The Effect of Exchange Rate Volatility on Economic Growth in South Korea

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Abstract This paper uses a three-dimensional vector autoregression model to analyze the effect of exchange rate volatility on economic growth and international trade for South Korea, before and after the Asian financial crisis of 1997. Exchange rate volatility is measured as the coefficient of variation of the real effective exchange rate. Economic growth is the quarterly growth rate of real GDP and international trade is the quarterly growth rate of exports plus imports. A onetime, one standard deviation shock to exchange rate volatility leads to a 0.6 percent increase in economic growth in the long run. In the short run however, the effect is negative. A shock to exchange rate volatility leads to an increase in international trade by 3 percent in the five subsequent years, although this effect is statistically insignificant. However, the effect in the short run is a decrease in the growth rate of trade. The Asian financial crisis of 1997 did not have an impact on the relationship between exchange rate volatility and international trade. After the crisis, the negative short-run effect and the positive medium-run effect of exchange rate volatility on economic growth were smaller than in the pre-crisis period. Nevertheless, the long-run effect remained the same.

I. Introduction

In the 1990s, Indonesia, Malaysia, Philippines, South Korea and Thailand experienced rapid economic growth and globalization. Because of their quick economic development, these countries were called the 'Tiger Economies' of the 1990s. However, the Asian financial crisis of 1997 brought an end to that period. All five countries had a large short-term external debt to foreign reserves ratio (Radelet & Sachs, 1998). In the early 1990s, this did not lead to any problems, because the exchange rate was relatively stable, so the domestic price of foreign debt remained stable as well. However, the underlying problems were exposed in 1997, when investors started to withdraw their capital from the Asian countries, leading to steep devaluations of the currencies (Radelet & Sachs, 1998). Thailand was the first victim of a speculative attack and the Thai baht depreciated quickly. Because Thailand had difficulties responding to the attack, there was a signal that other countries may also be vulnerable to similar attacks. As a result of this signaling effect, other Asian countries followed Thailand soon and their currencies depreciated. South Korea got in severe liquidity and financial problems in November 1997, and therefore called for the assistance of the International Monetary Fund. Between October and December 1997, the Korean won depreciated dramatically, from 900 won per US dollar to almost 2000 won per US dollar at the end of December. This put Korea in a severe recession, with a negative real growth rate of 7% in the first quarter of 1998. As part of the structural reform package, Korea decided to adopt an independently floating exchange rate to prevent similar speculative attacks from happening. In the decades before the crisis, Korea had adopted several exchange rate regimes. In the 1990s, the regime could be characterized as a managed floating exchange rate regime (Tiwari, 2003). Between 1990 and 1997, the Korean won to US dollar exchange rate depreciated very gradually from 680 to 850 won per dollar. The exchange rate was thus relatively stable. However, after Korea adopted a fully floating exchange rate regime, the nominal exchange rate became more volatile.

In the academic literature it is generally accepted that flexible exchange rates lead to higher exchange rate volatility, compared to fixed exchange rates (Wilson & Ren, 2008). Whether a fixed or a flexible exchange rate regime is more appropriate for a country, depends on the characteristics of the economy and the shocks it faces (Crosby, 2001). In the academic literature, there is no consensus on the effect of exchange rate volatility on economic growth. Because exchange rate volatility increases foreign transaction costs, high volatility can hurt international trade. Assuming international trade and economic growth are positively associated, an increase in volatility thus has a negative effect on economic growth (Crosby, 2001). On the other hand, flexible, and more volatile, exchange rates enable countries to react to asymmetric shocks, thereby stimulating economic growth. Volatility also decreases the possibility of a speculative attack, which was the trigger of the Asian financial crisis (Schnabl, 2008).

The empirical findings are mixed as well, although most results point towards a negative effect on international trade or economic growth. High exchange rate volatility is found to have a negative effect on economic growth in emerging markets in Eastern Europe and Asia (Schnabl, 2008). On the other hand, Qian and Varangis (1994) find a positive relationship between volatility and exports for some countries, and a negative relationship for other countries. They suggest that the effect on exports is dependent on the currency of invoicing. If exports are invoiced in the exporter's currency, there is a positive effect of exchange rate volatility on exports (Qian & Varangis, 1994).

There appears to be no theoretical or empirical consensus on the effect of exchange rate volatility on economic growth. The aim of this paper is to analyze this effect for South Korea. Therefore, the research question is:

What is the effect of exchange rate volatility on economic growth in South Korea, before and after the Asian financial crisis of 1997?

Exchange rate volatility is measured as the coefficient of variation of the real effective exchange rate (REER). Economic growth is defined as the quarterly growth rate of real GDP, compared to the previous quarter and seasonally adjusted. Furthermore, as an approximation of international trade, the sum of exports plus imports is used. It is rather difficult to isolate the effect of exchange rate volatility on economic growth or international trade, because many other variables have a significant effect as well. This problem can be resolved by using panel data and an instrumental variable, or by using a vector autoregression model. A vector autoregression model estimates the variables as a multivariate series, which captures the dynamics better. Furthermore, it deals with the endogeneity of variables by only including lagged values as explanatory variables.

This paper aims to contribute to the existing literature by examining the case of South Korea specifically, and to examine if the Asian financial crisis had a significant effect on the relationship between exchange rate volatility and economic growth. There is already research into this area, although at that time the crisis was still recent. This paper uses a wider range of data to better capture the long-run effects after the crisis. Furthermore, South Korea is chosen because its post-crisis exchange rate regime can be characterized by an independently floating regime, whereas the other crisis countries' currencies were less flexible (Tiwari, 2003). Since a floating exchange rate is likely to lead to a greater contrast with the pre-crisis period, South Korea is an interesting case to analyze.

The structure of this paper is as follows. The next section constructs a theoretical framework, where the causes of the Asian financial crisis are discussed. Furthermore, a more detailed research into the theoretical and empirical findings on the effects of exchange rate volatility on economic growth and international trade is given. Based on this theoretical framework, four hypotheses are proposed in order to answer the research question. Section 3 describes the data and gives further motivation for the research question. The methodology of this research is described in section 4, where the model is explained and the basis for the empirical research is constructed. The next section describes the results of the empirical research. Robustness checks are performed in the following section and in the last section a conclusion is given, where limitations and suggestions for further research are also discussed.

II. Theoretical framework

Asian financial crisis

The Asian financial crisis of 1997 occurred after a series of steep depreciations of the Thai, Malaysian, Philippine, Indonesian, and Korean currencies. These countries were hit because they had a large short-term foreign debt-to-reserves ratio and a successful speculative attack on Thailand sent out a signal that a similar attack might be possible for other countries as well. Table 1 shows these ratios, where short-term debt is defined as short-term foreign debt to international banks, and reserves as the foreign exchange reserves at the central bank (Radelet & Sachs, 1998). These ratios were either already at a high level, or they increased rapidly within three years. Mexico and Argentina were hit by a crisis in 1994, when they had similar foreign debt to reserves ratios as Indonesia, Korea and Thailand in 1997. On the other hand, Taiwan had a very low ratio, and suffered little from the crisis. Malaysia and the Philippines also did not have a high ratio, although the ratio increased with a factor of around 2 or 3, respectively. Still, the ratio was not high compared to other Asian countries, but they may have been victim of a signaling effect. Because the situation in Thailand was worrisome, foreign investors thought that it might be the same in other East-Asian developing countries, leading to speculative attacks. Radelet and Sachs (1998) find evidence that a large short-term foreign debt-to-reserves ratio significantly increases the probability of a financial crisis.

Table 1. Short-term foreign debt-to-reserves ratio

Country	June 1994	June 1997
Argentina	1.325	1.210
Indonesia	1.724	1.704
Korea	1.623	2.073
Malaysia	0.252	0.612
Mexico	1.721	1.187
Philippines	0.405	0.848
Taiwan	0.189	0.244
Thailand	0.992	1.453
Venezuela	0.808	0.275

Source: Radelet and Sachs (1998)

The crisis emerged when investors withdrew their funds from Thailand, leading to a large depreciation of the Thai baht. Once this speculative attack proved to be successful, investors did the same in other countries with similar debt positions, because of the signaling effect. Following the depreciations, even more foreign capital was withdrawn from the countries, putting a huge amount of pressure on the countries' abilities to pay off the foreign debt with the foreign exchange reserves. Consequently, these reserves were decreasing quickly (Radelet & Sachs, 2000). This large outflow of capital had a very negative effect on the economies, because most of the foreign debt was short-term and denominated in foreign currency. Since the debt had a short maturity, less than a year, it had to be rolled over often, leading to an increasing outflow. This outflow was not matched by an increasing inflow, because the currencies were expected to depreciate further, making foreign investments in the Asian countries less attractive. Moreover, because the debt was denominated in foreign currency, and the domestic currency was quickly losing its value, the cost of external debt in domestic currency rose rapidly. This steep depreciation even pushed healthy firms into liquidity problems (Hahm & Mishkin, 2000).

Table 2. Macroeconomic fundamentals South Korea

	1991	1992	1993	1994	1995	1996	1997	1998
Fiscal surplus / GDP	-1.9	-0.7	0.3	0.5	0.4	0.3	-1.5	-4.2
Current account / GDP	-2.82	-1.25	0.29	-0.96	-1.74	-4.42	-1.71	12.46
REER[1)]	93.5	98.8	100.9	98.3	98.0	96.0	104.6	131.1
CPI inflation	9.3	6.3	4.8	6.2	4.5	4.9	4.5	7.5
Real GDP growth	9.2	5.4	5.5	8.3	8.9	6.8	5.0	-5.8
Gross savings ratio	37.3	36.4	36.2	35.5	35.5	33.8	33.4	33.2

[1)] A value below 100 indicates overvaluation.
Source: Hahm and Mishkin (2000)

A striking point is that the Asian countries appeared to have strong economies at first. Table 2 shows the macroeconomic fundamentals for South Korea. Korea had a healthy fiscal policy, a stable inflation rate, rapid GDP growth, and a relatively high savings rate. The main question that arises is how it could happen that these apparently strong emerging economies were hit by a currency crisis, leading to a financial crisis. There are several views on the causes of the crisis. Hahm and Mishkin (2000) argue that for South Korea it is mainly the consequence of asymmetric information in the financial sector. Asymmetric information problems can arise in various ways. When the balance sheets in the financial sector deteriorate, financial institutions can either attract capital or decrease lending. Since new capital can only be obtained at a high cost, they will choose the latter option. This leads to an economic slowdown, or in extreme cases, to a credit crunch, a sudden contraction in the supply of loans. A credit crunch can evolve into a banking panic when it forces financial institutions to go bankrupt. (Hahm & Mishkin, 2000). This also seemed to be the case for Korea. Although the economy was growing at a high rate, external liabilities grew at more than 30% per year, deteriorating the balance sheets of Korean financial institutions and making them more vulnerable to a crisis (Hahm & Mishkin, 2000).

Furthermore, an increase in the lending interest rate will lead to credit rationing, when there is asymmetric information (Stiglitz & Weiss, 1981). If the bank cannot fully observe the risk of the investment project, there is adverse selection. By increasing the interest rate, the bank mainly attracts risky investment projects, which have a large probability of default (Stiglitz & Weiss, 1981). In the years before the crisis, the non-performing loans ratio decreased or remained stable in Korea and other crisis countries (Radelet & Sachs, 1998). However, Hahm and Mishkin (2000, p. 15) use a different measure for Korea, using potentially non-performing credit, which is the borrowing of corporate firms with an interest coverage ratio less than one. They find that in the years prior to the crisis, bank asset quality decreased and the ratio of latent non-performing loans to total financial credit increased from 17 to 26 percent in only two years. Furthermore, the return on assets for the 30 largest *chaebols*[1] decreased between 1995 and 1997 (Hahm & Mishkin, 2000). This indicates that credit rationing was real, because banks invested in risky projects, which can be seen from the decreasing asset quality and higher latent non-performing loans ratio. Other examples of asymmetric information are an increase in uncertainty and a deterioration of the balance sheets in the non-financial sector, which are supported by the data for Korea (Hahm & Mishkin, 2000).

