interest rate (money market rate or discount rate) of a small open economy, which are analyzed in this paper, have a close relationship with a monetary policy. Thus, the rise of the domestic interest rate change responding to the foreign interest rate hike shocks may imply "coupling in monetary policy" between the monetary policy of the U.S. and the monetary policy of a small open developing country, in order to deal with inflationary pressure.[35]

<Figure 4.6> shows impulse responses of type 4 countries that represent high financial restriction-net external debt countries such as Indonesia, Philippines and

[35] Grilli and Roubini (1995) show that the monetary policy of non-U.S., G-7 countries strongly follows that of the U.S. based on the idea that the U.S. is the "leader country" that determines overall monetary policy for the G-7 area.

Brazil. Under foreign interest rate hike shocks on type 4 countries, the high financial restriction may have two conflicting effects. The high financial restriction may mitigate both the negative portfolio reallocation effect and the negative intertemporal substitution effect because it becomes more difficult to invest or save in foreign financial assets rather than invest or consume domestically. On the other hand, the high financial restriction may intensify the negative wealth effect from the net external debt because it becomes more difficult to smooth consumption effectively by borrowing from foreign lenders. The empirical result of this paper shows that, responding to foreign interest rate hike shocks, both investment change and consumption change fall significantly due to the negative portfolio reallocation effect, the negative intertemporal substitution effect, and the negative wealth effect. Thus, the foreign interest rate hike shocks may cause "real contraction" in type 4 countries with high financial restriction-net external debt. Reflecting that the domestic financial market is less integrated with the global financial market, the domestic interest rate does not show a significant rise in spite of foreign interest rate hike shocks.

To scale the contribution of foreign interest rate shocks to the variation of domestic macroeconomic variables of small open economies, this paper performs a forecast error variance decomposition analysis for 4 types of countries. <Table 4.3> shows the percentage of 10-quarters-ahead and 20-quarters-ahead forecast error variance that is explained by foreign interest rate shocks for 5 domestic macroeconomic variables analyzed in this paper.

<Table 4.3> Forecast error variances decomposition analysis result

<10 quarters ahead>

Variable	% of forecast error variances explained by foreign interest rate shocks			
	Type 1	Type 2	Type 3	Type 4
Investment change	4.3	3.6	0.2	0.8
Consumption change	1.0	2.0	11.3	1.5
Inflation rate	1.3	0.6	0.8	0.0
Interest rate change	0.3	9.1	7.1	0.1
Exchange rate change	0.6	3.8	1.4	3.7

<20 quarters ahead>

Variable	% of forecast error variances explained by foreign interest rate shocks			
	Type 1	Type 2	Type 3	Type 4
Investment change	4.4	4.6	0.2	0.8
Consumption change	1.7	2.5	15.2	1.5
Inflation rate	6.7	0.9	0.8	0.0
Interest rate change	1.1	11.9	9.0	0.2
Exchange rate change	4.4	4.1	2.8	5.3

Note: (1) Percentage fraction of n-quarter-ahead forecast error variances that is explained by foreign interest rate shocks; (2) Type 1 countries represent high financial restriction-net external credit countries such as Malaysia, Thailand, and Russia; Type 2 countries represent low financial restriction-net external credit countries such as Norway and Switzerland; Type 3 countries represent low financial restriction-net external debt countries such as Peru, Canada and New Zealand; Type 4 countries represent high financial restriction-net external debt countries such as Indonesia, Philippines and Brazil; (3) Foreign interest rate change represents the percentage point change of the foreign interest rate YoY, investment change represents the percent change rate of investment YoY, consumption change represents the percent change rate of consumption YoY, inflation rate represents the inflation rate YoY, interest rate change represents the percentage point change of the interest rate YoY, exchange rate change represents the percent change rate of the exchange rate YoY.

The result of the forecast error variance decomposition analysis seems to support the "interest rate co-movement" and the "coupling in monetary policy" hypotheses that are found in the impulse response function analysis of countries with low financial restriction. As shown in <Table 4.3>, foreign interest rate shocks explain a higher fraction of the forecast error variance in domestic interest rate change in countries with low financial restriction. In type 2 countries and type 3 countries with low financial restriction, foreign interest rate shocks explain 9.1% and 7.1% at 10-quarters-ahead, and 11.9% and 9.0% at 20-quarters-ahead. On the contrary, in type 1 countries and type 4 countries with high financial restriction, foreign interest rate shocks explain 0.3% and 0.1% at 10-quarters-ahead, and 1.1% and 0.2% at 20-quarters-ahead.

It is also noticeable that foreign interest rate shocks explain a higher fraction of the forecast error variance in consumption change in type 3 countries. In type 3 countries with low financial restriction and net external debt, foreign interest rate shocks explain 11.3% at 10-quarters-ahead and 15.2% at 20-quarters-ahead. This result seems to support the fact that foreign interest rate hike shocks cause the significant fall of consumption change in type 3 countries due to the negative intertemporal substitution effect and the negative wealth effect.

6. Conclusion

This paper suggests a new method to categorize small open economies based on the size of net external credit (or debt) and the level of financial integration. By introducing a reliable proxy number for net external credit (or debt), this categorization method overcomes the problem of the lack of official data. By using the new financial restriction data set by the IMF, this categorization method captures the intensity of financial restrictions. Based on the above two criteria, this paper classifies (1) Malaysia, Thailand, and Russia into the high financial restriction-net external credit country type, (2) Norway and Switzerland into the low financial restriction-net external credit country type, (3) Peru, Canada, and New Zealand into the low financial restriction-net external debt country type, (4) Indonesia, Philippines, and Brazil into high financial restriction-net external debt country type.

The impulse response function analysis result and the forecast error variance decomposition analysis result based on the panel VAR model shows that the effect of foreign interest rate hike shocks on domestic macroeconomic variables may differ substantially depending on the type of small open economy. Foreign interest rate hike shocks cause "real expansion" in countries with high financial restriction-net external credit. On the contrary, foreign interest rate hike shocks cause "real contraction" in countries with high financial restriction-net external debt. In countries with low financial restriction, the foreign interest rate hike shocks cause a significant rise of the domestic interest rate change, which implies "interest rate co-movement" or "coupling in monetary policy". This strong linkage between the foreign interest rate and the domestic interest rate in countries with enhanced international financial integration is supported by the fact that foreign interest rate shocks explain a higher fraction of the forecast error variance in domestic interest rate change in countries with low financial restriction.

On the whole, the empirical results of this paper are consistent with the theoretical model that is based on 3 transmission channels such as (1) the portfolio reallocation effect, (2) the intertemporal substitution effect, and (3) the wealth effect. Thus, the empirical results of this paper show that both the size of net external credit (or debt) and the level of financial restriction play an important role in transmission channels through which foreign interest rate shocks are transmitted to a small open economy. This implies that, to make more precise prediction regarding the effect of foreign interest rate shocks on a small open economy, we should consider (1) whether the country is a net creditor or a net borrower in the global financial market, (2) how the domestic financial market of the country is integrated with the global financial market. In this context, the new methodology introduced in this paper to categorize small open economies based on the size of net external credit (or debt) and the level of financial integration could be a useful tool.

