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Working Paper Series Vol. 2012-10
October 2012

The International Centre for the Study of East Asian Development, Kitakyushu

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Abstract

This study examines inter-regional spillovers in Fukuoka Prefecture that is located on the west side of Japan, near the Korean peninsula. There are two government-designated major cities in Fukuoka Prefecture: the Fukuoka city, the central city in Fukuoka Prefecture, and the Kitakyushu city, a big city with a population of about one million. The relationship between Fukuoka and Kitakyushu cities is with problems. Because the two cities are independently administered, each government can execute policies that best suit its own interests. However, it is important for Fukuoka Prefecture that both cities cooperate for achieving mutual economic benefits.

We analyze this spillover within the framework of a multi-region vector autoregressive (VAR) model. To express the economic relationship in this study, Fukuoka Prefecture is divided into three parts: Fukuoka city, Kitakyushu city, and the rest of Fukuoka Prefecture. We subject the model to extensive sensitivity analysis, with particular attention to effects on the results of strong common output movements.

JEL classification: O53, R11, R12
Keywords: Spillover, Fukuoka Prefecture, VAR model

October 2012

[♦] For their many useful comments, the author thanks the participants of the 51st European Regional Science Association Congress at the University of Barcelona (August 2011). The author is responsible for any errors.

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1. Introduction

This study examines the inter-regional spillovers in Fukuoka Prefecture that is located on the west side of Japan, near the Korean peninsula. It is the largest economic prefecture in Kyushu Island and the 4th largest economic bloc in Japan. There are two government-designated major cities in Fukuoka Prefecture: the Fukuoka city, the central and merchant city in Fukuoka Prefecture, and the Kitakyushu city, a big city with a population of about one million. Kitakyushu has a larger manufacturing economy than Fukuoka. The relationship between Fukuoka and Kitakyushu cities is with problems. Because the two cities are independently administered, each government can execute policies that best suit its own interests. However, it is important for Fukuoka Prefecture that both cities cooperate for achieving mutual economic benefits.

It is important to analyze the economic trends of each city. However, it cannot be said that each city is economically independent. In fact, one should rather understand the competitive and complementary positions of each city with regard to the surrounding area, and analyze these together with their relationship to the surrounding area rather than analyzing each city alone. Therefore, this study suggests an economic system to analyze the trends in the aforementioned two cities, the rest of Fukuoka Prefecture, and the surrounding area.

There are many worthwhile economic systems; several of them specialize in the type of time-series analysis needed for this study.[1] This study employs a very simple system for analysis, a method derived from the characteristics of the data it calculates. This system is called the vector autoregressive (VAR) model in econometrics (Sims, 1980). This is a model in which each dependent variable has its own associated lag. The model is often employed in economics for data analysis.

Therefore, this study applies the framework of a VAR model to a regional economic analysis, and the change in variables between regions is measured. The application of VAR to a regional economic analysis is not unusual; doing so supports the case study even if the technique is only applied to the data of Fukuoka Prefecture.[2] However, there is not much literature analyzing the dependency between regions using the comparatively small economies found at the level of cities; therefore, this study can provide regional economic analysis with a new viewpoint.

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[1] The analysis using the interregional input–output table is one example.

[2] For instance, Carlino and DeFina (1995) and Kouparitsas (2002) are case studies in the U.S.; Groenewold et al. (2007 and 2008) are case studies in China.

2. The Model

A set of time-series variables is said to be cointegrated if they are integrated in the same order and have a stationary linear combination. Such linear combinations would then point to the existence of a long-term relationship among the variables (Johansen and Juselius, 1990). An advantage of cointegration analysis is that through building an error-correction model (ECM), the dynamic co-movement among variables and the adjustment process toward long-term equilibrium may be examined. Our goal in this study is to use Johansen's (1988) vector error-correction (VEC) model to formulate regional output variables. Although Engle and Granger's (1987) two-step ECM may also be used in a multi-variate context, VEC yields more efficient estimators of cointegrating vectors. This is because VEC is a full information maximum likelihood estimation model, which allows testing for cointegration in a whole system of equations in one step without requiring a specific variable to be normalized. This allows us to avoid carrying over errors from the first step to the second step, as would be the case if Engle–Granger's methodology was used. It also has the advantage of not requiring a priori assumptions of endogenity or exogenity of the variables. The VEC is of the form