[1] *Chaebols* are large Korean conglomerate companies who are active in almost every economic sector and thus have economic, but also political power.

Another well-recognized factor was the financial liberalization that was implemented in the early 1990s. Short-term capital markets were opened up to foreign investors, whereas there were still capital restrictions for long-term capital markets. This led to a mismatch between short-term external debt, and long-term domestic assets. The mismatch contributed significantly to the financial crisis (Hahm & Mishkin, 2000). Financial liberalization can lead to a decrease in asset quality and a rapid credit expansion. Credit indeed expanded rapidly, but the increasing trend was not affected by the liberalization (Hahm & Mishkin, 2000). Furthermore, credit growth was more rapid in other crisis countries, therefore it is unlikely that the financial liberalization was the main cause of a lending boom in Korea and its contribution should not be exaggerated (Hahm & Mishkin, 2000).

On the other hand, Radelet and Sachs (1998) view the financial liberalization as the main cause of the financial crisis in Korea. It is suggested that the poorly managed liberalization did cause credit to expand more rapidly. The credit expansion led to a very high short-term external debt to reserves ratio, which made the Korean economy vulnerable. Because of the liberalization, investments were poorly managed, unproductive, and contributed for a great deal to the crisis in Korea (Radelet & Sachs, 1998). The financial liberalization facilitated the growth of crony capitalism, where *chaebols* could obtain cheap loans and use it for expansion, not necessarily the most productive investments. In the 1990s, the debt to equity ratio was around 3 in Korea, much higher than in other, comparable, countries, as shown in table 3 (Choi, 1999).

Table 3. Debt-to-equity ratio

Country	**Debt-to-equity ratio**
Korea	3
30 largest *chaebols* in Korea	3.8
Japan	2.1
United States	1.7
Taiwan	0.87

Source: Choi (1999)

For Radelet and Sachs (1998), this was a reason to prefer the financial system before the liberalization, because it was more stable and entailed fewer risks. They give a large role to the financial liberalization as a cause of the crisis, but do not consider it as a necessary step in the economic development of Korea. During the authoritarian regimes in the decades before the crisis, the Korean economy was characterized by leveraged growth. Mainly *chaebols* were able to attract cheap loans from the government, giving rise to crony capitalism (Choi, 1999). This type of system was unsustainable, therefore financial liberalization was necessary. Radelet and Sachs (2000) do have a point that the liberalization was poorly executed, since it enabled the maturity mismatch between short-term liabilities and long-term assets. If the liberalization had included long-term capital markets, the problems might have been less severe.

Exchange rate volatility and economic growth

Before the Asian financial crisis, the crisis countries had a more or less fixed exchange rate regime, which was abandoned by 4 out of 5 crisis countries including Korea. After the crisis, Korea adopted an independent floating exchange rate regime. However, this change led to an increase in exchange rate volatility (Tiwari, 2003). Using a counterfactual analysis, Wilson and Ren (2008) find that Korea could benefit from a hypothetical unilateral basket peg or common basket peg, which would reduce exchange rate volatility. Generally, exchange rates exhibit higher volatility under floating than under fixed exchange rates (Mussa, 1986). The short-term variability of the exchange rate is much higher under floating exchange rates, which cannot be explained by the variability in underlying ratios of national price levels (Mussa, 1986). Furthermore, under a floating exchange rate regime, a change in the real exchange rate is more persistent (Mussa, 1986). However, there are exceptions to this generality, because the exchange rate of the Dutch guilder to the Deutsch Mark between the 1970s and 1980s was very stable, even though officially the countries adopted a floating exchange rate. However, since the Netherlands followed German monetary policy, the exchange rate had a low volatility, almost close to zero. Nevertheless, Mussa (1986) finds supportive evidence for several developed countries that a floating exchange rate leads to higher exchange rate volatility.

A common informal explanation for the increase in exchange rate volatility after a switch from a fixed rate a flexible exchange rate regime, is that volatility is ‘bottled up’ in a fixed exchange rate regime (Rose, 1996). Once the system collapses, this ‘bottled up’ volatility is released, so that floating exchange rates are more volatile after the regime change. However, Rose (1996) does not find empirical evidence for such inter-temporal tradeoff of exchange rate volatility. Rose (1996) further argues that since fixed exchange rate regimes do not shift exchange rate volatility, they reduce it. Therefore exchange rate volatility is non-fundamental and can be largely eliminated by using fixed exchange rates, which entails few macroeconomic costs.

After the crisis, exchange rate volatility has increased in Korea. This confirms the general case for a transition from a fixed to a floating exchange rate regime. Fixed exchange rate regimes do not ‘bottle up’ exchange rate volatility, but they instead reduce it. Therefore, the increase in exchange rate volatility is not a special phenomenon. However, this does not tell whether the increase in exchange rate volatility also had an impact on economic growth.

The optimal choice of exchange rate regime depends on the type of shocks a country faces. Using the Mundell-Fleming model, which assumes fixed prices and imperfect capital mobility, the effect of certain shocks under floating and fixed exchange rates can be analyzed. Under a floating exchange rate, an expansionary monetary shock leads to a depreciation of the exchange rate. This depreciation leads to more exports and less imports; a positive demand shock. In the end, the interest rate has decreased, the exchange rate has depreciated, income has increased and the current account balance has improved.

An expansionary monetary shock under fixed exchange rates reduces interest rates, increases income and deteriorates the current and capital account in the short run. However, the increase in money supply is offset by the decrease in foreign reserves, so in the long run the only change is a fall in the reserves. The interest rate, income and the balance of payments have not changed. Comparing the case under fixed and floating exchange rates, a floating exchange rate is preferable when a country faces an expansionary monetary supply shock. On the other hand, a negative shock would hurt the economy more under floating, than under fixed exchange rates.

A positive demand shock, for example fiscal expansion, leads to an increase in income and the exchange rate under floating exchange rates. The demand shock leads to more income and imports, resulting in a deterioration of the current account. The increase in the interest rate leads to an appreciation of the exchange rate, which in turn has a negative effect on demand. Therefore, the increase in income is partially offset but the overall effect on income is still positive.

Regarding the case of fixed exchange rates, a positive demand shock leads to a higher interest rate and more income in the short run. The higher interest rate attracts foreign capital, leading to an increase in reserves. In the long run the interest rate falls a little, because the increase in foreign reserves increases money supply, and the overall balance of payments decreases to zero, whereas the current account is in deficit. In the long run, income increases even more than in the short run. Therefore, fixed exchange rates are more desirable when the country faces a positive demand shock.

Exchange rate volatility can be beneficial to economic growth, since it enables countries to react to asymmetric shocks. A quick adjustment to a shock leads the economy to reach equilibrium faster. Volatility also decreases the probability for speculative attacks and overheating (Schnabl, 2008). On the other hand, exchange rate volatility increases transaction costs and therefore decreases international trade. Assuming international trade and economic growth are positively associated, exchange rate volatility thus decreases economic growth. This effect is worse when firms are more risk-averse, have less opportunities to hedge against risks and the greater is the share of foreign revenues (Crosby, 2001).

Exchange rate volatility is higher under a flexible exchange rate regime, and it is likely to have a negative effect on trade and growth. However, these arguments consider exchange rate volatility as an autonomous phenomenon. Evidence shows that a fixed exchange rate regime reduces exchange rate volatility, but fixed exchange rates have an effect on economic growth through different channels as well. The Asian financial crisis is a good example of the problems of fixed exchange rates. The currencies were overvalued, so the central bank had to buy domestic currency and sell foreign exchange to maintain the official exchange rate. Even though Korea did not have a hard peg against the dollar, they maintained a relatively stable exchange rate. When investors supplied more of the domestic currency and demanded more foreign currency, e.g. dollars, the reserves started to decrease quickly. Furthermore, the currencies depreciated rapidly, putting great pressure on the foreign reserves of the central banks. Eventually, the fixed exchange rate regime collapsed. The case for a fixed exchange rate regime, on the basis of a reduction in exchange rate volatility, does not consider a fixed exchange rate at an overvalued level. The effect of the collapse on economic growth was very negative. Exchange rate volatility was lower before the crisis, but it came at the cost of a currency and financial crisis, and a deep recession. Considering this, the costs of a fixed exchange rate regime may outweigh the benefits of lower exchange rate volatility. In other words, for a floating exchange rate regime, the benefits of a floating exchange rate regime may outweigh the costs of higher exchange rate volatility.

Exchange rates are not the only field of economics which makes a reference to volatility. It is also an important concept in finance and especially in option pricing. Following the Black-Scholes model, an increase in the volatility of the underlying asset leads to a higher valuation of the option (Black & Scholes, 1973). When volatility is higher, the probability of a good outcome increases, and therefore the value of the option increases as well. Relating this to exchange rate volatility, a small depreciation is often related to an increase in competitiveness, and therefore an increase in exports and economic growth[2]. With higher exchange rate volatility, this event is more likely to occur, and therefore exchange rate volatility and economic growth are positively related.

Although most of the theoretical literature points towards a negative relationship between exchange rate volatility and economic growth, there is no general consensus. The same holds for the empirical literature. Koray and Lastrapes (1989) find a negative effect of permanent shocks to volatility on imports. The effect is larger for flexible exchange rate regimes than for fixed exchange rate regimes, although this relationship is weak for temporary shocks (Koray & Lastrapes, 1989). However, these results may be country-specific, since Qian and Varangis (1994) find mixed evidence using an ARCH-in-mean model. An increase in exchange rate volatility by 10 percent decreased Canadian and Japanese exports to the United States by 7.4 and 3 percent, respectively (Qian & Varangis, 1994). On the other hand, an increase in exchange rate volatility increased total exports for Sweden by 4.7 percent. These results indicate the effect of exchange rate volatility on exports is country-specific. This can be explained by a theoretical model that examines the effect between invoicing and international trade. Floating and more volatile exchange rates can have a positive effect on exports, when the invoices are denominated in the exporter's domestic currency (Qian & Varangis, 1994). However, when the invoices are denominated in the importer's currency, there is a negative relationship between exchange rate volatility and exports. The negative effect of exchange rate volatility on economic growth is supported by panel data for emerging countries in Eastern Europe and East Asia (Schnabl, 2008).

Schnabl (2008) further argues that a part of the exchange rate volatility can be explained by volatility in the macroeconomic fundamentals. However, this argument is not without controversy. The quest for the root of exchange rate volatility takes an important place in international macroeconomics, but still no conclusive answer can be given. Flood and Rose (1999) argue that macroeconomic fundamentals are irrelevant in explaining exchange rate volatility. Using the monetary model of exchange rates, they find that neither volatility in money supply, nor in output, interest rates and in the combination of these variables can sufficiently explain the volatility in exchange rates (Flood & Rose, 1999).

[2] However, a large depreciation can have devastating effects on the economy, as shown by the Asian financial crisis of 1997

To conclude, the literature shows that flexible exchange rate regimes experience higher volatility, compared to fixed exchange rate regimes. Furthermore, the volatility in exchange rates cannot be explained by volatility in macroeconomic fundamentals. Finally, the relationship between exchange rate volatility and economic growth is widely disputed, but evidence points towards a negative relationship. Based on the theoretical framework constructed above, this paper tests the following hypotheses in order to answer the research question.

H_1: Exchange rate volatility has a negative effect on the growth rate of real GDP for South Korea.
H_2: After the Asian financial crisis of 1997, the negative effect of exchange rate volatility on the growth rate of real GDP increased, compared to before the crisis.
H_3: Exchange rate volatility has a negative effect on the growth rate of trade for South Korea.
H_4: After the Asian financial crisis of 1997, the negative effect of exchange rate volatility on the growth rate of trade increased, compared to before the crisis.