Lastly, we may consider the following directions for future study related to this topic. First, to measure the extent of a country's financial integration with the global economy, this paper uses "A new data set" by the IMF, which is based on *de jure* restrictions on capital account transactions. Instead, one may use *de facto* capital flows across national borders, which is usually measured by either the ratio of gross capital inflows and outflows to GDP or the ratio of gross stocks of foreign assets and liabilities to GDP. Second, if longer time-series are available on macroeconomic variables, the net external credit (or debt), and the level of financial restriction level of small open economies, then it is possible to consider finding a structural break in the interrelationship between macroeconomic variables. The candidates for the structural break could be the Asian financial crisis in the late 1990s or the global financial crisis in 1998. If there exists a structural break, we may find the more correct interrelationship between macroeconomic variables by identifying the structural break and dividing the total period into pre-break and post-break periods.

CHAPTER V

CONCLUDING REMARKS

Chapter 2 enhances our understanding of the structural break in time-series data and the unit root test method that considers that structural break. The empirical results of chapter 2 show that the structural break point identification and the unit root test result may change substantially depending on the choice of endogenous structural break unit root test. This implies that, to find a structural break point more correctly and determine the stationarity of a variable more precisely, it is essential to understand characteristics of the endogenous structural break unit root test used. Comparing advantages and disadvantages of various endogenous structural break unit root test methods, this study points out important weak points of the LM test and the KP test that have been ignored in many preceding studies. The LM test has a low probability to identify a true break point when a variable is nonstationary, and a low power of the test when a variable is stationary. Even though the KP test has the most desirable properties as the endogenous structural break unit root test, it has the practical problem that there is no clear decision rule when unit root test results of multiple test statistics of the KP test are not consistent.

This result proposes the following future study topics regarding the application of the KP test: (1) Which data-generating process is more appropriate for the variable analyzed among the AO model and the IO model? (2) If the AO model is chosen, which test statistic is more reliable among the test statistic based on the original data and the test statistic based on the trimmed data?

In addition, the empirical result of chapter 2 provides us important information regarding time-series data of major domestic macroeconomic variables of South Korea. The Perron-Yabu test, which is valid regardless of whether a variable is stationary or nonstationary, suggests that there exists a structural break for all 5 macroeconomic variables of South Korea. It also turns out that the Asian financial crisis in the late 1990s seems to be the most significant structural break of most macroeconomic variables of South Korea for the last 20 years. Even though this result comes from the univariate analysis, this may provide useful and practical intuition for the multivariate analysis of South Korea economy. If the Asian financial crisis were also to be identified as the structural break in the multivariate analysis, it would be better for us to analyze the pre-break period and the post-break period separately. Since it is likely that the interrelationship between macroeconomic variables changes through the Asian financial crisis, we should find different interrelationships between macroeconomic variables in the pre-break period and the post-break period.

In this context, chapter 3 enlarges our understanding of the response of a small open economy to foreign interest rate shocks considering a structural break, the foreign indebtedness position, and the level of financial integration. Through the Asian financial crisis in the late 1990s, South Korea changed from the net debtor to the net creditor in the global capital market, and the domestic financial market of South Korea is more integrated with the international financial market. Thus, it seems that the pre-break period of South Korea represents the small open economy with net external debt and less integrated financial market, and the post-break period of South Korea represents the small open economy with net external credit and more integrated financial market.

The empirical results of chapter 3 show that the responses of the Korean economy to foreign interest rate shocks change substantially through the Asian financial crisis. Before the Asian financial crisis, foreign interest rate hikes cause real contraction, the fall of the domestic interest rate and the rise of the exchange rate. After the Asian financial crisis, foreign interest rate hikes cause real expansion, the rise of the domestic interest rate and the fall of the exchange rate. Regarding the effect of net external credit, this result implies that, when a small open economy has sizable net external credit instead of net external debt, the positive wealth effect may outweigh the negative portfolio reallocation effect and the negative intertemporal substitution effect of foreign interest rate hikes. Regarding the effect of financial integration, this result also implies that the enhanced financial integration of a small open economy may cause co-movement of the foreign interest rate with the domestic interest rate. According to Canova (2005) and Grilli and Roubini (1995), this implies that the effect of foreign interest rate shocks may be strengthened by the co-moving domestic interest rate of a small open economy, and the interest rate channel becomes more important in the transmission of foreign interest rate shocks. This is also supported by the forecast error variance decomposition analysis result that foreign interest rate shocks explain a higher proportion of fluctuations in financial variables of South Korea after the Asian financial crisis.

Meanwhile, we need to admit that another macroeconomic theory like the intertemporal model also might explain the empirical result of chapter 3. This implies that, to check which theoretical model is more appropriate to explain the empirical findings in the chapter 3, we may need to include in our model additional macroeconomic variables such as the balance of trade, exports, imports and capital flows. This seems to be an interesting topic for future study.

Another direction for the expansion of this issue may be to analyze other small open economies that have different levels of financial integration and external debt positions. In this vein, the chapter 4 proposes a new and useful method to categorize small open economies. Since the size of net external credit (or debt) and the level of financial integration of a small open economy play important roles in the response of that economy to foreign interest rate shocks, the new categorization method is based on the above 2 criteria. By applying this categorization method, this study classifies (1) Malaysia, Thailand, and Russia into the high financial restriction-net external credit country type, (2) Norway and Switzerland into the low financial restriction-net external credit country type, (3) Peru, Canada, and New Zealand into the low financial restriction-net external debt country type, (4) Indonesia, Philippines, and Brazil into high financial restriction-net external debt country type.

The empirical result of chapter 4 shows that the effect of foreign interest rate hike shocks on domestic macroeconomic variables may differ substantially depending on the type of a small open economy. It turns out that foreign interest rate hike shocks cause real expansion in countries with high financial restriction-net external credit while foreign interest rate hike shocks cause real contraction in countries with high financial restriction-net external debt. It also turns out that the foreign interest rate hike shocks cause a significant rise of domestic interest rate change, interest rate co-movement, in countries with low financial restriction. This strong linkage between the foreign interest rate and the domestic interest rate in countries with enhanced international financial integration is also supported by the forecast error variance decomposition analysis result. These results seem to be consistent with the result in the chapter 3 and the theoretical model based on 3 kinds of transmission channels. This implies that the information regarding foreign indebtedness position and the level of financial integration of a small open economy may contribute to the expectation regarding the response of the small open economy to foreign interest rate shocks.

Regarding future study related to this topic, we may consider applying *de facto* capital flows instead of *de jure* restrictions on capital account transactions to measure the level of financial integration of a small open economy. Another possible direction for future study may be to consider a structural break in the interrelationship between macroeconomic variables even in the analysis of multiple small open economies if we can obtain longer time-series data of those countries.

BIBLIOGRAPHY

Aizenman, Joshua & Lee, Yeonho & Rhee, Youngseop, 2007. "International reserves management and capital mobility in a volatile world: Policy considerations and a case study of Korea," *Journal of the Japanese and International Economics* 21, pages 1-15.

Amsler, Christine and Junsoo Lee, 1995. "An LM test for a unit-root in the presence of a structural change," *Econometric Theory*, 11, pages 359-368.

Andrews, Donald W K, 1993. "Tests for parameter instability and structural change with unknown change point," *Econometrica*, Vol. 61(4), pages 821-56, July.

Andrews, Donald W K & Ploberger, Werner, 1994. "Optimal tests when a nuisance parameter is present only under the alternative," *Econometrica*, Vol. 62(6), pages 1383-1414, November.

Ang, James B., 2010. "Research, technological change and financial liberalization in South Korea," *Journal of Macroeconomics*, 32, pages 457-468.

Arellano, Manuel & Bover, Olympia, 1995. "Another look at the instrumental variable estimation of error-components models," *Journal of Econometrics*, Elsevier, Vol. 68(1), pages 29-51, July.