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} - \alpha_1 Z_{t-k} + \mu + e_t \quad (1)$$

$$Z_t = \beta_1 X_t \quad (2)$$

where $\Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1}$ and Z_{t-k} are the VAR component in first differences and error-correction components, respectively, in levels of Eq. (2). X_t is a $p \times 1$ vector of variables and is integrated of order one. μ is a $p \times 1$ vector of constants. k is a lag structure, while e_t is a $p \times 1$ vector of white noise error terms. Γ_j is a $p \times p$ matrix that represents short-term adjustments among variables across p equations at the jth lag. β is a $p \times r$ matrix of cointegration vectors and Δ denotes first differences. α is a $p \times r$ matrix of speed of adjustment parameters representing the speed of an error correction mechanism. A larger α suggests a faster convergence toward long-run equilibrium in cases of short-run deviations from this equilibrium.

In estimating the VEC, we first check for unit roots by performing the augmented Dickey–Fuller (ADF) tests on the variables in levels and first differences (Dickey and Fuller, 1981). Only variables integrated of the same order may be cointegrated; the unit root tests will help us determine which variables are integrated of order one, or $I(1)$. Then, we check the number of cointegration vectors using Johansen's (1988) test. If there are no cointegration vectors among the variables, we use the VAR model to estimate the system.

3. Data

First of all, Fukuoka Prefecture, the study region, has two cities directly under its control, which are administratively independent: Fukuoka and Kitakyushu cities. We segregate the rest of Fukuoka Prefecture from the economies of Fukuoka and Kitakyushu cities; these are the three regions used in the study. The economy of Fukuoka Prefecture is not limited to its own prefecture, although it is the region where the economy is comparatively more developed in Japan. Therefore, other regions that influence the economy of these three regions are also considered in the analysis. Needless to say, these include other prefectures in Japan (the rest of Japan). We want to investigate the influence of economic dependence within the three regions on the rest of Japan. Next, the study examines the relationship with surrounding countries, because Fukuoka Prefecture is geographically near East Asia. Therefore, China and South Korea near Fukuoka Prefecture are added to the system of the model.

The data covering the rest of Fukuoka Prefecture, Fukuoka city, and Kitakyushu city have been sourced from "*Kenmin Keizai Keisan*," published by the Cabinet Office of Japan on its homepage. The data of Japan, China, and South Korea have been sourced from "*World Development Indicators* (WDI) 2009," by the World Bank. Both are the total quantity of GDP and gross regional product (GRP) of the respective regions, assumed to be comparable to the price of the US dollar in the year 2000. The calculation period is assumed to be from 1976 to 2007.

4. Calculation result

We show the result of the analysis based on the previous section's procedure. First, using the unit root test, it is estimated that the rest of Japan slightly exceeds by 10% significance. It can be seen that almost all series except the rest of Japan become stationary at the first order difference in Table 1. Therefore, we can test the cointegration of the series of $I(1)$. In the cointegration test in Table 2, three models were examined. The first is a system in six regions. The second is a system in four regions of Japan, with China and South Korea as the exogenous variables. The third is a system in four regions of Japan. The table shows up to one cointegration vector in the maximum eigenvalue test, while more than one cointegration vector is seen in the trace test.[3] It supports the conclusion that all systems should be estimated by the VEC model with one cointegration vector rather than by the VAR model because each system has at least one cointegration vector.[4]

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[3] Because P value is about 12%, it can have one cointegration vector system in four regions.
[4] There is a method for confirming stationary of the unit root test: using the time series that adds the structural change dummy because VAR can be used if a time series is stationary (Groenewold et al., 2007 and 2008).

The three models estimated with VEC show the impulse response function (one unit innovations) when giving a shock to each variable in Figure 1. Lag to the endogenous variable of VEC assumes the first order. The purpose of this lag structure is to deal with the model of the Markov chain. Each model quickly reaches the next equilibrium; the error correction is well demonstrated.