III. Data

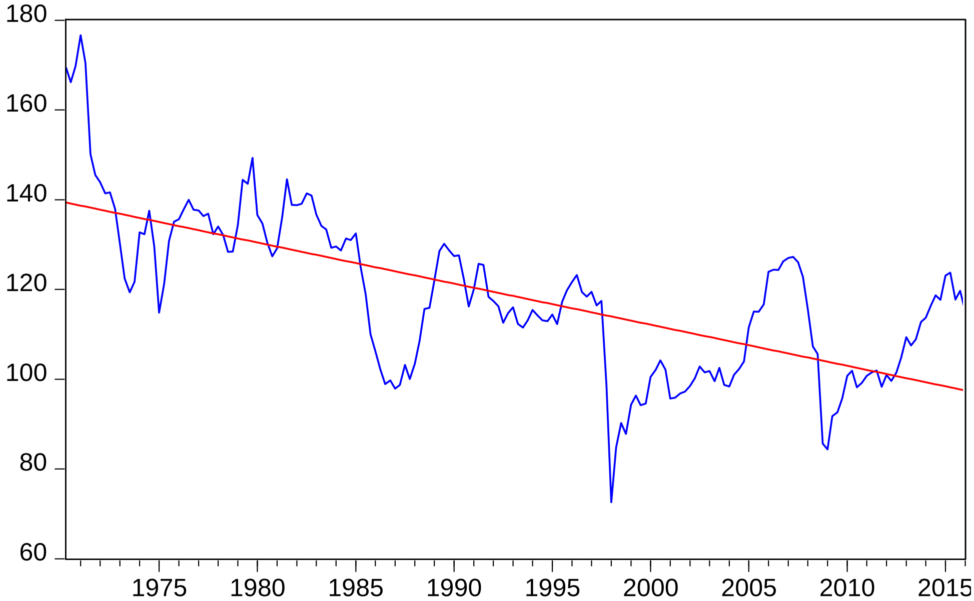
In this paper, exchange rate volatility is measured as the coefficient of variation of the real effective exchange rate.

$$Coefficient\ of\ variation = \frac{standard\ deviation\ over\ 2\ years}{mean\ real\ effective\ exchange\ rate\ over\ 2\ years}$$

The standard deviation and mean are computed over a rolling window of two years. This paper uses quarterly data, so each period includes eight observations, and every new period one quarter is dropped and a new one is added. Data for the REER for Korea are obtained from the Bank of International Settlements (BIS). The coefficient of variation is not the only measure of exchange rate volatility. For example, Wilson and Ren (2008) use an ARCH-GARCH technique to compute the conditional heteroskedastic variance in logs of first differences. On the other hand, Schnabl (2008) measures exchange rate volatility as the standard deviation of the nominal exchange rate, computed over a rolling window of two years. Koray and Lastrapes (1989) compute exchange rate volatility as the moving standard deviation of the growth rate of the real exchange rate. This paper adapts the use of the standard deviation by dividing it by the mean of the REER, to make observations comparable in terms of units.
Another possibility is to divide the standard deviation by the difference between the first and third quartile of the observations, because theoretically the mean could be equal to zero. Since

dividing by zero is a mathematical impossibility, this may lead to a problem. However, because an index for the real effective exchange rate is used, the mean is never equal to zero. Therefore, this issue is not relevant for this paper. The method using the difference between the first and third quartile is also not perfect. Suppose there are two sets of observations of the real exchange rate over two years. If they have the same standard deviation, but the first one has a smaller spread between the first and third quartile than the second observation, the measure of exchange rate volatility will be larger for the first observation. However, this is counterintuitive because the spread between the first and third quartile is smaller, indicating that the volatility has been lower. Therefore, because of simplicity and clarity, this paper uses the coefficient of variation as measure of exchange rate volatility. Nevertheless, in section 6 other measures will be used as a robustness check.

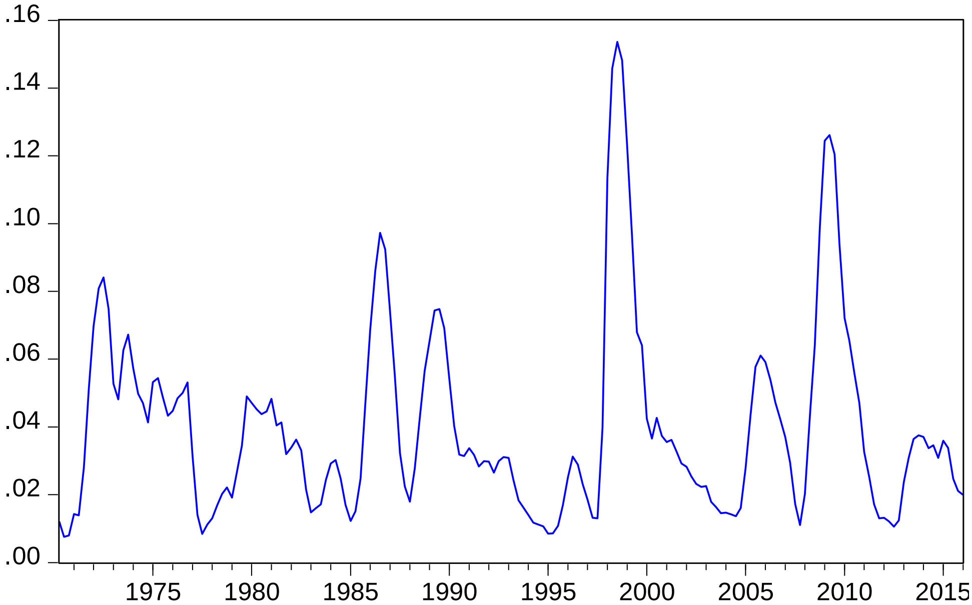
Figure 1. Real effective exchange rate (2010 = 100)



Source: Bank of International Settlements

Figure 1 shows that the REER has been depreciating over time, with some periods of steep depreciations, followed by strong appreciations. The red line denotes the linear, decreasing trend. Figure 2 shows that the REER has been volatile for decades. It seems that the general trend until the crisis has been a gradual decrease in volatility, although interrupted by some peaks in volatility. From 1991 until mid-1997, the exchange rate volatility was very low. This coincides with South Korea's managed floating exchange rate regime, which led to a stable exchange rate in the years before the crisis. However, after the crisis the peaks appear to be larger, although for some periods the volatility was very low. The two largest peaks, 1998 and 2010, coincide with the Asian financial crisis and the global financial crisis.

Figure 2. Coefficient of variation



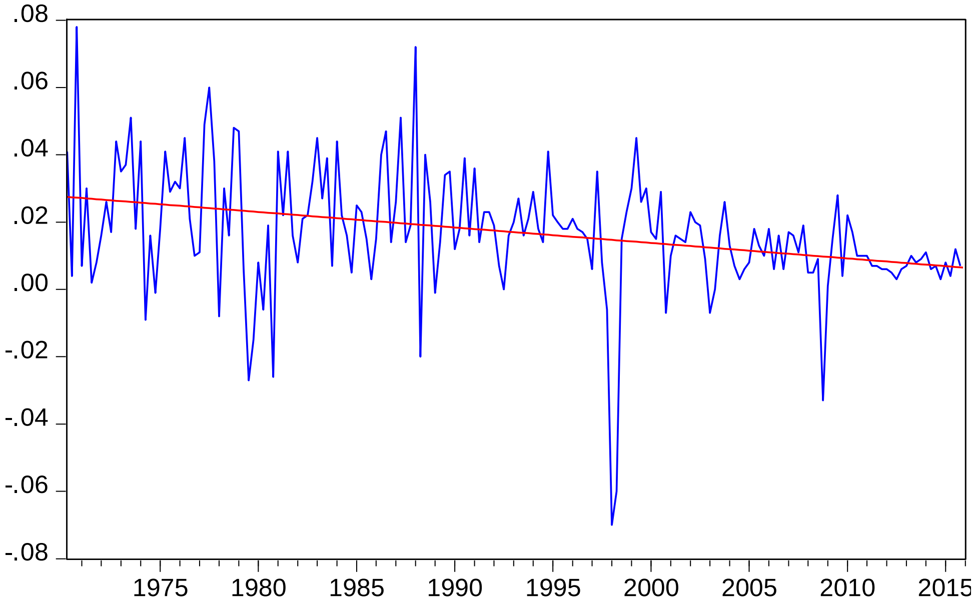
Source: Bank of International Settlements and author's calculations

The average coefficient of variation is 0.036 for the period 1970Q2 until 1997Q2, the pre-crisis period. For the post-crisis period, 1998Q3 until 2016Q1, the average coefficient of variation is 0.044. The *p* value of the t-test is 0.06. Therefore, the increase in exchange rate volatility after the crisis is not statistically significant at the 5% level, but it is significant at the 10% level.

The next variable of interest is the growth rate of real GDP, computed as the quarterly growth rate of real GDP compared to the previous quarter and seasonally adjusted. Data on the real GDP growth rate are obtained from Organization for Economic Coordination and Development (OECD).

The average quarterly growth rate is 1.7%, with a minimum of -7% in 1998Q1, the Asian financial crisis, and a maximum of 7.8% in 1970Q4. Although it is rather unclear in the graph, there is a slightly decreasing trend over time. From 1970Q2 until 1997Q2, the pre-crisis period, the average growth rate was 2.2%. From 1998Q3 until 2015Q4, the post-crisis period, the average growth rate was 1.2%, almost a half of the pre-crisis period. This shows that the growth rate has significantly decreased after the crisis. Since exchange rate volatility has increased significantly after the crisis, there might be a negative association between exchange rate volatility and economic growth. This relationship is tested formally in the next section.

Figure 3. Quarterly growth rate of real GDP, compared to the previous quarter



Source: OECD

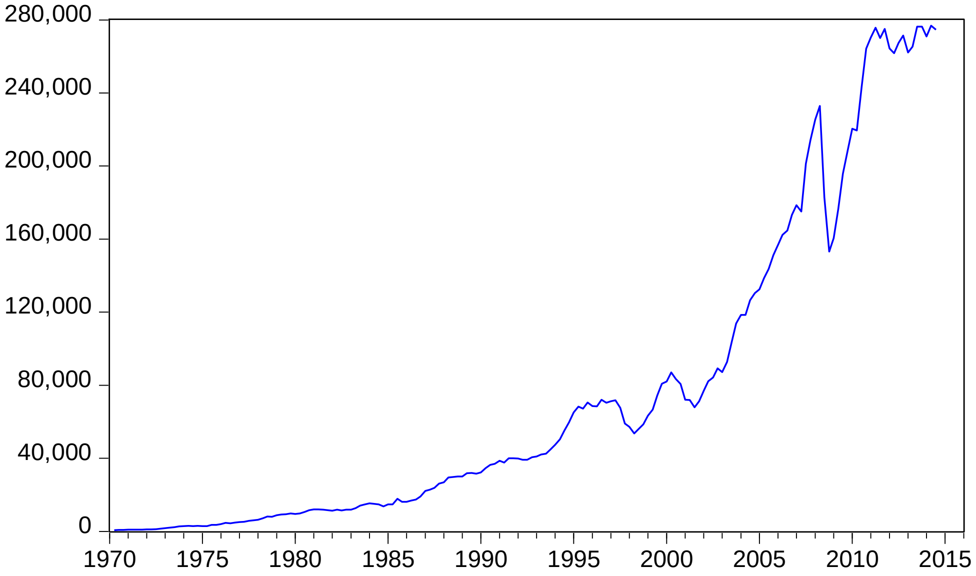
International trade is defined as the sum of exports and imports. A common measure of international trade is the ratio of trade to GDP, however, this leads to some issues. When the growth rate of trade to GDP is used, it depends, by definition, on the growth rate of GDP. The growth rate of trade to GDP can be rewritten as follows

$$\frac{\left(\frac{trade}{GDP}\right)_t - \left(\frac{trade}{GDP}\right)_{t-1}}{\left(\frac{trade}{GDP}\right)_{t-1}} = d\ln\left(\frac{trade}{GDP}\right) = d\ln(trade) - d\ln(GDP)$$

$$d\ln(GDP) = d\ln(trade) - d\ln\left(\frac{trade}{GDP}\right)$$

Since this paper will also analyze the relationship between the growth rates of GDP and international trade, the definition of trade as the ratio of trade to GDP is problematic. By construction, an increase in the growth rate of trade to GDP leads to a decrease in the growth rate of GDP. Since the results will be affected by this, it is better to use the sum of exports and imports as measure of trade, and then apply the growth rate.