Bai, Jushan & Pierre Perron, 1998. "Estimating and testing linear models with multiple structure changes," *Econometrica*, Vol. 66, No.1, pages 47-78.

Bai, Jushan & Pierre Perron, 2003. "Computation and analysis of multiple structural change models," *Journal of Applied Econometrics*, Vol. 18, pages 1-22.

Buch, Claudia M. & Doepke, Joerg & Pierdzioch, Christian, 2005. "Financial openness and business cycle volatility," *Journal of International Money and Finance*, Vol. 24(5), pages 744-765, September.

Cameron, A. Colin & Trivedi, Pravin K., 2005. "Microeconometrics: Methods and applications," Cambridge University Press, New York, May.

Canova, Fabio, 2005. "The transmission of US shocks to Latin America," *Journal of Applied Econometrics*, Vol. 20(2), pages 229-251.

Cho, Young Moo, 2011. "The effect of net external credit and financial integration on the response to foreign interest rate shocks: before and after the structural break of South Korea," working paper.

Christiano, Lawrence J., 1992. "Searching for a break in GNP," *Journal of Business and Economic Statistics*, Vol.10, pages 237-249.

Christiano, Lawrence J. & Eichenbaum, Martin & Evans, Charles, 1996. "The effects of monetary policy shocks: evidence from the flow of funds;" *Review of Economics and Statistics* 78, pages 16-34.

Christiano, Lawrence J. & Eichenbaum, Martin & Evans, Charles, 1998. "Monetary policy shocks: what have we learned and to what end?" *NBER Working Paper* No. 6400.

Demirel, Ufuk Devrim, 2009. 'The transmission of foreign interest rate shocks to a small-open economy: The role of external debt and financial integration," *The B.E. Journal of Macroeconomics* , Vol. 9: iss. 1, Article 3.

Ehrmann, Michael & Fratzscher, Marcel, 2009. "Global financial transmission of monetary policy shocks," *Oxford Bulletin of Economics and Statistics*, Department of Economics, University of Oxford, Vol. 71(6), pages 739-759, December.

Eichenbaum, Martin & Evans, Charles L, 1995. "Some empirical evidence on the effects of shocks to monetary policy on exchange rates," *The Quarterly Journal of Economics*, Vol. 110(4), pages 975-1009, November.

Elliott, Graham & Thomas J Rothenberg & James H Stock, (1996). "Efficient tests for an autoregressive unit root," *Econometrica*, Econometric Society, Vol. 64(4), pages 813-836.

Enders, Walter, 2004. "Applied econometric time series," second edition, New York: Wiley.

Frankel, Jeffrey A, 1992. "Measuring international capital mobility: A review," *American Economic Review*, Vol. 82(2), pages 197-202, May.

Granger, C W J, 1969. "Investigating causal relations by econometric models and cross-spectral methods," *Econometrica*, Vol. 37(3), pages 424-38, July.

Grilli, Vittorio & Roubini, Nouriel, 1995. "Liquidity and exchange rates: Puzzling evidence from the G-7 countries," Working Papers 95-17, New York University, Leonard N. Stern School of Business, Department of Economics.

Hansen, Bruce E, 1997. "Approximate asymptotic p values for structural-change tests," *Journal of Business & Economic Statistics*, Vol. 15(1), pages 60-67, January.

Harvey, I. David & Stephen J. Leybourne & Paul Newbold, 2001. "Innovational outlier unit root tests with an endogenously determined breaks in level," *Oxford Bulletin of Economics and Statistics* 63, pages 559-575.

Harvie, Charles & Mosayeb Pahlavani, 2006. "Testing for structural breaks in the Korean economy 1980-2005: An application of the Innovational Outlier and Additive Outlier Models," *Journal of the Korean Economy*, 7(2), pages 1-29.

Harvie, Charles & Mosayeb Pahlavani, 2009. "Effects of the Asian financial crisis on the Korean economy: some further empirical evidence," *The Empirical Economics letters*, Vol.8, No.9.

Heathcote, Jonathan & Perri, Fabrizio, 2002. "Financial autarky and international business cycles," *Journal of Monetary Economics*, Vol. 49(3), pages 601-627, April.

Holtz-Eakin, Douglas & Newey, Whitney & Rosen, Harvey S, 1988. "Estimating vector autoregressions with panel data," *Econometrica*, Econometric Society, Vol. 56(6), pages 1371-95, November.

Hong, Kiseok & Lee, Jong-Wha & Lee, Young Soo, 2004. "Investment by Korean conglomerates before and after the crisis," *Japan and World Economy*, Vol. 19.

International Monetary Fund. Statistics Department, 2002. " International investment position: A guide to data sources," Washington, D.C., October.

Kang, Sung Jin & Sawada, Yasuyuki, 2008. "Credit crunch and household welfare: The case of the Korean financial crisis," *The Japanese Economic Review*, Japanese Economic Association, Vol. 59(4), pages 438-458.

Kim, Dukpa & Pierre Perron, 2009. "Unit root tests allowing for a break in the trend function at an unknown time under both the null and alternative hypotheses," *Journal of Econometrics* 148, pages 1-13.

Kim, Hyesung & Heshmati, Almas & Aoun, Dany, 2006. "Dynamics of capital structure: The case of Korean listed manufacturing companies," *Asian Economic Journal*, East Asian Economic Association, Vol. 20(3), pages 275-302.

Kim, Soyoung & Roubini, Nouriel, 2000. "Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach," *Journal of Monetary Economics*, Vol. 45(3), pages 561-586, June.

Kim, Soyoung, 2001. "International transmission of U.S. monetary policy shocks: Evidence from VAR's," *Journal of Monetary Economics*, Vol. 48(2), pages 339-372, October.

Kose, M. Ayhan & Prasad, Eswar & Terrones, Marco, 2003. "Financial integration and macroeconomic volatility," IMF Working Papers 03/50, International Monetary Fund.

Kose, M. Ayhan & Prasad, Eswar S. & Taylor, Ashley D., 2011. "Thresholds in the process of international financial integration," *Journal of International Money and Finance*, Elsevier, Vol. 30(1), pages 147-179, February.

Lane, Philip R. & Milesi-Ferretti, Gian Maria, 2001. "The external wealth of nations: measures of foreign assets and liabilities for industrial and developing countries," *Journal of International Economics*, Elsevier, Vol. 55(2), pages 263-294, December.

Lee, Chien-Chiang & Chun-Ping Chang, 2008. "Trend stationary of inflation rates: evidence from LM unit root testing with a long span of historical data," *Applied Economics*, 40: 19, pages 2523-2536.

Lee, Jong-Wha & Rhee, Changyong, 2007. "Crisis and recovery: What we have learned from the South Korean experience?" *Asian Economic Policy Review*, Japan Center for Economic Research, Vol. 2(1), pages 146-164.

Lee, Junsoo & Mark C. Strazicich, 2001. "Break point estimation and spurious rejections with endogenous unit root tests," *Oxford Bulletin of Economics and Statistics*, 63:5, pages 535-558.

Lee, Junsoo & Mark C. Strazicich, 2003. "Minimum LM unit root test with two structural breaks," *Review of Economics and Statistics* 85(4), pages 1082-1089.

Lee, Junsoo & Mark C. Strazicich, 2004. "Minimum LM unit root test with one structural break," Working Papers 04-17, Department of Economics, Appalachian State University.