Figure 1 shows the response of each variable to the effect of Kitakyushu city. It has a large influence on the rest of Japan. Other regions also show a positive change. The effects of Fukuoka city in Figure 2 show a negative influence on other regions, including an especially large one on Kitakyushu city, although it is a positive effect for Japan. Fukuoka city's development could become disadvantageous for Kitakyushu city. In the effect of the rest of Fukuoka Prefecture shown in Figure 3, positive effects are seen in adjacent Kitakyushu and Fukuoka cities as well as in South Korea, with almost no effect in China and a negative effect in Japan. The effects of Fukuoka and Kitakyushu cities are first expected to spillover to Fukuoka Prefecture. The effect on the rest of Japan in Figure 4 is somewhat negative, although it is positive for Fukuoka city and South Korea. Because Fukuoka Prefecture is the 4th economic bloc in Japan, it can be thought that the Japanese economy easily influences Fukuoka city, being the center of Fukuoka Prefecture. The effect of China shown in Figure 5 is highly negative for the rest of Japan, although it is positive for some other regions. It can be said that China's growing power is undesirable for Japan. In the effect of South Korea shown in Figure 6, there is a large positive effect on Fukuoka city because it is adjacent to the sea. On the other hand, it seems that the two countries are competing based on the negative effect by China.

It appears that there are conflicts among the three regions of (the rest of) Japan, China, and South Korea when the change of effects in a six-region model is analyzed. On the other hand, the six-region model has a positive influence on Japan, although it indicates conflict between Fukuoka and Kitakyushu cities in Fukuoka Prefecture. Moreover, (the rest of) Fukuoka Prefecture has a positive influence on neighboring regions.

From Figure 7 to Figure 14 show the impulse response function of the four regions model based on the above. None of the six-region models show as big a difference as demonstrated in the result of each figures except Figure 10 (Kitakyushu city is the only one with a positive effect against the effect of Japan). The competition between Fukuoka and Kitakyushu cities and supplementary to both cities in (the rest of) Fukuoka Prefecture can be seen.

5. Conclusion

The spillover effect between regions in Fukuoka Prefecture and surrounding regions was analyzed within the framework of the VAR (VEC) model. The influence among regions was found to be mutually conflicting with (the rest of) Japan, China, and South Korea. Fukuoka and Kitakyushu cities compete against each other in Fukuoka Prefecture, and Fukuoka Prefecture was supplementary to both cities.

Although the relationships of interdependence among regions were analyzed by a very simple model, the fact that Japan, China, and South Korea are rivals may have a significant influence on economic policies at the country level. On the other hand, although Fukuoka and Kitakyushu cities are competitive, since they share part of the same border, they can be referred to, in conclusion, as Fukuoka Prefecture. However, the influence of Fukuoka Prefecture on other prefectures and on foreign countries is weak. Thus, it is effective to use a common econometric model to analyze the spillover effect between regions.

References

Carlino, G. and R. DeFina, (1995). "Regional income dynamics," *Journal of Urban Economics*, 37, pp. 88–106.

Dickey, D. A. and W. A. Fuller, (1981). "Likelihood ratio statistics for autoregressive time series with a unit root," *Econometrica*, 49, pp.1057–1072.

Engle, R. E. and C. W. J. Granger, (1987). "Cointegration and error-correction: representation, estimation and testing," *Econometrica*, 55, pp. 251–276.

Groenewold, N., G. P. Lee, and A. P. Chen, (2007). "Regional output spillovers in China: Estimates from a VAR model," *Papers in Regional Science*, 86, pp.101–122.

Groenewold, N., G. P. Lee, and A. P. Chen, (2008). "Inter-regional spillovers in China: The importance of common shocks and the definition of the regions," *China Economic Review*, 19, pp. 32–52.

Johansen, S., (1988). "Statistical analysis of cointegrating vectors," *Journal of Economic Dynamics and Control*, 12, pp. 231–254.

Johansen, S. and K. Juselius, (1990). "Maximum likelihood estimation and inference on cointegration with application to the demand for money," *Oxford Bulletin of Economics and Statistics*, 52, pp. 169–210.

Kouparitsas, M. A., (2002). "Understanding US regional cyclical co-movement: How important are spillovers and common shocks?" *Federal Reserve Bank of Chicago Economic Perspectives*, 4th quarter, pp. 30–41.

Sims, C., (1980). "Macroeconomics and Reality," *Econometrica*, 48, pp. 1–48.