Figure 4. Trade

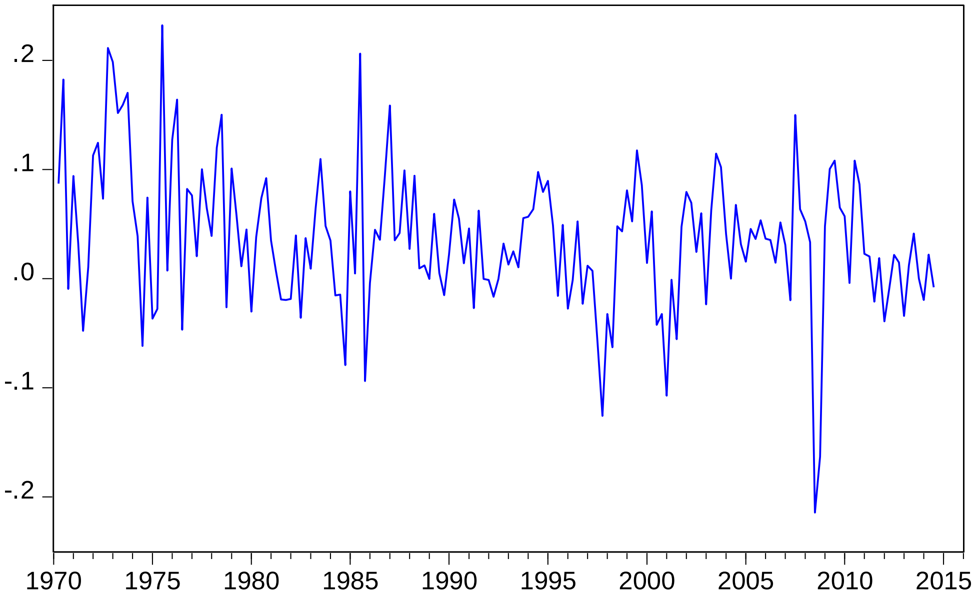


Source: Federal Reserve Bank of St. Louis

The previous section discussed the relationship between international trade and exchange rate volatility. Although the evidence is mixed, most of the research points towards a negative relationship. This indicates that the growth rate of trade is expected to have declined after the crisis, because exchange rate volatility has increased. The level of trade is defined as the sum of exports and imports. The data for exports and imports are obtained from the Federal Reserve Bank of St. Louis. Figure 4 shows the trend of international trade in million US dollars. There is a clear increasing trend, although interrupted by periods of a decrease in trade. These intervals coincide with the Asian financial crisis of 1997 and the global financial crisis of 2008 and 2009. Since the level of trade is non-stationary, the growth rate is applied to make it stationary. This is the quarterly growth rate of trade, compared to the previous quarter. Figure 5 shows the growth rate of trade over time. There are large fluctuations, but in the period until the Asian financial crisis, trade grew rapidly. The average growth rate between 1970Q2 and 1997Q2, the pre-crisis period, was 4.6 percent per quarter. After the crisis, between 1998Q3 and 2014Q3, the average growth rate was 2.7 percent per quarter. Although trade is still growing at a steady rate, the growth rate has been almost cut in half, compared to the pre-crisis period.

The quarters 1997Q3 until 1998Q2 are left out of the comparison, because they include the crisis. During those four quarters, trade declined at almost 7 percent per quarter. Using the t-test there is no significant difference at the 5% level between the pre- and post-crisis growth rates of trade, because the *p* value is 0.058. However, it would be significant at the 10% level, therefore there is strong evidence that the two growth rates differ.

Figure 5. Growth rate of trade



Source: Federal Reserve Bank of St. Louis and author's calculations

Table 4. Descriptive statistics

	Real GDP growth	REER (2010 = 100)	Coefficient of variation REER	Trade growth
Mean	0.017	118.433	0.040	0.037
Median	0.016	117.582	0.032	0.036
Minimum	-0.070	72.580	0.008	-0.214
Maximum	0.078	176.667	0.154	0.232
Standard deviation	0.018	17.817	0.028	0.065
Observations	183	184	184	178

IV. Methodology

To estimate the effect of exchange rate volatility on economic growth and international trade, this paper uses a vector autoregression model (VAR). A VAR can be unrestricted or restricted. A type of a restricted VAR is a vector error correction model (VEC). A VEC addresses issues with non-stationary variables and their long-term relationship. The choice between an unrestricted and a restricted VAR depends on whether the variables are non-stationary and whether there exists a cointegrating relationship between the variables. If a long-run equilibrium exists between exchange rate volatility, economic growth and the growth rate of international trade, then these variables are cointegrated (Verbeek, 2004, p. 315). To test for non-stationarity, the Adjusted Dickey Fuller (ADF) is applied. The Johansen Cointegration test is used to test for a cointegrating relationship between the variables (Johansen, 1988). If the null hypothesis of a unit root is rejected, there is no need to test for cointegration, because the variable is stationary. If all of the variables are non-stationary and the null hypothesis of no cointegrating relationship is rejected, the variables are cointegrated. Then, an unrestricted VAR is inappropriate, since it assumes no cointegrating relationship exists between the variables. However, a VEC takes this into account, and therefore is a more appropriate model when two or more non-stationary variables are cointegrated. In case of cointegration between the variables, a VAR in levels can still be used to elicit the long-run relationship, whereas a VAR with first differences would ignore this, and would thus not be appropriate. This issue is not relevant for this paper, because a VAR with stationary variables is used.

The purpose of using a multivariate model, and not a univariate, is that a VAR does not impose restrictions on the variables, such as exogeneity (Koray & Lastrapes, 1989). Since the exchange rate and exchange rate volatility are influenced by many factors, including GDP and international trade, they are not exogenous variables. However, by only including lags, and this applies to other variables as well, there is no problem with endogeneity (Sims, 1980). A VAR is not the only method to address endogeneity of the variables. An instrumental variable for panel data is also useful, since it uses an instrument to estimate the effect of exchange rate volatility on economic growth. A good instrumental variable needs to be relevant, that is, correlated with X, and exogenous, that is, uncorrelated with the error term. The only way in which an instrument has an effect on Y, is through X. However, for panel data, several subjects should be studied, and since this paper only studies the case of South Korea, it is best to use time series analysis. Therefore, this paper uses a VAR. The optimum number of lags to include is determined on the basis of the Schwarz Information Criterion.

The growth rate of real GDP, the coefficient of variation of the REER and the growth rate of trade are all stationary, meaning they are $I(0)$. However, the level of real GDP and trade are non-stationary, but the growth rates are applied, because variability relates to growth rates and not to levels. Therefore, a VAR can be used. If one of the variables had been $I(1)$, then a distributed lag or autoregressive distributed lag model would be used, because a VAR requires variables to be of the same order. Since the three relevant variables are of the same order, a VAR is used.

A three-dimensional VAR(1) model has the following form,

$$Y_{1,t} = \alpha_1 + \beta_{11}Y_{1,t-1} + \beta_{12}Y_{2,t-1} + \beta_{13}Y_{3,t-1} + \varepsilon_{1,t}$$
$$Y_{2,t} = \alpha_2 + \beta_{21}Y_{1,t-1} + \beta_{22}Y_{2,t-1} + \beta_{23}Y_{3,t-1} + \varepsilon_{2,t}$$
$$Y_{3,t} = \alpha_3 + \beta_{31}Y_{1,t-1} + \beta_{32}Y_{2,t-1} + \beta_{33}Y_{3,t-1} + \varepsilon_{3,t}$$

In this paper, Y_1 is the growth rate of real GDP (*g*), $Y_2$is the coefficient of variation of the REER (*cov*) and Y_3 is the growth rate of trade (*xm*). $\varepsilon_{1,t}$, $\varepsilon_{2,t}$ and $\varepsilon_{3,t}$ are white noise processes, meaning they do not depend on the previous values of Y_1, Y_2 or Y_3. Then, the abovementioned general formulas can be translated into a specific formula for a VAR(1) model.

$$g_t = \alpha_1 + \beta_{11} g_{t-1} + \beta_{12} cov_{t-1} + \beta_{13} xm_{t-1} + \varepsilon_{1,t}$$

$$cov_t = \alpha_2 + \beta_{21} g_{t-1} + \beta_{22} cov_{t-1} + \beta_{23} xm_{t-1} + \varepsilon_{2,t}$$

$$xm_t = \alpha_3 + \beta_{31} g_{t-1} + \beta_{32} cov_{t-1} + \beta_{33} xm_{t-1} + \varepsilon_{3,t}$$

The three formulas can also be written as,

$$\begin{pmatrix} Y_{1,t} \\ Y_{2,t} \\ Y_{3,t} \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} + \begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} \\ \beta_{21} & \beta_{22} & \beta_{23} \\ \beta_{31} & \beta_{32} & \beta_{33} \end{pmatrix} \begin{pmatrix} Y_{1,t-1} \\ Y_{2,t-1} \\ Y_{3,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{pmatrix}$$

Let $\vec{Y}_t = (Y_{1,t}, Y_{2,t}, Y_{3,t})$, $\vec{\varepsilon}_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, \varepsilon_{3,t})$, and let each ω_j be a $k \times k$ matrix. $\vec{\varepsilon}_t$ is a *k*-dimensional vector of white noise terms with covariance matrix Σ (Verbeek, 2004, p. 322). Then, a VAR(p) model can be written as,

$$\vec{Y}_t = \alpha + \omega_1 \vec{Y}_{t-1} + \cdots + \omega_p \vec{Y}_{t-p} + \vec{\varepsilon}_t$$

Using a VAR model, the effect of a shock to one variable on all other variables, *ceteris paribus*, can be observed using an impulse-response function[3]. The impulse-response function shows the effect of a onetime increase in a variable by its standard deviation on the other variables in the VAR.

The test of the second and fourth hypothesis is to examine if there is a structural break in the effect of exchange rate volatility on economic growth and international trade. If there is a structural break, the effect in the post-crisis period differs from the pre-crisis period. Since it is not possible to conduct a Quandt-Andrews or a Chow breakpoint test directly in a VAR[4], the model is transformed into a system of equations. When the VAR(2) model is transformed into a system, the coefficients and standard errors are the same. Even though the least squares estimation method is used, the results are not different. To test for a structural break, an interaction effect between the post-crisis period and the coefficient of variation is added to the model. 1998Q3 is the first quarter of the post-crisis period, because then real GDP started to

[3] For a formal derivation of the matrix of the impulse-response functions, refer to a textbook on econometrics, for example Verbeek (2004, pp. 322-324).

[4] At least in EViews, the software used for this paper.

grow again, signifying economic recovery. Including this interaction effect, the models take the following forms,

$$g_t = \alpha_1 + \beta_{11} g_{t-1} + \beta_{12} g_{t-2} + \beta_{13} cov_{t-1} + \beta_{14} cov_{t-2} + \beta_{15} cov_{t-1} * D + \beta_{16} cov_{t-2} * D + \beta_{17} xm_{t-1} + \beta_{18} xm_{t-2} + \varepsilon_{1,t}$$

$$cov_t = \alpha_2 + \beta_{21} g_{t-1} + \beta_{22} g_{t-2} + \beta_{23} cov_{t-1} + \beta_{24} cov_{t-2} + \beta_{25} cov_{t-1} * D + \beta_{26} cov_{t-2} * D + \beta_{27} xm_{t-1} + \beta_{28} xm_{t-2} + \varepsilon_{2,t}$$

$$xm_t = \alpha_3 + \beta_{31} g_{t-1} + \beta_{32} g_{t-2} + \beta_{33} cov_{t-1} + \beta_{34} cov_{t-2} + \beta_{35} cov_{t-1} * D + \beta_{36} cov_{t-2} * D + \beta_{37} xm_{t-1} + \beta_{38} xm_{t-2} + \varepsilon_{3,t}$$

Again, *g* is the quarterly growth rate of real GDP, *cov* is the coefficient of variation of the REER, *xm* is the quarterly growth rate of trade, and D signifies the post-crisis dummy. D takes a value of 1 if the observation is from 1998Q3 or later, and 0 otherwise. If there is a structurally different relationship between the coefficient of variation and the dependent variables, the coefficients of the interaction effects are jointly significant, using the Wald coefficient test.