Love, Inessa & Zicchino, Lea, 2006. "Financial development and dynamic investment behavior: Evidence from panel VAR," *The Quarterly Review of Economics and Finance*, Elsevier, Vol. 46(2), pages 190-210, May.

Lumsdaine, Robin L. & David H. Papell, 1997. "Multiple trend breaks and the unit root hypothesis," *Review of Economics and Statistics*, 79(2), pages 212-218.

Mackowiak, Bartosz, 2007. "External shocks, U.S. monetary policy and macroeconomic fluctuations in emerging markets," *Journal of Monetary Economics*, Vol. 54(8), pages 2512-2520, November.

Maddala, G. S. & Wu, Shaowen, 1999. " A Comparative study of unit root tests with panel data and a new simple test," *Oxford Bulletin of Economics and Statistics*, Department of Economics, University of Oxford, Vol. 61(0), pages 631-52, Special I.

Madsen, Jakob & Vinod Mishra & Russell Smyth, 2008. "Are labour force participation rates non-stationary? Evidence from 130 years for G7 countries," *Australian Economic Papers*, Blackwell Publishing, Vol. 47(2), pages 166-189.

Mendoza, Enrique G, 1991. "Real business cycles in a small open economy," *American Economic Review*, Vol. 81(4), pages 797-818, September.

Narayan, Paresh Kumar, 2006. "Are bilateral real exchange rates stationary? Evidence from Lagrange multiplier unit root tests for India," *Applied Economics*, 38: 1, pages 63-70.

Narayan, Seema & Russell Smyth, 2008. "Unit roots and structural breaks in PNG macroeconomic time series," *International Journal of Social Economics*, Vol. 35 Iss: 12, pages 963-984.

Nelson, C. R. & C. I. Plosser, 1982. "Trends and random walks in economic time series," *Journal of Monetary Economics*, 10, pages 139-162.

Ng, Serena & Perron, Pierre, 2001. "LAG length selection and the construction of unit root tests with good size and power," *Econometrica*, Econometric Society, Vol. 69(6), pages 1519-1554.

Nunes, Luis C. & Paul Newbold & Chung-Ming Kuan, 1997. "Testing for unit roots with breaks: Evidence on the Great Crash and the unit root hypothesis reconsidered," *Oxford Bulletin of Economics and Statistics*, 59:4, pages 435-448.

Obstfeld, Maurice & Rogoff, Kenneth, 1995. "Exchange rate dynamics redux," *Journal of Political Economy*, vol. 103(3), pages 624-60, June.

Pedroni, Peter, 1999. " Critical values for cointegration tests in heterogeneous panels with multiple regressors," *Oxford Bulletin of Economics and Statistics*, Department of Economics, University of Oxford, Vol. 61(0), pages 653-70, Special I.

Pedroni, Peter, 2004. "Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the Ppp hypothesis," *Econometric Theory*, Cambridge University Press, vol. 20(03), pages 597-625, June.

Perron, Pierre, 1989. "The Great Crash, the Oil Shock, and the unit root hypothesis," *Econometrica*, 57, pages 1361-1402.

Perron, Pierre & Timothy J. Vogelsang, 1992. "Testing for a unit root in a time series with a changing mean: corrections and extensions," *Journal of Business & Economic Statistics*, American Statistical Association, Vol. 10(4), pages 467-70.

Perron, Pierre, 1994. "Unit root and structural change in macroeconomic time series, cointegration for the applied economist," Macmillan, London.

Perron, Pierre, 1997. "Further evidence on breaking trend functions in macroeconomic variables," *Journal of Econometrics*, Vol.80, No.2, pages 355-385.

Perron, Pierre & Xiaokang Zhu, 2005. "Structural breaks with deterministic and stochastic trends," *Journal of Econometrics* 129, pages 65-119.

Perron, Pierre, 2005. "Dealing with structural breaks", draft for *the Palgrave Handbook of Econometrics*, Vol. 1: Econometric Theory.

Perron, Pierre & Yabu, Tomoyoshi, 2009. "Testing for shifts in trend with an integrated or stationary noise component," *Journal of Business & Economic Statistics*, Vol. 27(3), pages 369-396.

Quantitative Micro Software, 2009. "EViews 7 user's guide"

Ra, Hee-Ryang, 2007. "Demand for international reserves: A case study of Korea," *The Journal of the Korean Economy*, Vol. 8, No.1, pages 147-175.

Ra, Hee-Ryang, 2008. "Financial market volatility and international reserve holding behavior: A case study for Korea, Indonesia, Philippine, and Thailand," *Global Economic Review*, 37: 3, pages 311-332.

Rogoff, Kenneth & Kose, M. Ayhan & Prasad, Eswar & Wei, Shang-Jin, 2004. "Effects on financial globalization on developing countries: Some empirical evidence," IMF Occasional Papers 220, International Monetary Fund.

Schindler, Martin, 2009. "Measuring financial integration: A new data set," IMF Staff Papers, Vol. 56, no. 1.

Schmidt, Peter & Peter C.B. Phillips, 1992. "LM Tests for a unit root in the presence of deterministic trends," *Oxford Bulletin of Economics and Statistics* 54, pages 257-287.

Sims, Christopher A. & Stock, James H. & Watson, Mark W., 1990. "Inference in linear time series models with some unit roots," *Econometrica* 58 (1): pages 161-82.

Sousa, Joao & Zaghini, Andrea, 2008. "Monetary policy shocks in the euro area and global liquidity spillovers," *International Journal of Finance & Economics*, John Wiley & Sons, Ltd., Vol. 13(3), pages 205-218.

Svensson, Lars E. O. & van Wijnbergen, Sweder, 1989. "Excess capacity, monopolistic competition, and international transmission of monetary disturbances," *Economic Journal*, Vol. 99(397), pages 785-805, September.

Uribe, Martin & Yue, Vivian Z., 2006. "Country spreads and emerging countries: Who drives whom?" *Journal of International Economics*, Vol. 69(1), pages 6-36, June.

Vogelsang, Timothy J. & Pierre Perron, 1998. "Additional tests for a unit root allowing for a break in the trend function at an unknown time," *International Economic Review*, Vol. 39(4), pages 1073-1100.

Zivot, Eric & Donald W. K. Andrews, 1992. "Further evidence on the Great Crash, the Oil Price Shock, and the unit root hypothesis," *Journal of Business and Economic Statistics*, Vol.10, No.3, pages 251-270.

APPENDIX 1. The derivation of the unit root test equation of the LM test

The following is a rearrangement of the derivation of the LM test included in Schmidt and Phillips (1992). We begin with the data generating process as given in the equation (2.4) of the main text. Let's assume that $\delta_3 = 0$ and $\delta_4 = 0$ for simplicity. Then the data generating process is:

$$\begin{aligned} y_t &= \psi + \xi t + X_t \\ X_t &= \beta X_{t-1} + \varepsilon_t \end{aligned} \tag{A1.1}$$

By iteration, it implies:

$$\begin{aligned} y_1 &= \psi + \beta X_0 + \xi + \varepsilon_t \\ y_t &= \beta y_{t-1} + \psi(1-\beta) + \xi(t+\beta-t\beta) + \varepsilon_t, \quad t = 2,\dots,T \end{aligned} \tag{A1.2}$$