Table 1 Unit Root Test (ADF)

	Level		Differential	
	t-Statistic	Probability	t-Statistic	Probability
KK	−3.0217	0.0438	−3.7628	0.0080
FC	−1.8523	0.3492	−3.3900	0.0194
FP	−2.3946	0.1514	−4.3702	0.0017
JP	−1.9637	0.3004	−2.6192	0.1003
CN	0.7286	0.9907	−2.9406	0.0538
KR	−1.8146	0.3668	−4.5593	0.0011

Table 2 Cointegration Test (Johansen)

Series: KK, FC, FP, JP, CN, KR (VEC 1)					
	Eigenvalue	Trace	Probability	Max-Eigen	Probability
None	0.8403	135.2655	0.0000	55.0379	0.0005
At most 1	0.6418	80.2277	0.0059	30.7970	0.1116
At most 2	0.5230	49.4306	0.0353	22.2079	0.2099
At most 3	0.3650	27.2228	0.0963	13.6258	0.3965
At most 4	0.3558	13.5970	0.0947	13.1943	0.0733
At most 5	0.0133	0.4027	0.5257	0.4027	0.5257
Series: KK, FC, FP, JP; Exogenous series: CN, KR (VEC 2)					
	Eigenvalue	Trace	Probability	Max-Eigen	Probability
None	0.7502	88.4941	0.0000	41.6183	0.0004
At most 1	0.4986	46.8758	0.0002	20.7081	0.0572
At most 2	0.4246	26.1677	0.0009	16.5830	0.0211
At most 3	0.2735	9.5847	0.0020	9.5847	0.0020
Series: KK, FC, FP, JP (VEC 3)					
	Eigenvalue	Trace	Probability	Max-Eigen	Probability
None	0.5581	55.3031	0.0085	24.4985	0.1183
At most 1	0.4214	30.8046	0.0382	16.4149	0.2015
At most 2	0.3585	14.3897	0.0728	13.3185	0.0701
At most 3	0.0351	1.0713	0.3007	1.0713	0.3007

Figure 1 Impulse Response Function of VEC 1 (one unit innovations, response of KK)

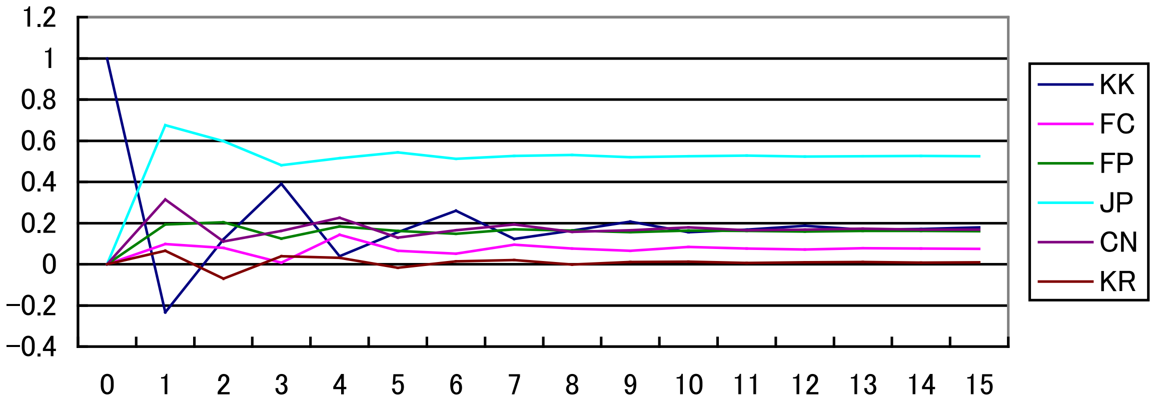

Figure 2 Impulse Response Function of VEC 1 (one unit innovations, response of FC)