V. Results

Whether a VAR or VEC is more appropriate, depends on whether the variables are stationary and cointegrated. The Adjusted Dickey-Fuller test shows that the quarterly growth rate of real GDP, the coefficient of variation for the REER and the quarterly growth rate of trade are all stationary in their levels. In other words, the growth rate of real GDP, the coefficient of variation and the growth rate of trade are $I(0)$. Since these three variables are of the same order, and stationary in their levels, a cointegrating relationship does not exist. Therefore, they can be estimated together using a VAR.

Using data from 1971Q2 until 2014Q3, a VAR(2) model is the best to examine the effect of exchange rate volatility on economic growth and international trade, because the VAR(2) model has the lowest Schwarz Information Criterion.

The VAR(2) model satisfies the stability condition, because there is no root that lies outside the unit circle. Furthermore, using the lag exclusion Wald test, neither of the 2 lags should be excluded, they both are jointly significant for all the three variables. Since true causality cannot be measured, but Granger causality can, the Granger causality test is applied. Granger causality differs from normal causality by testing whether one time series can forecast another time series (Granger, 1969). Granger causality refers to predictive causality. Both the coefficient of variation and the growth rate of trade individually Granger cause the growth rate of real GDP. Furthermore, they are also jointly significant, meaning the combination of the time series has predictive power in explaining the growth rate of real GDP. For the coefficient of variation, neither the growth rate of real GDP nor the growth rate of trade is individually nor jointly significant. Finally, the coefficient of variation is individually Granger causal for the growth rate of trade. However, the growth rate of real GDP is not, although both time series are jointly significant. These results already give some interesting insights. First of all, the growth rate is not a good predictor for neither the coefficient of variation nor the growth rate of trade. Rather, the Granger causality runs the opposite direction. This seems in line with Flood and Rose (1999) who argue that exchange rate volatility cannot be explained by macroeconomic fundamentals. Furthermore, exchange rate volatility seems to influence the growth rate of trade. Given the large body of literature on the positive and negative effects of exchange rate volatility on trade, this is not a surprising result. The coefficients and the accompanying impulse-response functions below give a more detailed insight into these results.

Table 5. VAR(2) with real GDP growth, coefficient of variation of the REER and trade growth

	Real GDP growth	**Coefficient of variation REER**	**Trade growth**
Real GDP growth (-1)	0.120	-0.036	0.478
	(0.080)	(0.039)	(0.299)
Real GDP growth (-2)	0.037	0.035	0.144
	(0.073)	(0.036)	(0.274)
Coefficient of variation (-1)	-0.300**	1.571***	0.044
	(0.121)	(0.059)	(0.464)
Coefficient of variation (-2)	0.366***	-0.710***	0.443
	(0.119)	(0.058)	(0.446)
Trade growth (-1)	0.083***	-0.018*	0.187**
	(0.021)	(0.010)	(0.078)
Trade growth (-2)	-0.007	0.006	0.082
	(0.021)	(0.010)	(0.081)
Constant	0.009***	0.006***	-0.005
	(0.003)	(0.001)	(0.011)
Observations	174	174	174
R-squared	0.252	0.929	0.165
Individual SC	-5.267	-6.698	-2.623
Schwarz Criterion		-14.674	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

The main explanatory variable of interest, the coefficient of variation, has a significant effect on the growth rate of real GDP and on the coefficient of variation itself. The effect of the first lag on real GDP growth is negative, whereas the effect of the second lag is positive. In the long term the effect is thus stable, but slightly positive. The first lag of the coefficient of variation has a strongly positive effect on the coefficient of variation itself. Since the coefficient is larger than 1, there seems to be an even larger increase in exchange rate volatility. However, the effect of the second lag diminishes this, since it is significantly negative and around half of the size of the coefficient of the first lag. Thus, in the long run the increase in exchange rate volatility dies out, although the coefficients suggest that this does not happen immediately, because the effect is relatively large. Finally, exchange rate volatility does not have a significant effect on the growth rate of trade. However, no conclusion can be given by looking at the model as a univariate model, since the VAR is applied to capture the multivariate aspects of the time series. As seen in the results of the Granger causality test, the growth rate of GDP does not have a significant effect on the other two variables. In fact, its lags are not even significant for the growth rate of GDP itself.

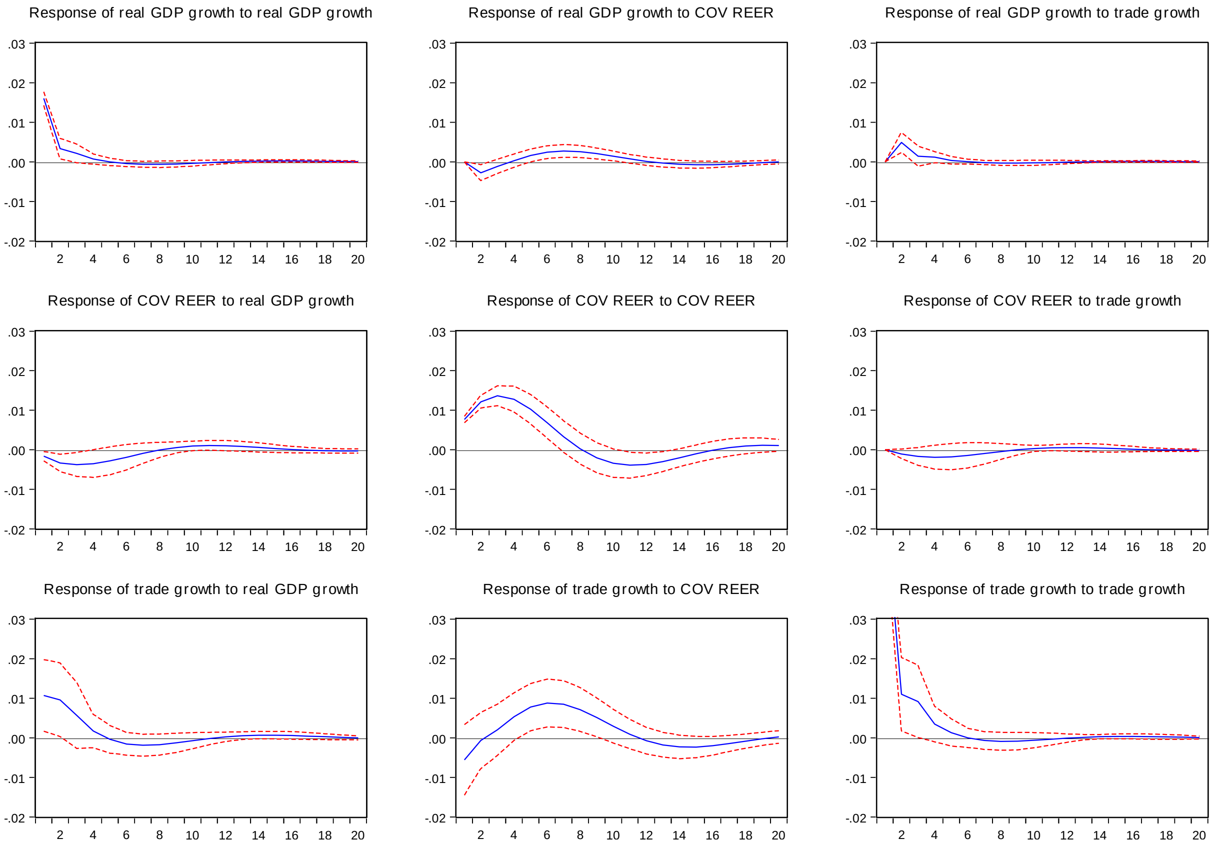
An increase in the growth rate of trade has a positive effect on economic growth. The first lag of the growth rate of trade is significantly positive, whereas the coefficient of the second lag is not significantly different from zero. Furthermore, an increase in trade has a negative, but insignificant effect on exchange rate volatility. Finally, the first lag of the growth rate of trade has a positive and significant effect on the growth rate of trade, whereas the effect of the second lag is positive, but not significant. A clear interpretation of the results can be given using the accompanying impulse-response functions.

The impulse-response functions show the effect of a one standard deviation increase in one variable on the other variables. The standard deviation of the growth rate of real GDP is 0.018, the standard deviation of the coefficient of variation is 0.028 and the standard deviation of the growth rate of trade is 0.065. The Cholesky ordering is real GDP growth, coefficient of variation and trade growth. However, different Cholesky orderings give similar impulse-response functions.

The graphs show that a one standard deviation increase in exchange rate volatility has a negative effect on economic growth in the subsequent three quarters. However, this effect is relatively small, the largest negative effect is in a decrease in economic growth by 0.3 percent in the second quarter after the shock. Interestingly, the effect of the shock has a positive effect on economic growth from the fourth quarter onwards and 12 quarters after the shock the effect fades out. In the periods when there is a positive effect, the magnitude of this effect is around a 0.03 percent increase in GDP growth. This effect can also be seen in the regression output, where the first lag had a negative effect on GDP growth, but the second lag had a positive, and larger, effect on economic growth. Furthermore, the model confirms the general view that international trade has a positive effect on economic growth. An increase in international trade leads to an increase in real GDP growth by 0.5 percent, but this effect is only temporary and goes to zero after 7 quarters.

The impulse-response function for the coefficient of variation of the REER shows that economic growth decreases volatility. On the other hand, a shock to the coefficient of variation itself leads to a large increase in volatility, but after 7 quarters this effect becomes negative. This shows that a shock to volatility does not die out quickly, which was expected from the regression results. Finally, as found in the model, an increase in international trade has a very small and negative effect on exchange rate volatility.

Figure 6. Impulse-response functions for VAR(2) with real GDP growth, coefficient of variation of the REER and trade growth