When we treat the initial condition X_0 as fixed, we obtain the following log likelihood:

$$\begin{aligned} &\ln L = \text{constant} - \frac{T}{2}\ln\sigma^2 - \frac{1}{2\sigma^2}\text{SSE} \\ &\text{where SSE} = \varepsilon_1^2 + \sum_{t=2}^{T}\varepsilon_t^2 \\ &\quad = (y_1 - \psi - \beta X_0 - \xi)^2 + \sum_{t=2}^{T}[(y_t - \beta y_{t-1}) - \psi(1-\beta) - \xi(t+\beta-t\beta)]^2 \end{aligned} \tag{A1.3}$$

At the maximum, $\tilde{\sigma}^2$ = SSE/T and so the concentrated log likelihood is:

$$\ln L^* = \text{constant} - \frac{T}{2}\ln(\text{SSE}/T) \tag{A1.4}$$

This implies that the log likelihood is maximized when SSE is minimized. To derive the Maximum Likelihood Estimator (MLE) subject to the unit root null restriction $\beta = 1$, we note that, when $\beta = 1$, SSE simplifies to:

$$\text{SSE*} = (y_1 - \psi_x - \xi)^2 + \sum_{t=2}^{T} (\Delta y_t - \xi)^2 \tag{A1.5}$$
where $\psi_x = \psi + X_0$

This is minimized by the following restricted MLEs calculated by the Lagrange Multiplier (LM) method:

$$\tilde{\xi} = \text{mean of } \Delta y = \frac{(y_t - y_1)}{(T-1)}, \quad \tilde{\psi}_x = y_1 - \tilde{\xi} = \frac{(Ty_1 - y_T)}{(T-1)} \tag{A1.6}$$

Note that the estimate of $\tilde{\xi}$ comes from estimation of (A1.1) in differences[36]. Using $\tilde{\sigma}^2$ = SSE/T, we can calculate the efficient score:

$$\frac{\partial \ln L^*}{\partial \beta} = -\frac{1}{2\sigma^2} \frac{\partial \text{SSE}}{\partial \beta}$$
where
$$\frac{\partial \text{SSE}}{\partial \beta} = -2X_0 (y_1 - \psi - \beta X_0 - \xi) - 2\sum_{t=2}^{T} [(y_t - \beta y_{t-1}) - \psi(1-\beta) - \xi(t + \beta - t\beta)] \, [y_{t-1} - \psi - \xi(t-1)] \tag{A1.7}$$

If $\beta = 1$ and $\tilde{S}_{t-1} = y_{t-1} - \tilde{\psi}_x - \tilde{\xi}(t-1)$, the efficient score will be:

$$\frac{\partial \ln L^*}{\partial \beta} = \frac{1}{\sigma^2} \sum_{t=2}^{T} (\Delta y_t - \tilde{\xi}) \, \tilde{S}_{t-1}$$
since
$$\frac{\partial \text{SSE}}{\partial \beta} = -2\sum_{t=2}^{T} (\Delta y_t - \tilde{\xi}) \, \tilde{S}_{t-1} \tag{A1.8}$$

This implies that the efficient score evaluated at the restricted MLEs is proportional to the term $\sum_{t=2}^{T} (\Delta y_t - \tilde{\xi}) \, \tilde{S}_{t-1}$, which is the numerator of the estimated regression coefficient (φ) of $\tilde{S}_{t-1}$ in the regression:

[36] Since in this appendix we assume that δ_3=0 and that δ_4=0 in equation (2.4) of the main text, we can expect that Z_t=[1, t], ΔZ_t=[1], and $\tilde{\xi}$ in (A1.6) corresponds to $\tilde{\delta}$ in the equation (2.5) of the main text.

$$\Delta y_t = \text{intercept} + \phi\, \tilde{S}_{t-1} + \text{error}, \qquad t = 2,...,T \tag{A1.9}$$

Therefore, the usual t-statistic for $\varphi = 0$ is the LM unit root test statistic.

APPENDIX 2. The derivation of the equation (2.9)

The following is a rearrangement of the derivation of the equation (2.9) in Kim and Perron (2009). We begin with the following specification of Model I3:

$$y_t = z'_{t,1}\phi_1 + \psi^*(L)\, z(T_B)'_{t,2}\phi_2 + u_t \tag{A2.1}$$

where $z_{t,1} = (1,t)'$, $\phi_1 = (\mu, \beta)'$, $z(T_B)_{t,2} = (DU_t, DT_t)'$, $\phi_2 = (\mu_b, \beta_b)'$;

$A(L)u_t = B(L)\varepsilon_t$, ε_t ~i.i.d. $(0,\sigma^2)$;

$A(L)$ and $B(L)$ are polynomials in the lag operator of order $p+1$ and q ; $(1-aL)A^*(L)\, u_t = B(L)\varepsilon_t$;

the null hypothesis is $a = 1$ and the alternative hypothesis is $|\alpha| < 1$;

$\psi^*(L) = A^*(L)^{-1} B(L) = (1-\alpha L)\, \psi(L)$

This is a more general representation of the data generating process for Model I3 since breaks in the trend and the shock to the error do not have to evolve in the same way.

In particular, the term $\psi^*(L)\, z(T_B)'_{t,2}\phi_2$ in (A2.1) will be:

$$
\begin{aligned}
&\psi^*(L)\, z(T_B)'_{t,2}\phi_2 \\
&= DU(T_B)_t\,\mu_b + DT(T_B)_t\beta_b + \sum_{i=1}^{\infty}\psi_i^{\ *}\, z(T_B+i)'_{t,2}\phi_2 \\
&= D(T_B)_t(\mu_b+\beta_b) + DU(T_B+1)_{t+1}(\mu_b+\beta_b) \\
&\quad + DT(T_B+1)_t\beta_b + \sum_{i=1}^{\infty}\psi_i^{\ *}\, z(T_B+i)'_{t,2}\phi_2 \\
&= \sum_{i=0}^{k-1} D(T_B+i)_t\,[\mu_b\sum_{j=0}^{i}\psi_j^{\ *} + \beta_b\sum_{j=0}^{i}\psi_j^{\ *}(i-j+1)] \\
&\quad + DU(T_B+k)_t\,[\mu_b\sum_{j=0}^{k}\psi_j^{\ *} + \beta_b\sum_{j=0}^{k-1}\psi_j^{\ *}(k-j)] \\
&\quad + DT(T_B+k)_t\,[\beta_b\sum_{j=0}^{k}\psi_j^{\ *}] + \sum_{i=k+1}^{\infty}\psi_i^{\ *}\, z(T_B+i)'_{t,2}\phi_2 \\
&= \sum_{i=0}^{k-1} D(T_B+i)_t\,\xi_i + z(T_B+k)'_{t,2}\zeta_2 + \sum_{i=k+1}^{\infty}\psi_i^{\ *}\, z(T_B+i)'_{t,2}\phi_2
\end{aligned}
\tag{A2.2}
$$

where $\xi_i = \mu_b\sum_{j=0}^{i}\psi_j^* + \beta_b\sum_{j=0}^{i}\psi_j^*(i-j+1),\ \zeta_2' = (\mu_b\sum_{j=0}^{k}\psi_j^* + \beta_b\sum_{j=0}^{k-1}\psi_j^*(k-j),\ \beta_b\sum_{j=0}^{k}\psi_j^*)$