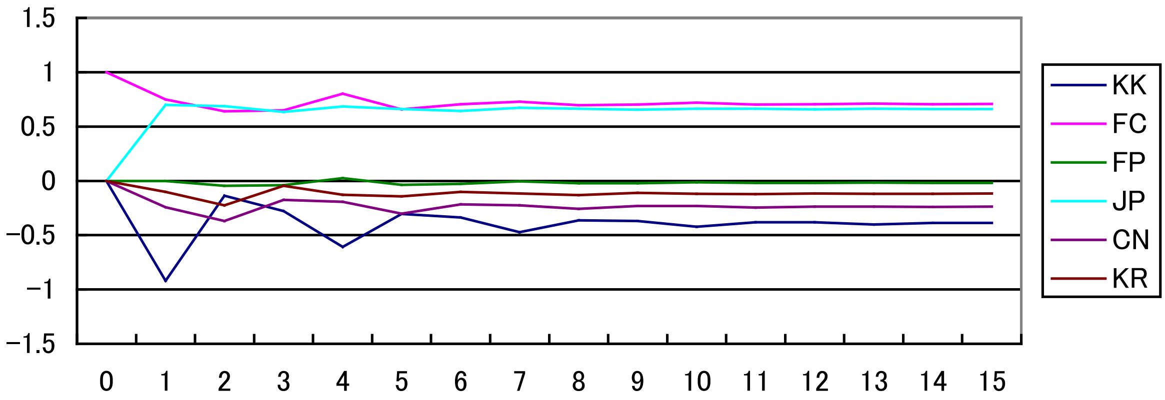

Figure 3 Impulse Response Function of VEC 1 (one unit innovations, response of FP)

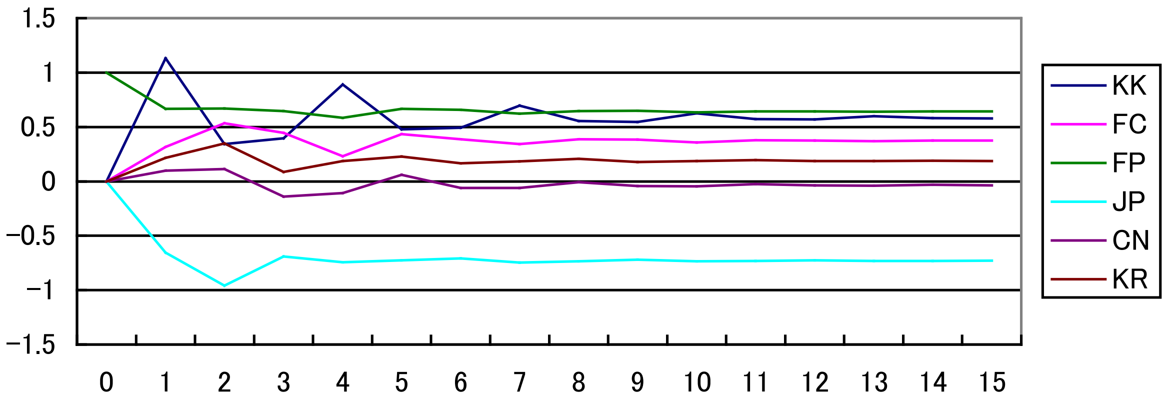

Figure 4 Impulse Response Function of VEC 1 (one unit innovations, response of JP)

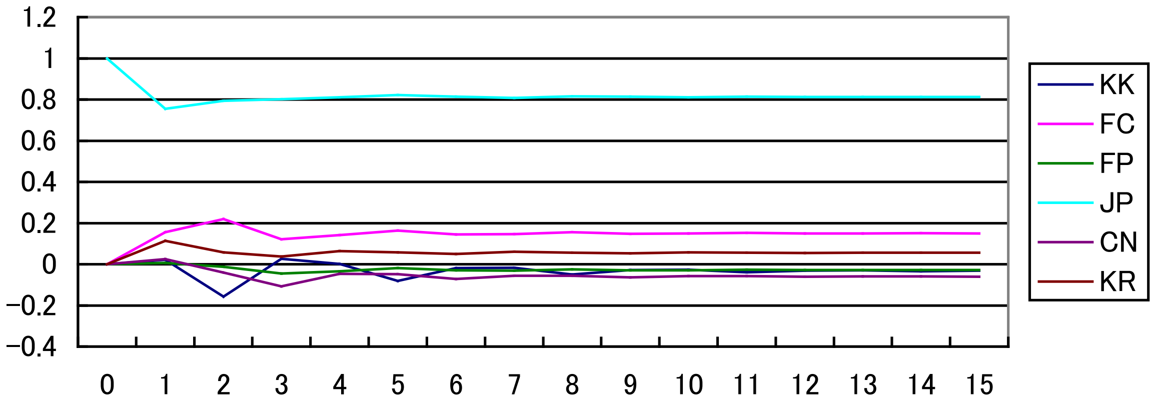

Figure 5 Impulse Response Function of VEC 1 (one unit innovations, response of CN)