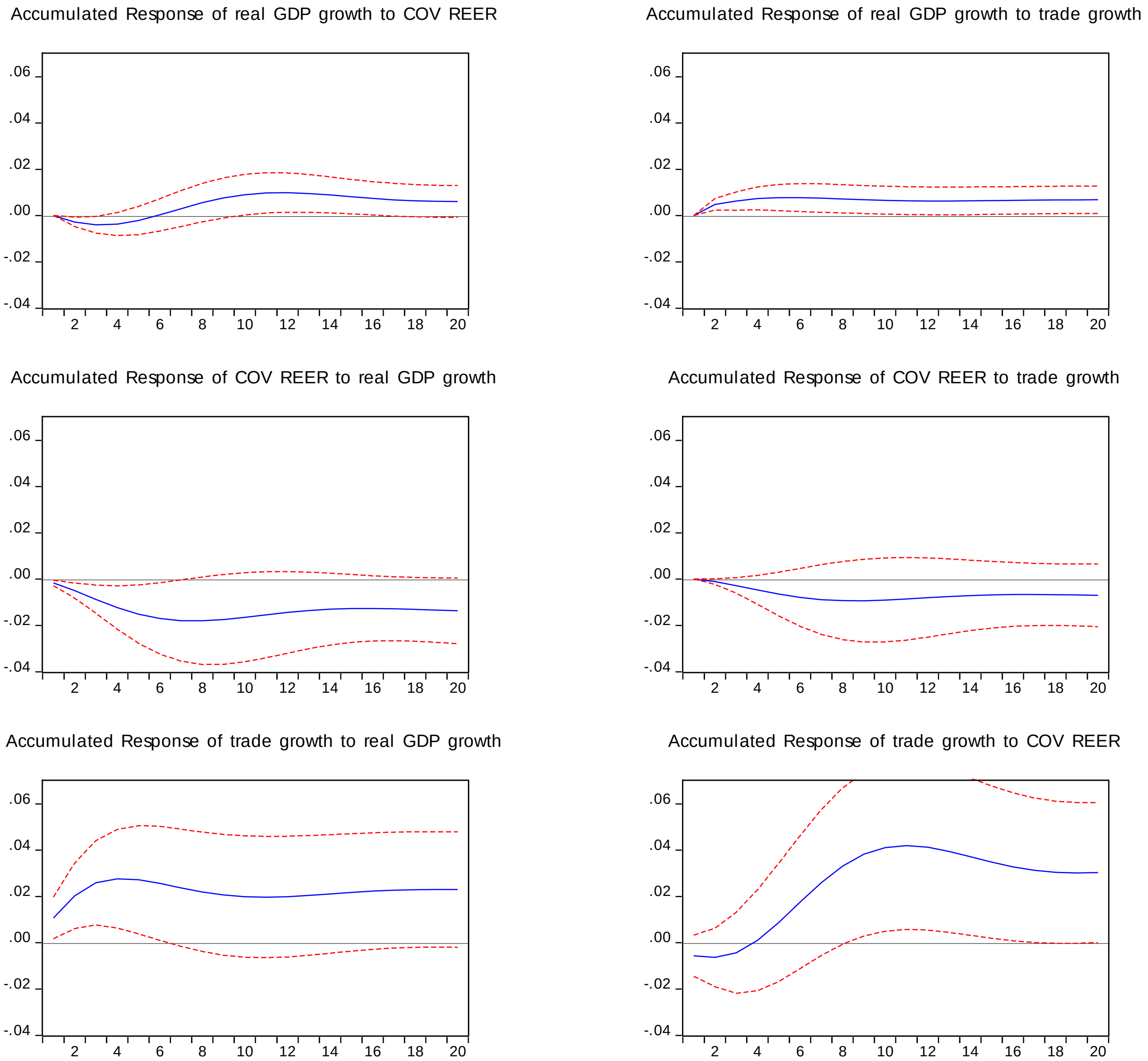


The last row shows that the growth rate of trade is affected by a shock in volatility. The immediate effect is a decrease in international trade by around 0.6 percent, which is probably due to an increase in transaction costs. However, in the following two years, exchange rate volatility has a positive effect on the growth rate of trade. Although the coefficients were not significant in the VAR model, the impulse-response functions show that the effect is substantial.

Furthermore, a onetime increase in economic growth by around 1.8 percent leads to an increase in international by around 1 percent in the first four quarters after the shock. After that period, the effect is close to zero.

An insight into the long-run effects can be gained using impulse-response functions with accumulated responses, which are shown in figure 7[5]. For example, the value for 5th quarter is the sum of the effects in the previous quarters and the effect in the 5th quarter. This way, the long-run effect can be obtained.

Figure 7. Impulse-response functions with accumulated responses for VAR(2) with real GDP growth, coefficient of variation of the REER and trade growth



[5] Figure 7 does not include the own responses to shocks, because they are not relevant for this paper. For all three variables a shock led to a long-run increase in that variable.

Although an increase in exchange rate volatility first negatively affects economic growth, in the long run it leads to an increase of 0.6 percent[6]. This can be explained by the adaption of the Black-Scholes option valuation model, where an increase in volatility increases the value of an option. For exchange rates, the probability of a good outcome increases with higher volatility, which is shown by the long-run positive effect of exchange rate volatility on economic growth. The long-run effect of a shock to international trade is an increase in economic growth by 0.7 percent. The confidence interval is relatively small, indicating that the effect is significant. Furthermore, economic growth decreases exchange rate volatility. An increase in international trade is also likely to reduce volatility, although the effect is small and could well be zero or even slightly positive in the long run. Finally, a shock to economic growth increases international trade by around 2.3 percent and a shock to exchange rate volatility increases trade by 3 percent in the long run. However, these last results should be interpreted carefully, because the large confidence interval indicates that the effect can easily be smaller or larger, although they are very likely to be positive.

To test for a structural break, the VAR model is transformed into a system of equations and an interaction effect for the post-crisis period is added. The results show that the interaction effect is individually and jointly significant for the equation with the growth rate of real GDP as dependent variable. In the other two models, the null hypotheses of both coefficients are equal to zero cannot be rejected. This means that the effect of exchange rate volatility on volatility itself and international trade did not change significantly after the crisis. However, the crisis did have an effect on the relationship between exchange rate volatility and economic growth, the main focus of this paper. Before the crisis, the coefficient of the first lag of the coefficient of variation is -0.526, after the crisis it becomes -0.070, diminishing the negative effect of volatility on growth. However, for the second lag the pre-crisis coefficient is 0.690 and after the crisis it becomes 0.115, diminishing the positive effect on economic growth. This change can be due to the development of Korea, by becoming less dependent on foreign countries for economic growth. Furthermore, because flexible exchange rates allow for quicker adjustment to foreign shocks, the effect of these shocks is smaller after the crisis, when Korean adopted a flexible exchange rate regime. These pre- and post-crisis coefficients are different from the estimates for the VAR model without interaction effects, where the coefficients of the first two lags are -0.300 and 0.366, respectively.

[6] Note that the scaling of the graphs differs with the scaling in figure 6.

Table 6. System of equations with interaction effect for post-crisis period

	Real GDP growth	Coefficient of variation REER	Trade growth
Real GDP growth (-1)	0.069	-0.029	0.404
	(0.080)	(0.040)	(0.307)
Real GDP growth (-2)	0.021	0.040	0.060
	(0.074)	(0.037)	(0.287)
Coefficient of variation (-1)	-0.526***	1.594***	-0.052
	(0.141)	(0.071)	(0.544)
Coefficient of variation (-2)	0.690***	-0.745***	0.725
	(0.151)	(0.076)	(0.583)
Coefficient of variation (-1)	0.456**	-0.034	-0.083
***post-crisis**	(0.212)	(0.107)	(0.817)
Coefficient of variation (-2)	-0.574***	-0.055	-0.169
***post-crisis**	(0.209)	(0.105)	(0.805)
Trade growth (-1)	0.082***	-0.018*	0.178**
	(0.020)	(0.010)	(0.079)
Trade growth (-2)	-0.006	0.006	0.077
	(0.021)	(0.011)	(0.081)
Constant	0.008***	0.006***	-0.005
	(0.003)	(0.001)	(0.011))
Observations	174	174	174
R-squared	0.299	0.929	0.172

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

A reason for these differences can be a change in the value of the coefficient of variation. The total effects, calculated as the coefficient multiplied by the standard deviation of the coefficient of variation, are compared to see if they are different before and after the crisis. Between 1971Q2 and 1998Q2, the standard deviation of the coefficient of variation was 0.019. Between 1998Q3 and 2014Q3, the standard deviation of the coefficient of variation was 0.026. Thus, for the first lag, the total effect for the pre- and post-crisis period is -0.010 and -0.002, respectively. For the second lag, the total effect for the pre- and post-crisis period is 0.013 and 0.003. This indeed confirms the finding from observing the coefficients that both the negative effect for the first lag and the positive effect for the second lag decrease after the crisis.

Since there are no accompanying impulse-response functions for the system of equations, it is difficult to tell if the effect of a shock to volatility has a different effect than in the VAR model without interaction effects. However, since the negative coefficient for the first lag of the coefficient variation on economic growth becomes less negative and the positive coefficient for the second lag becomes less positive, the overall effect of volatility on economic growth is probably smaller after the crisis, but still stable. It is reasonable to expect the effect in the short term to be less negative and the effect in the long term to be less positive.

An imperfect approximation of the model can be made using separate VAR models for 1971Q2 until 1998Q2 and 1998Q3 until 2014Q3. The coefficients of real GDP growth and trade growth in the system of equations take into account the entire period from 1971Q2 until 2014Q3 and should therefore be treated with caution, since they cover different periods. Nevertheless, the coefficients for exchange rate volatility in the system of equations and the VAR(2) model for the pre-crisis period are quite similar, as can be seen in table A.1 in the appendix. However, for the post-crisis period, they are quite different, as shown in table A.2. Therefore, the impulse-response functions of the separate models, figures A.1 and A.2 in the appendix, can be used to get an insight into the change in effect, although they should be interpreted carefully. In the post-crisis period, the negative short-run effect and the medium-term positive effect of volatility on GDP growth are half of the size of the effects in the pre-crisis period. This confirms the previous statement that the positive and negative effects would diminish after the crisis. However, the long-run effect is the same for both periods. After 20 quarters the increase in real GDP growth is 0.5 percent.

Using this approximation, the effect of exchange rate volatility on economic growth changed slightly in the short and medium run, but remains the same in the long run, as expected from the change in coefficients after the Asian financial crisis. There is also a change in the effect of exchange rate volatility on international trade. For the pre-crisis period, a shock to volatility leads to a substantial increase in trade, by 4.3 percent in the long run. However, for the post-crisis period, the long-run effect is close to zero, although in the short run trade decreases by 2 percent. Again, the confidence intervals are very wide, meaning the effect is not likely to be significant. Nevertheless, this effect is different from what can be found in table 6, since there was no structural break in the relationship between exchange rate volatility and international trade. Because the impulse-response function is only an approximation of the system of equations, its results should be nuanced, since the coefficients are not the same.

VI. Robustness

As discussed above, the coefficient of variation of the REER is not the only measure of exchange rate volatility. Instead of the REER the nominal effective exchange rate, the NEER, can also be used. Furthermore, instead of taking the total growth rate of international trade, the growth rate of exports or current account balance is also a measure of trade. This section examines whether different measures of volatility and international trade lead to similar results as in the model described above.

To see whether the use of real or nominal effective exchange rates has an effect on the results, the coefficient of variation of the NEER is used. The coefficient of variation of the NEER has a mean of 0.045 and a standard deviation of 0.035. In that respect, the coefficient of variation of the REER and the NEER are very similar, especially after the crisis they are almost the same. The same applies to the results of the VAR(2) model, as shown in table A.3 in the appendix. The coefficients for the lags of GDP growth and trade growth are very similar in both models. The coefficient for the lags of exchange rate volatility have the same sign, but differ in magnitude. A large difference is that the coefficient of variation of the NEER does not have a significant effect on economic growth and international trade, although the effect is similar in sign and relative size with the main model used in this paper. The impulse-response functions in figure A.3 also show similar results. A shock to exchange rate volatility has a positive long-run effect on the growth rate of real GDP by 0.5 percent. However, there is no short-run negative effect, which was the case with the REER. Furthermore, the long-term effect of exchange rate volatility on international trade is very similar. In the long run a shock to volatility leads to a 2.6 percent increase in trade, although this effect is not significant. In conclusion, the distinction between the real and nominal effective exchange rate does not seem to influence the analysis to a great extent, since both measures give similar results.

Another common measure of volatility is the standard deviation of the REER or the NEER, computed over a rolling window. This paper adjusted this by dividing it by the mean, but that may not be necessary. As a second robustness test, exchange rate volatility is measured as the standard deviation of the REER computed over a rolling window of two years. The standard deviation and the coefficient of variation of the REER follow a very similar pattern, but they differ in magnitude. The mean standard deviation of the REER is 3.822 and its standard deviation is 3.181. Table A.4 describes the VAR(2) model with the standard deviation of the REER, which shows similar results with the main VAR model used in this paper. Because the variables differ in magnitude, the coefficients do as well, but the sign and significance of the lags of all explanatory variables are very similar in both models. Figure A.4 shows that the impulse-response functions of the two models are almost equal as well. With the standard deviation of the REER, a shock to volatility leads to a 0.8 percent increase in real GDP in the long run, whereas the short-run effect is slightly negative. Furthermore, the long-term effect on trade is an increase by around 4 percent, although this again is insignificant. Consequently, using the standard deviation of the REER as measure of exchange rate volatility does not have a large effect on the results.