$$
\begin{aligned}
y_t &= z'_{t,1}\phi_1 + \sum_{i=0}^{k-1} D(T_B+i)_t\,\xi_i + z(T_B+k)'_{t,2}\zeta_2 + \sum_{i=k+1}^{\infty}\psi_i^{\ *}\, z(T_B+i)'_{t,2}\phi_2 + u_t \\
&= z'_{t,1}\phi_1 + \sum_{i=0}^{k-1} D(T_B+i)_t\,\xi_i + z(T_B+k)'_{t,2}\zeta_2 + \sum_{i=1}^{\infty}\psi_{k+i}^{\ \ *}\, z(T_B+k+i)'_{t,2}\phi_2 + u_t \\
&= z'_{t,1}\phi_1 + \sum_{i=0}^{k-1} D(T_B+i)_t\,\xi_i + z(T_B+k)'_{t,2}\zeta_2 \\
&\quad + \sum_{i=1}^{\infty}\psi_{k+i}^{\ \ *}\,[z(T_B+k)_{t,2} - \sum_{j=0}^{i-1} d(T_B+k+j)_{t,2}]'\phi_2 + u_t \\
&= z'_{t,1}\phi_1 + \sum_{i=0}^{k-1} D(T_B+i)_t\,\xi_i + z(T_B+k)'_{t,2}\zeta^*_2 + u_t^s
\end{aligned}
\tag{A2.3}
$$

where $\zeta_2^* = \zeta_2 + (\sum_{i=1}^{\infty}\psi_{k+i}^*)\phi_2,\quad s_t = \sum_{i=1}^{\infty}\psi_{k+i}^*\sum_{j=0}^{i-1} d(T_B+k+j)'_{t,2}\ \phi_2,\quad u_t^s = u_t - s_t$

Therefore we get equation (2.9) in the main text. This is the regression equation from which the KP test selects the break fraction for Model I3 ($\hat{\lambda}^{IO}$) by minimizing the sum of squared residuals.

APPENDIX 3. Applying different threshold values in categorization

Chapter 4 of this dissertation applied threshold values in its categorization of small open economies to identify evident characteristics of each category. These threshold values were 0.4 and 0.1 for the average financial restriction level, and 10% and -10% for the average net external credit ratio. These threshold values were determined by considering the overall distribution of both the average financial restriction levels and the average net external credit ratios of small open economies. As a result of applying these threshold values, the countries whose average financial restriction level is between 0.4 and 0.1 or the countries whose average net external credit ratio is between 10% and -10% were not included in the analysis in chapter 4.

As a kind of robustness check, this study also performed the same analysis by applying different threshold values in its categorization. To be more specific, the analysis in this Appendix 3 applied 0.25 (the median of 0.4 and 0.1) to the average financial restriction level and 0% (the median of 10% and -10%) to the average net external credit ratio for its categorization. Thus, the analysis in this Appendix 3 categorized small open economies into the following four categories:

(Type 1') high financial restriction-net external credit

: the average financial restriction level > 0.25 and
the average net external credit ratio > 0%

(Type 2') low financial restriction-net external credit

: the average financial restriction level < 0.25 and
the average net external credit ratio > 0%

(Type 3') low financial restriction-net external debt

: the average financial restriction level < 0.25 and the average net external credit ratio < 0%

(Type 4') high financial restriction-net external debt

: the average financial restriction level > 0.25 and

the average net external credit ratio < 0%

<Table A3.1> shows the result of the above categorization and both the average financial restriction levels and the average net external credit ratios of 20 small open economies analyzed in this Appendix 3. As a result of applying different threshold values, 9 additional countries were included in the analysis, which are represented by bold characters in <Table A3.1>.

Stationary first seasonal differenced variables were analyzed in this Appendix 3, because all variables in each of the 4 types turned out to be nonstationary by the Fisher-type panel unit root test, and also turned out to have no cointegration relationship by the Pedroni panel cointegration test. This Appendix 3 used the same panel VAR methodology suggested by Holtz-Eakin, Newey and Rosen (1988) and Love and Zicchino (2006), which was also used in chapter 4.

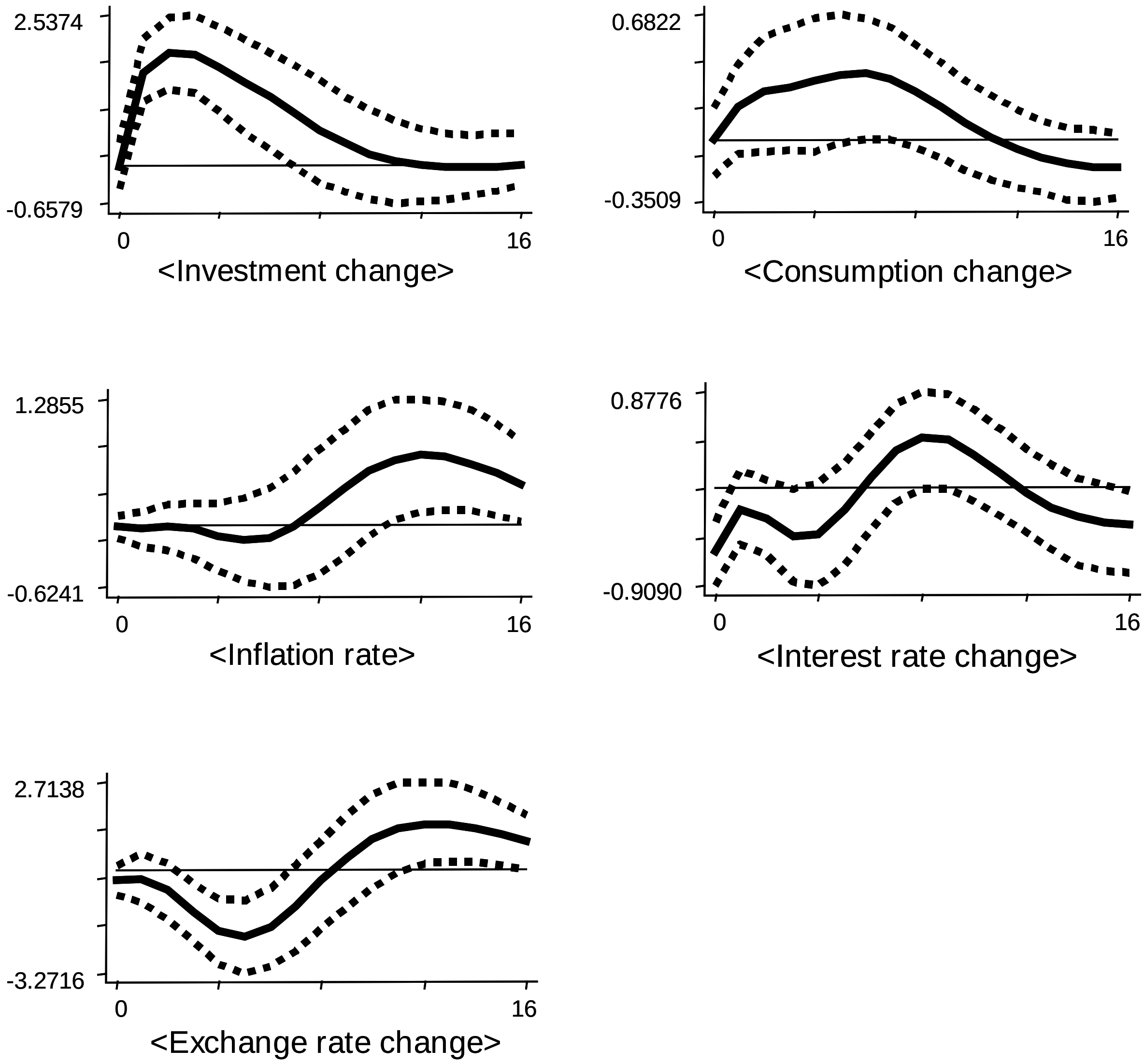
<Figure A3.1> through <Figure A3.4> present results of the impulse response function analysis of type 1' through type 4' countries, respectively. These graphs show that the overall empirical result of this appendix 3 is very similar to the empirical result explained in chapter 4, in spite of changing threshold values in the categorization of small open economies. To be more specific, foreign interest rate hike shocks cause real expansion in countries with high financial restriction-net external credit, while foreign interest rate hike shocks cause real contraction in countries with high financial restriction-net external debt. Foreign interest rate hike shocks cause a significant rise in the domestic interest rate change, which implies interest rate co-movement or coupling in monetary policy in countries with low financial restriction.