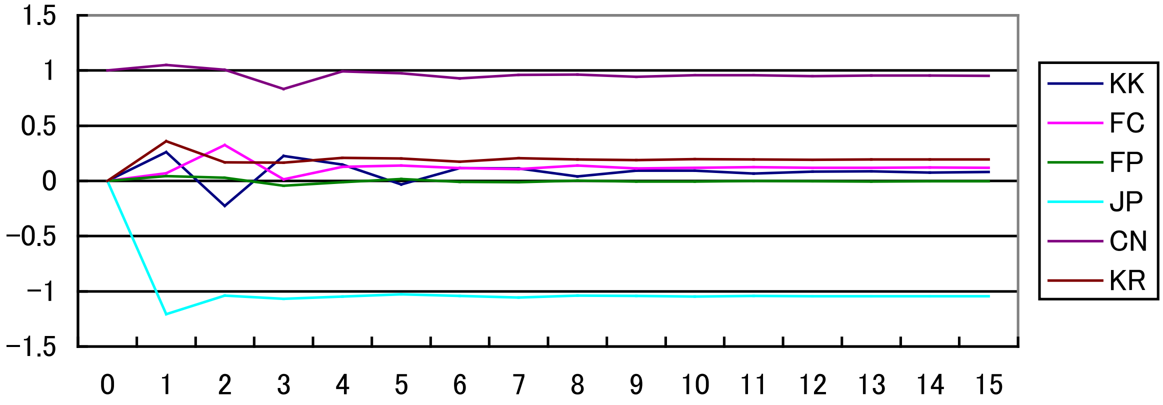

Figure 6 Impulse Response Function of VEC 1 (one unit innovations, response of KR)

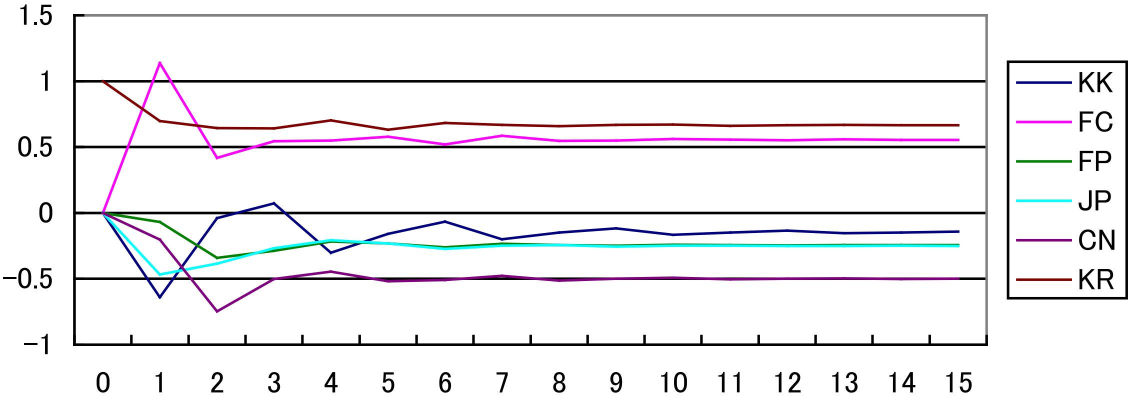

Figure 7 Impulse Response Function of VEC 2 (one unit innovations, response of KK)

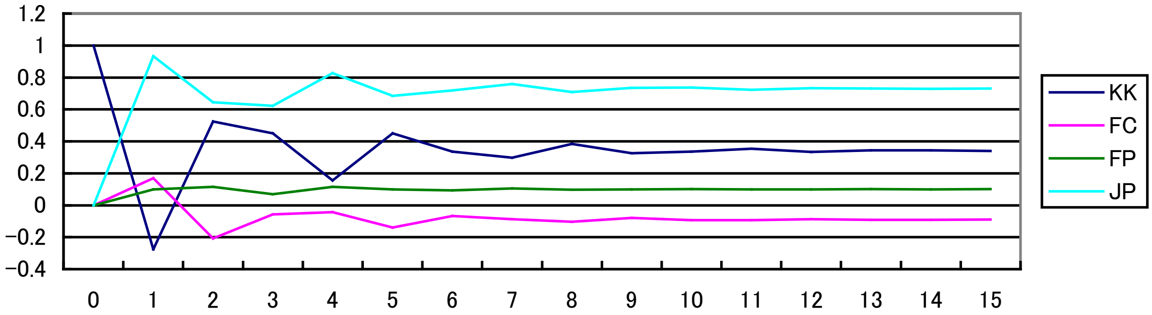

Figure 8 Impulse Response Function of VEC 2 (one unit innovations, response of FC)