Finally, as measure of international trade, the quarterly growth rate of trade is replaced by the quarterly growth rate of exports. Both variables show a similar trend over time. The mean growth rate of exports is 0.040 and its standard deviation is 0.068. Again, this is roughly equal to the descriptive statistics of the growth rate of trade. A VAR(2) model is used for the growth rate of GDP, the coefficient of variation of the REER and the growth rate of exports. The estimation results are similar to that of the main VAR model used in this paper, as can been seen in table A.5. The coefficients for the lags of trade and exports growth are approximately equal in size and significance. In the previous model exchange rate volatility did not have a significant effect on international trade, and this results holds when the growth rate of exports is used. The impulse-response functions in figure A.5 confirm the results that were found in the previous model. A shock to exchange rate volatility increase exports by 3.6 percent in the long run, although this effect is not significant, as can be seen by the wide confidence interval. A shock to exports leads to a 1 percent increase in economic growth, whereas a shock to economic growth leads to a 2.1 percent increase in exports. However, this last effect is not significant.

These results show the robustness of the results found in the previous section. The coefficient of variation of the REER and the growth rate of trade are appropriate measures for exchange rate volatility and international trade, respectively, because other measures show similar results.

A final robustness test is using the levels of real GDP and trade, instead of the growth rates. This paper uses the growth rates because they are stationary and the levels are not. However, a VAR model with the levels of real GDP and trade, in billion US dollars, can still be run to see if the results are similar to the main model in this paper. An argument to use the level of a variable, although non-stationary, is that applying the first difference would ignore valuable information about a long-run relationship between the variables. Therefore, this paper also runs the model with the levels of real GDP and trade. Unsurprisingly, the VAR model has at least one root outside the unit circle, and is therefore not stable. In general, the coefficients are equal in sign, but not in size and significance, as shown in table A.6. The impulse-response functions show somewhat similar results, as seen in figure A.6. For example, a shock to volatility first has a negative effect on the level of GDP, but later this becomes positive, and the same applies to the response of trade to a shock to volatility. However, they naturally differ in size. Following a shock to volatility, real GDP increases by 35 billion after 20 quarters, and trade by 15 billion. The model with growth rates shows that a shock to volatility, the same shock because the coefficient or variation of the REER did not change, leads to a 0.6 percent increase in real GDP and a 3 percent increase in trade. A 35 billion dollar increase in real GDP is indeed a 0.6 percent increase, if the level of real GDP is 5,833 billion dollar. The level of real GDP of Korea was 1,288 billion dollar in 2016Q1. Using this level, a 35 billion increase corresponds with an increase of 2.7 percent. And this is even a low estimate. The average of real GDP was 533 billion. In this case, a 35 billion increase corresponds with a 6.6 percent increase in real GDP. Furthermore, a 15 billion dollar increase in trade is indeed a 3 percent increase, if the level of trade is 500 billion dollars. In 2014Q3, the level of trade was 275 billion dollars. The low estimate of the increase is thus 5.5 percent. However, when using the average level of trade, 75 billion, a 15 billion increase indicates a 20 percent increase in trade, much higher than the 3 percent the main model predicted. Following, the model does not yield similar results when considering the long run.

However, it may show more similarity in the short run. After 4 quarters, a shock to volatility has an accumulated effect of a decrease in real GDP by 4 billion, whereas the main model predicts a 0.4 percent decrease. These estimates are the same when the level of real GDP is 1000 billion dollars, which does not seem extraordinary. Since 2007, the level of real GDP of Korea has been above 1000 billion dollars. However, when comparing a 4 billion decrease with the mean level of real GDP, it corresponds with a 0.75 percent decrease, still within the confidence interval of the main model.

The effect of a shock to volatility on trade is also a 4 billion decrease. The predicted effect by the main model is a 0.1 percent increase in trade, which is clearly contradictory. However, since the effect is not significant, the confidence intervals are wide. Using the most recent observation for trade, a level of 275 billion in 2014Q3, a 4 billion decrease indicates a 1.5 percent decrease in trade, which is still within the confidence interval. Finally, when comparing it with the mean level of trade, it corresponds with a 5.3 percent decrease. This is without the confidence interval of the main model. It is not very surprising that these two models differ, because the effect of exchange rate volatility on international trade is insignificant in both models.

To conclude, the model with the level of real GDP and trade clearly differs from the model with the growth rates. Comparing the long-run accumulated responses, the models predict very different results, although the sign is the same. Nevertheless, when comparing the short run, the estimated effect on real GDP is quite similar. However, the effect on international trade is different from the effect in the main model, although this can probably be explained by the fact that exchange rate volatility does not have a significant effect on international trade.

VII. Conclusion

The academic literature generally predicts a negative effect of exchange rate volatility on economic growth and international trade, although some evidence indicates a positive relationship. This paper examined the case of South Korea and additionally analyzed whether there has been a change in the relationship following the Asian financial crisis of 1997. Since after adopting a freely floating exchange rate, exchange rate volatility increased and economic growth slowed down, a negative relationship is expected. This would confirm the large body of research into this topic. The results of the empirical research indeed indicate a negative relationship, although only in the short run. After a year, a shock to exchange rate volatility has a positive effect on economic growth, and this effect is permanent. In the long run, real GDP increases by 0.6 percent. Therefore, the first hypothesis is rejected for the long run, instead of a negative relationship there is a long-run positive relationship between exchange rate volatility and economic growth. Furthermore, the Asian financial crisis only diminished the negative and positive effects in the short and medium run. The long-term effect remained the same. Therefore, the second hypothesis is also rejected, the Asian financial crisis of 1997 does not seem to have had a significant effect on the relationship between exchange rate volatility and economic growth in the long run.

Additionally, the literature shows mixed evidence for the effect of exchange rate volatility on international trade. High volatility leads to an increase in transaction costs, which would result in a decrease in trade. However, volatile exchange rates can increase exports when the exports are invoiced in the domestic currency. This paper does not find significant evidence for either of these predicted effects. Nevertheless, a shock to volatility leads to a decrease in international trade in the short run, but to an increase of 3 percent in the long run. These results should be treated with caution, because the confidence interval is very wide. Therefore, the third hypothesis is not rejected for the immediate short run, but in the medium and long run there rather seems to be a positive effect of exchange rate volatility on international trade, albeit not significant. This finding is the same in both the pre- and post-crisis periods, therefore the fourth hypothesis is rejected as well.

The analysis of this paper suggests that exchange rate volatility has a negative effect on economic growth and international trade in the short run, but a positive effect in the long run. The Asian financial crisis of 1997 did not have an impact on the relationship between volatility and international trade, but it did diminish the effect of exchange rate volatility on economic growth. However, this change in effect only occurred in the short and medium run. The long run result is still the same. On average, a shock to exchange rate volatility leads to an increase in economic growth by 0.6 percent, as can be seen from the accumulated responses in figure 7. This can be explained by the quicker adjustment to real shocks under flexible exchange rates, so that the long-run equilibrium is reached with only a short transition phase and by the Black-Scholes model which states that higher volatility leads to a higher probability of a good outcome. In this case, higher exchange rate volatility leads to a higher probability of an increase in economic growth and international trade.

However, one should be careful with generalizing the findings of this paper, because it only studied one country. Further research could focus on different countries, especially the ones that were hit by the Asian financial crisis, to see if in those countries the effect is the same as in Korea. An interesting case would be Malaysia, since ìt kept a fixed peg to the dollar after the crisis, whereas Korea adopted a floating exchange rate regime. For Korea, the effects of exchange rate volatility can be further analyzed. Further research could estimate the effect of exchange rate volatility on many other relevant variables, which were left out of the analysis in this paper. For example, exchange rate volatility is likely to have a significant effect on foreign investment and international capital flows. Additionally, the effect of bilateral exchange rate volatility on bilateral trade is also relevant for monetary policy, especially if the two countries are highly dependent on each other for trade. This research could also be adapted to see whether exchange rate volatility has a different effect for developing and developed countries and if floating, and thus more volatile, exchange rates provide a path to development. Finally, sources of exchange rate volatility should be analyzed more thoroughly, since macroeconomic fundamentals seem unable to explain it.

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Appendix

Table A.1 VAR(2) with real GDP growth, coefficient of variation of the REER and trade growth for the pre-crisis period

	Real GDP growth	**Coefficient of variation REER**	**Trade growth**
Real GDP growth (-1)	0.044	-0.030	0.570
	(0.107)	(0.049)	(0.358)
Real GDP growth (-2)	0.010	0.032	0.274
	(0.104)	(0.048)	(0.348)
Coefficient of variation (-1)	-0.559***	1.586***	0.183
	(0.176)	(0.081)	(0.588)
Coefficient of variation (-2)	0.620***	-0.771***	0.492
	(0.186)	(0.085)	(0.621)
Trade growth (-1)	0.082***	-0.014	0.110
	(0.029)	(0.014)	(0.099)
Trade growth (-2)	-0.016	0.009	0.165*
	(0.030)	(0.014)	(0.010)
Constant	0.013***	0.008***	-0.013
	(0.005)	(0.002)	(0.016)
Observations	109	109	109
R-squared	0.257	0.885	0.182
Individual SC	-4.906	-6.468	-2.493
Schwarz Criterion		-13.976	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Table A.2 VAR(2) with real GDP growth, coefficient of variation of the REER and trade growth for the post-crisis period

	Real GDP growth	**Coefficient of variation REER**	**Trade growth**
Real GDP growth (-1)	0.003	-0.075	-0.225
	(0.095)	(0.086)	(0.703)
Real GDP growth (-2)	-0.022	0.043	-0.218
	(0.077)	(0.070)	(0.573)
Coefficient of variation (-1)	-0.206*	1.522***	-0.972
	(0.114)	(0.103)	(0.842)
Coefficient of variation (-2)	0.302***	-0.639***	1.304*
	(0.108)	(0.098)	(0.800)
Trade growth (-1)	0.088***	-0.023	0.329**

	(0.018)	(0.017)	(0.136)
Trade growth (-2)	-0.045**	0.003	-0.130
	(0.019)	(0.017)	(0.140)
Constant	0.006***	0.006***	0.009
	(0.002)	(0.002)	(0.015)
Observations	65	65	65
R-squared	0.548	0.965	0.234
Individual SC	-6.605	-6.796	-2.598
Schwarz Criterion		-16.079	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Table A.3. VAR(2) with real GDP growth, coefficient of variation of the NEER and trade growth

	Real GDP growth	**Coefficient of variation NEER**	**Trade growth**
Real GDP growth (-1)	0.165**	-0.061	0.504*
	(0.080)	(0.041)	(0.293)
Real GDP growth (-2)	0.044	-0.017	0.133
	(0.075)	(0.038)	(0.276)
Coefficient of variation (-1)	-0.076	1.593***	0.250
	(0.099)	(0.051)	(0.364)
Coefficient of variation (-2)	0.130	-0.744***	0.146
	(0.096)	(0.050)	(0.362)
Trade growth (-1)	0.088***	-0.019*	0.188**
	(0.021)	(0.011)	(0.078)
Trade growth (-2)	-0.004	-0.005	0.084
	(0.022)	(0.011)	(0.081)
Constant	0.008***	0.009***	-0.003
	(0.003)	(0.001)	(0.010)
Observations	174	174	174
R-squared	0.219	0.945	0.164
Individual SC	-5.225	-6.571	-2.622
Schwarz Criterion		-14.499	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Table A.4. VAR(2) with real GDP growth, standard deviation of the REER and trade growth

	Real GDP growth	**Standard deviation REER**	**Trade growth**
Real GDP growth (-1)	0.116	-3.428	0.443
	(0.079)	(4.579)	(0.295)
Real GDP growth (-2)	0.046	4.936	0.158
	(0.072)	(4.155)	(0.268)
Standard deviation REER (-1)	-0.003***	1.571***	-0.001
	(0.001)	(0.060)	(0.003)
Standard deviation REER (-2)	0.003***	-0.717***	0.006
	(0.001)	(0.060)	(0.004)

Trade growth (-1)	0.078***	-1.725	0.166**
	(0.021)	(1.212)	(0.078)
Trade growth (-2)	-0.008	1.308	0.073
	(0.021)	(1.234)	(0.080)
Constant	0.008***	0.690***	-0.008
	(0.003)	(0.167)	(0.011)
Observations	174	174	174
R-squared	0.260	0.922	0.185
Individual SC	-5.279	2.834	-2.647
Schwarz Criterion		-5.166	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Table A.5. VAR(2) with real GDP growth, coefficient of variation of the REER and exports growth