<Table A3.1> The result of new categorization and the values of two criteria

Category	Country	Average net external credit ratio (%)	Average financial restriction level
Type 1'	Russia	21.3	0.93
	Malaysia	20.3	0.84
	Thailand	22.5	0.78
	South Africa	1.9	0.66
	South Korea	9.1	0.52
	Argentina	25.3	0.40
Type 2'	**Israel**	12.7	0.24
	Bolivia	4.1	0.09
	Switzerland	123.8	0.01
	Norway	16.7	0.00
Type 3'	Peru	-11.0	0.00
	Canada	-26.4	0.09
	New Zealand	-54.7	0.09
	Iceland	-300.7	0.16
Type 4'	**Turkey**	-20.8	0.29
	Australia	-44.7	0.31
	Indonesia	-24.8	0.44
	Mexico	-3.7	0.52
	Brazil	-12.3	0.61
	Philippines	-14.3	0.75

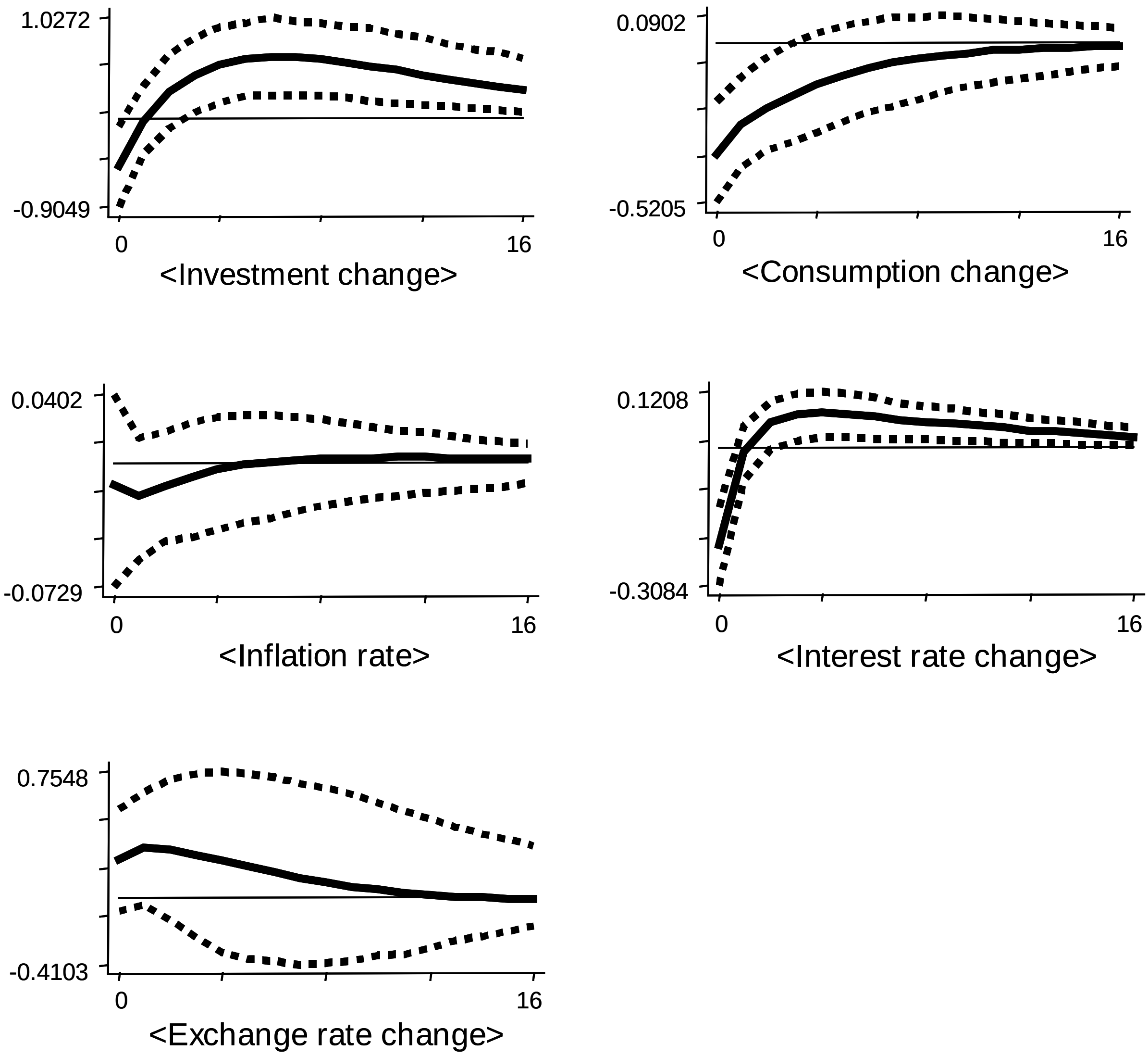
Note: (1) The average net external credit ratio represents the average of the ratio of the proxy for net external credit (or debt) to nominal GDP from 2001 to 2010; (2) The average financial restriction level represents the average of the measure of restrictions on overall cross-border financial transactions based on "A new data set" by the IMF from 1995 to 2005; (3) Type 1' represents high financial restriction-net external credit countries; Type 2' represents low financial restriction-net external credit countries; Type 3' represents low financial restriction-net external debt countries; Type 4' represents high financial restriction-net external debt countries.