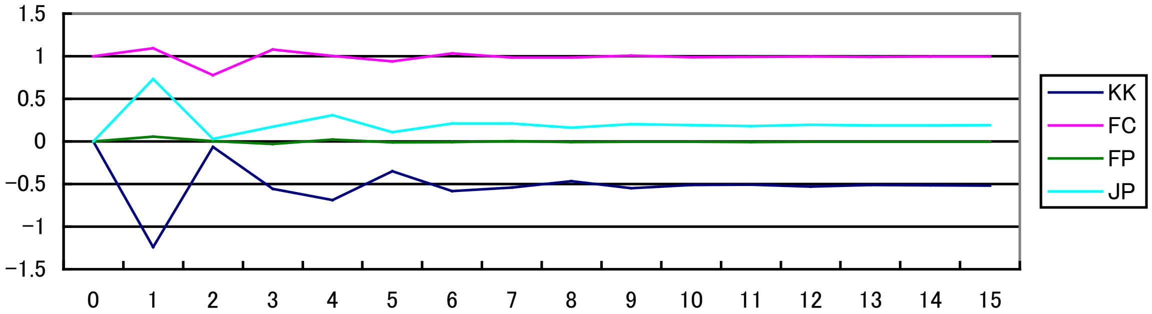

Figure 9 Impulse Response Function of VEC 2 (one unit innovations, response of FP)

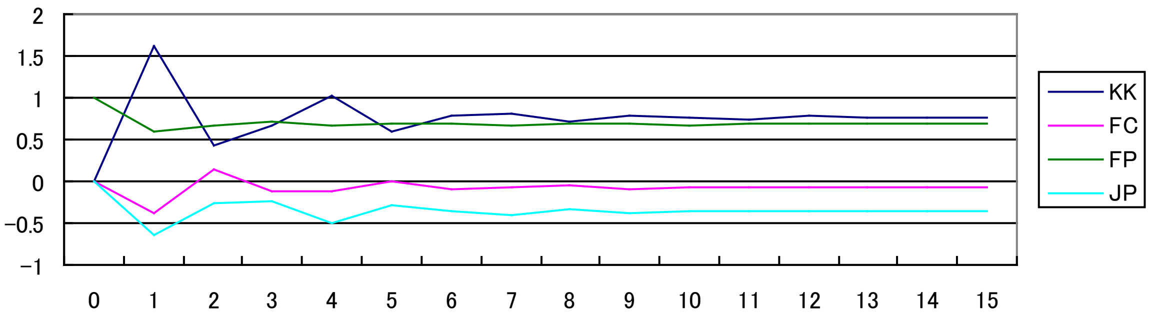

Figure 10 Impulse Response Function of VEC 2 (one unit innovations, response of JP)

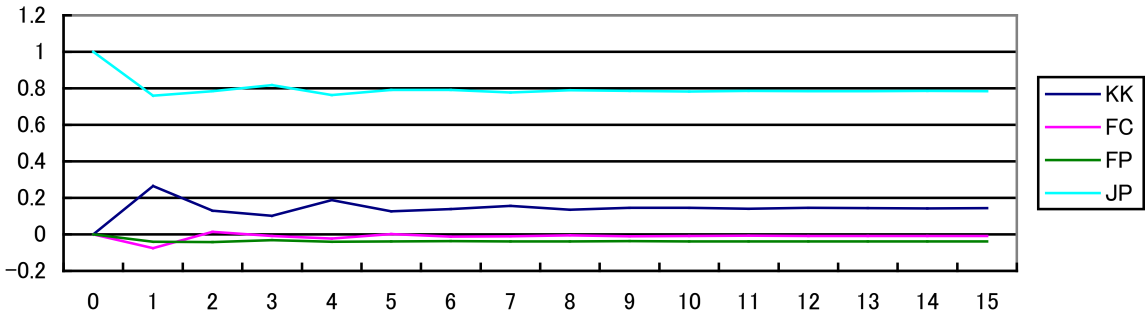

Figure 11 Impulse Response Function of VEC 3 (one unit innovation, response of KK)