	Real GDP growth	**Coefficient of variation REER**	**Exports growth**
Real GDP growth (-1)	0.108	-0.038	0.171
	(0.077)	(0.040)	(0.324)
Real GDP growth (-2)	0.039	0.031	0.231
	(0.073)	(0.036)	(0.294)
Coefficient of variation (-1)	-0.357***	1.581***	-0.138
	(0.120)	(0.059)	(0.481)
Coefficient of variation (-2)	0.430***	-0.725***	0.496
	(0.125)	(0.057)	(0.468)
Exports growth (-1)	0.073***	0.000	0.134*
	(0.019)	(0.009)	(0.076)
Exports growth (-2)	0.001	-0.005	0.234***
	(0.020)	(0.010)	(0.079)
Constant	0.009***	0.006***	0.003
	(0.003)	(0.001)	(0.012)
Observations	174	174	174
R-squared	0.250	0.928	0.151
Individual SC	-5.265	-6.680	-2.487
Schwarz Criterion		-14.524	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Table A.6. VAR(2) with real GDP, coefficient of variation of the REER and trade

	Real GDP (billions)	**Coefficient of variation REER**	**Trade (billions)**
Real GDP (-1)	0.988***	-8.32E-5	-0.047
	(0.074)	(9.5E-5)	(0.074)
Real GDP (-2)	0.028	8.51E-5	0.058
	(0.075)	(9.6E-5)	(0.075)
Coefficient of variation (-1)	-124.859**	1.526***	-68.741
	(47.839)	(0.061)	(47.782)
Coefficient of variation (-2)	166.51***	-0.670***	102.777**
	(47.914)	(0.061)	(47.856)

Trade (-1)	0.490***	-2.29E-4**	1.299***
	(0.075)	(9.6E-5)	(0.075)
Trade (-2)	-0.541***	2.27E-4**	-0.339***
	(0.076)	(9.6E-5)	(0.076)
Constant	0.243	0.006***	-2.555**
	(1.173)	(0.001)	(1.172
Observations	174	174	174
R-squared	1.000	0.930	0.995
Individual SC	6.624	-6.713	6.622
Schwarz criterion		6.391	

Standard errors between brackets; *, ** and *** denote 10%, 5% and 1% significance level, respectively.

Figure A.1 Impulse-response functions with accumulated responses for pre-crisis period

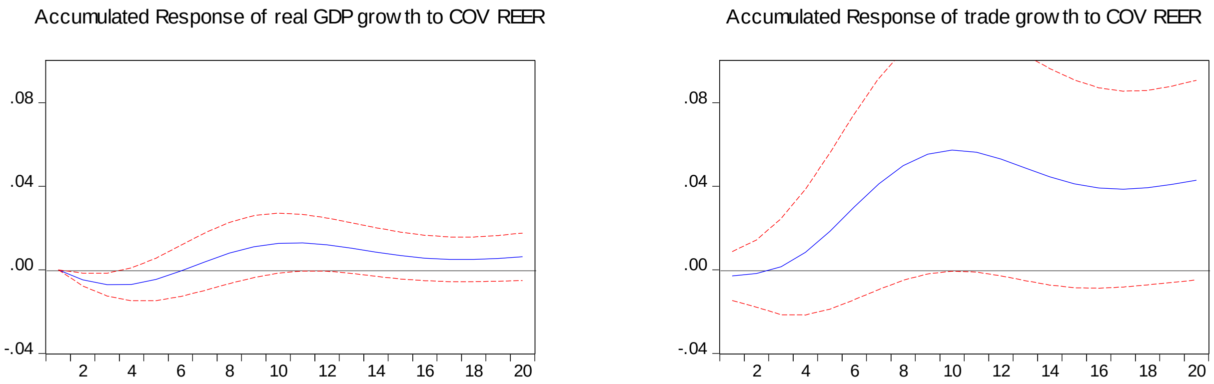

Figure A.2 Impulse-response functions with accumulated responses for post-crisis period

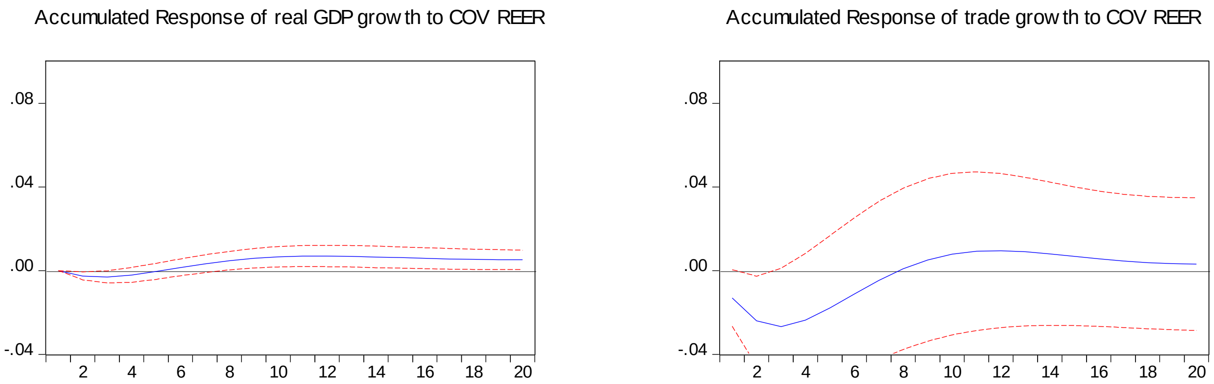

Figure A.3. Impulse-response functions with accumulated responses for VAR(2) with real GDP growth, coefficient of variation of the NEER and trade growth

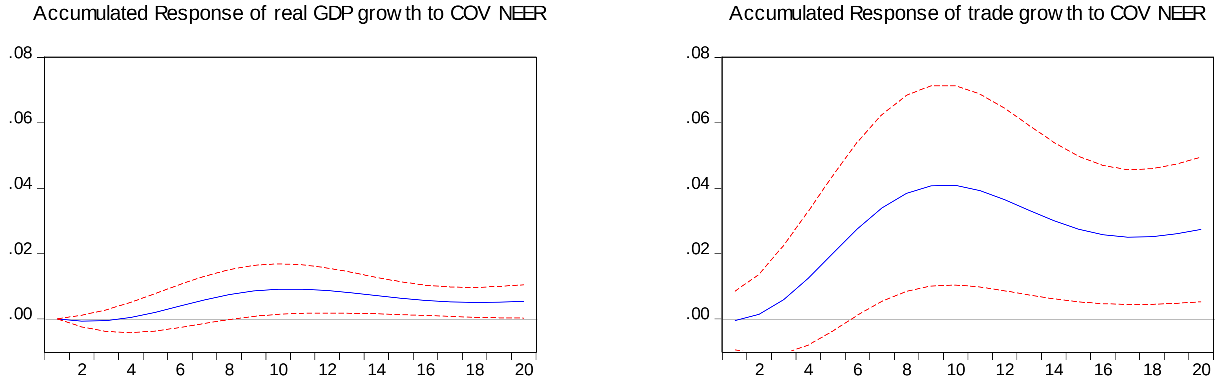

Figure A.4. Impulse-response functions with accumulated responses for VAR(2) with real GDP growth, standard deviation of the REER and trade growth

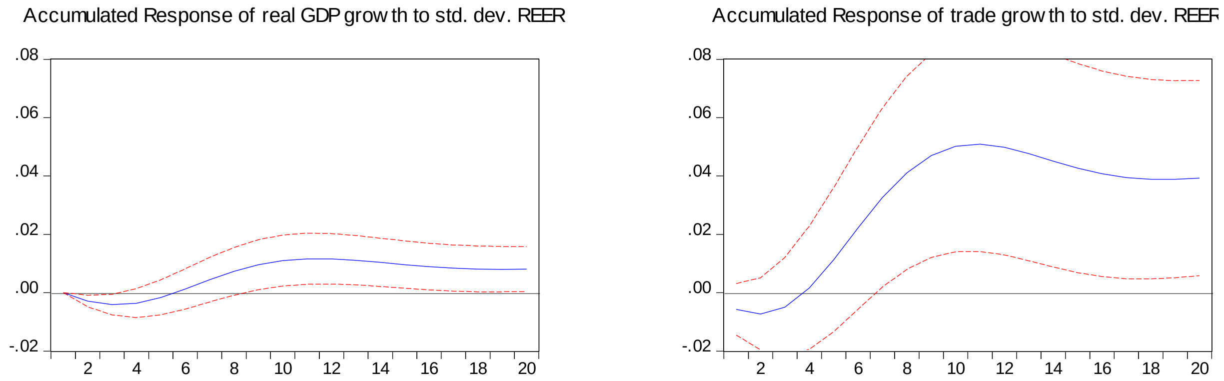

Figure A.5. Impulse-response functions with accumulated responses for VAR(2) with real GDP growth, coefficient of variation of the REER and exports growth

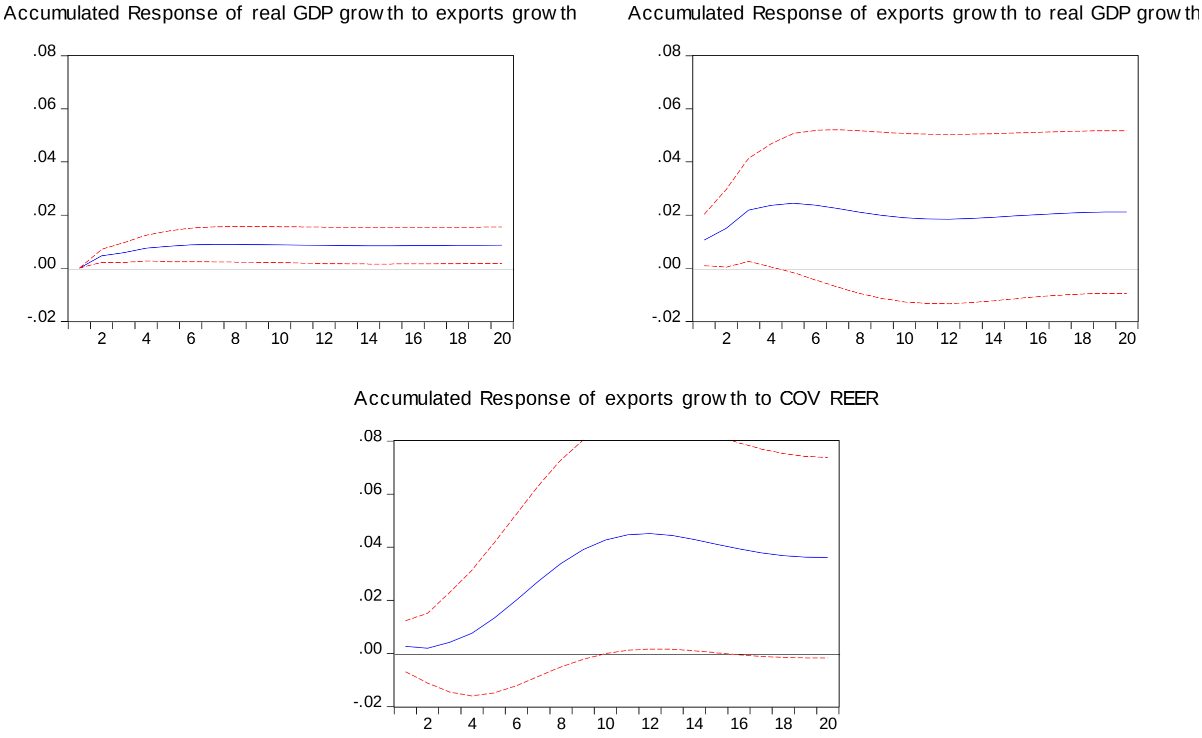

Figure A.6. Impulse-response functions with accumulated responses for VAR(2) with real GDP, coefficient of variation of the REER and trade