<Figure A3.1> Impulse responses of Type 1' countries



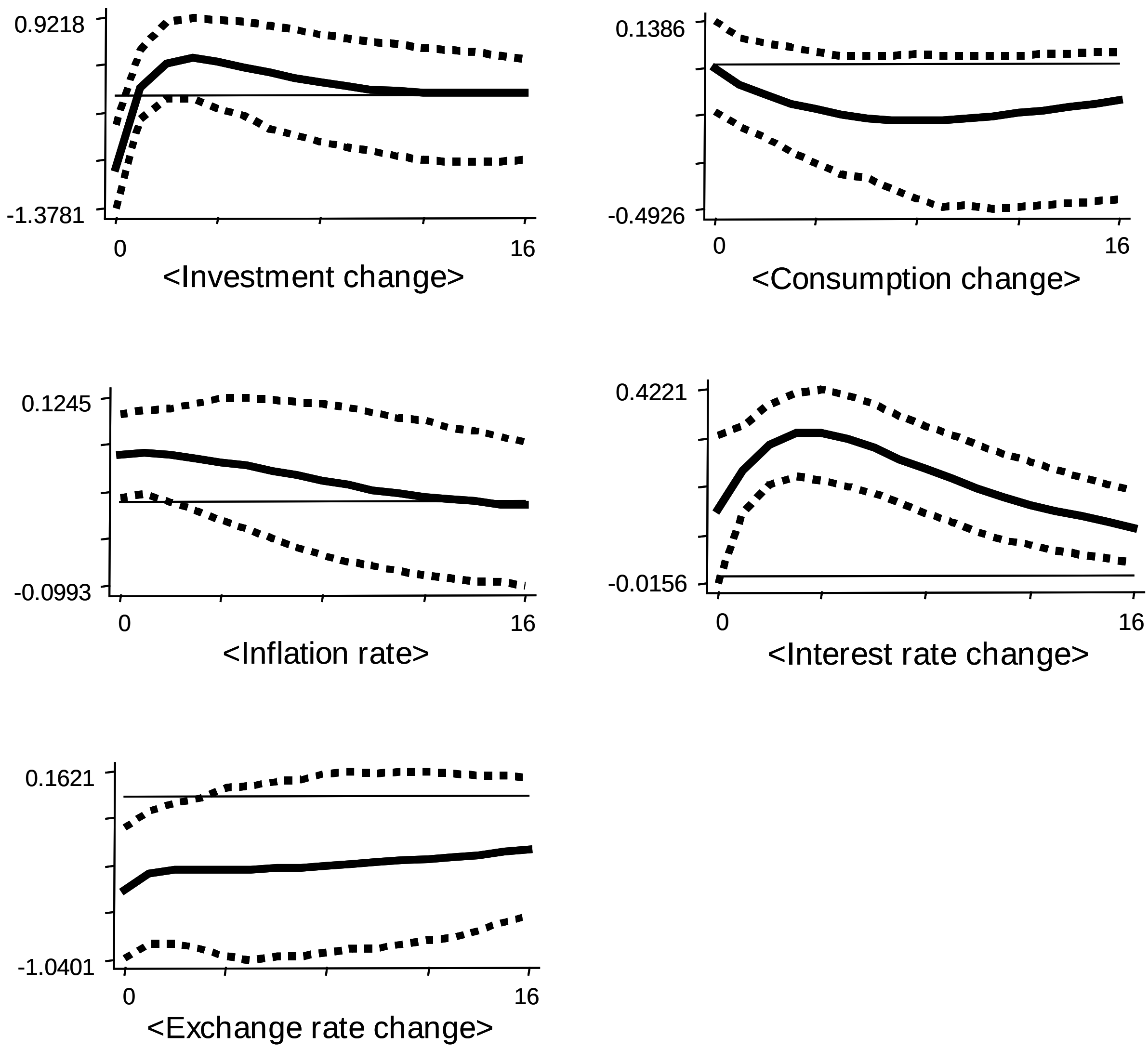
Note: (1) Type 1' countries represent high financial restriction-net external credit countries such as Malaysia, Thailand, Russia, South Africa, South Korea, and Argentina; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (5) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

<Figure A3.2> Impulse responses of Type 2' countries



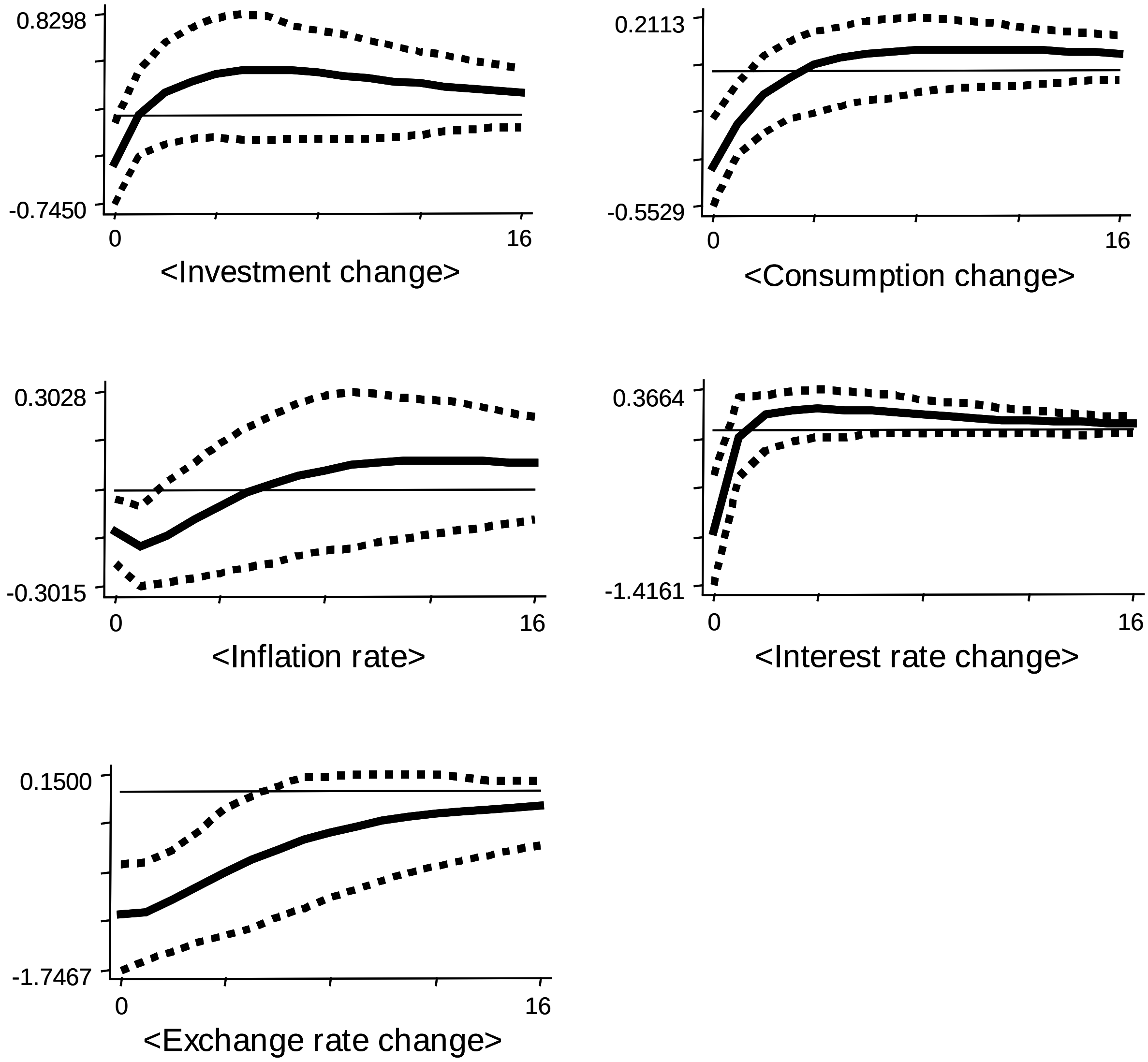
Note: (1) Type 2' countries represent low financial restriction-net external credit countries such as Norway, Switzerland, Israel, and Bolivia; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (5) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

<Figure A3.3> Impulse responses of Type 3' countries



Note: (1) Type 3' countries represent low financial restriction-net external debt countries such as Peru, Canada, New Zealand, and Iceland; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (5) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.

<Figure A3.4> Impulse responses of Type 4' countries



Note: (1) Type 4' countries represent high financial restriction-net external debt countries such as Indonesia, Philippines, Brazil, Mexico, Turkey, and Australia; (2) Investment, consumption, inflation rate and exchange rate represent percent changes over corresponding period of the previous year. Foreign interest rate and interest rate represent percent point changes over corresponding period of the previous year; (3) Bold solid lines represent impulse responses to 1-standard deviation shocks of foreign interest rate; (4) Dotted lines represent ±1-standard deviation error bands calculated by Monte-Carlo with 500 repetitions; (5) Numbers on the horizontal axis represent 16 quarters (4 years) from the shock.