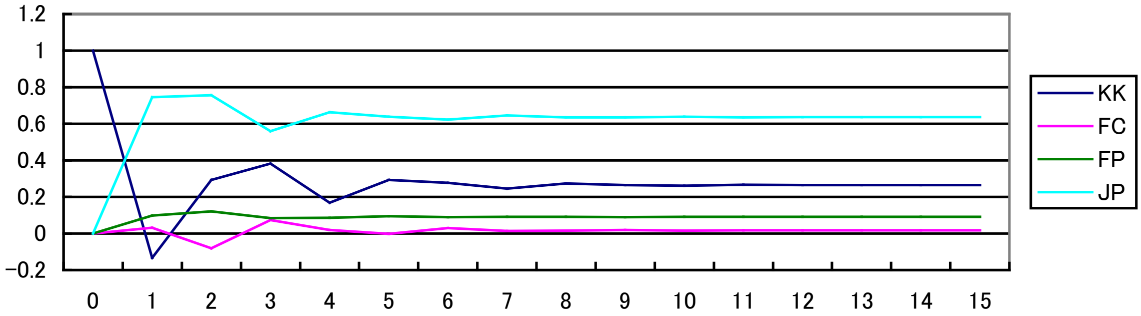

Figure 12 Impulse Response Function of VEC 3 (one unit innovations, response of FC)

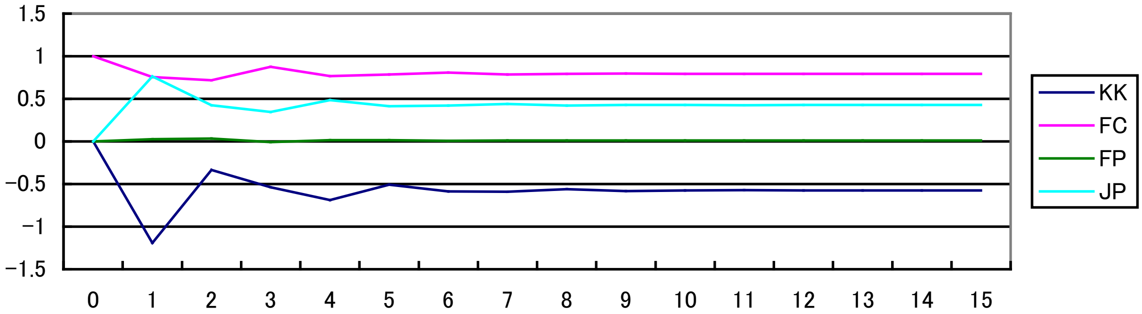

Figure 13 Impulse Response Function of VEC 3 (one unit innovations, response of FP)

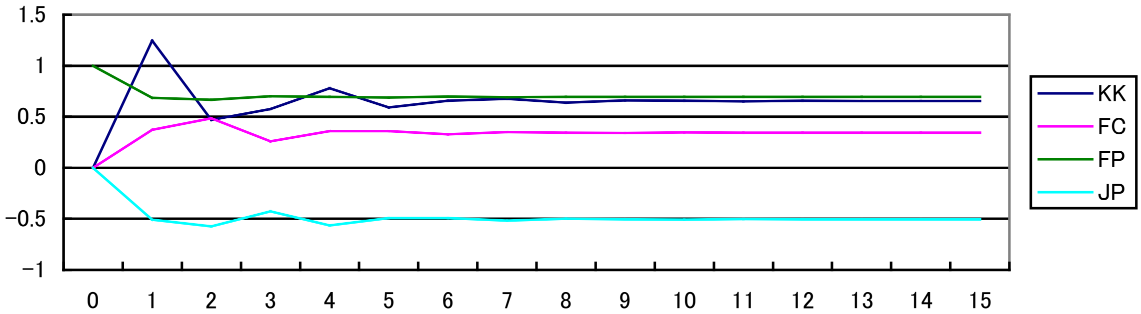

Figure 14 Impulse Response Function of VEC 3 (one unit innovations, response of JP)