Inter-regional spillovers in Fukuoka Prefecture:

Using VAR model

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Abstract

This paper examines the question of inter-regional spillovers in Fukuoka Prefecture. Fukuoka Prefecture is located on the west side of Japan, and is near the Korean peninsula. There are two government-designated major cities in Fukuoka Prefecture. One is Fukuoka City, which is the central city in Fukuoka Prefecture. The other is Kitakyushu City, which is a big city with a population of about one million. The relationship between Fukuoka City and Kitakyushu City is not without problems. Because the two cities are independently administered, each government can execute the policy that best suits its own interest. On the other hand, it is important for Fukuoka Prefecture that both cities economy cooperate.

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

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1. Introduction

This paper examines the question of inter-regional spillovers in Fukuoka Prefecture. Fukuoka Prefecture is located on the west side of Japan, and is near the Korean peninsula. There are two government-designated major cities in Fukuoka Prefecture. One is Fukuoka City, which is the central and merchant city in Fukuoka Prefecture. The other is Kitakyushu City, which is a big city with a population of about one million and of which share of manufacture is higher than Fukuoka city. The relationship between Fukuoka City and Kitakyushu City is not without problems. Because the two cities are independently administered, each government can execute the policy that best suits its own interest. On the other hand, it is important for Fukuoka Prefecture that both cities economy cooperate.

Table 1 shows some basic statistics on Fukuoka Prefecture. In 2007, the 2000 price of gross regional product (GRP) of Fukuoka Prefecture accounted for about 3.5% of Japan's total GRP. The GRP of Kitakyushu City is half or more than half that of Fukuoka City. Kitakyushu City's GRP per capita is below the national average though Fukuoka City's is higher than the national average. On the other hand, Fukuoka Prefecture's population shows an increasing tendency. However, the increasing tendency of the population of Fukuoka Prefecture differs greatly between Fukuoka City and Kitakyushu City. The trends of workers are also similar. In Fukuoka City, the ratio of manufacturing is extremely low and indicates an economic structure of the city type. That of Kitakyushu City is the same as that of the national economy. It is understood that there are some differences in the economic structure.

It is important to analyze an economic trend of both cities. However, it cannot be said it is economically independent, and in that case, both cities would rather possess the competition and the complementary position with the surrounding area, and analyze it together with the relation to the surrounding area than analyzing both cities alone. Then, this study suggests the economic systems to analyze with above two cities, the rest of Fukuoka Prefecture, and the surrounding area.

There are many considerable economic systems, and it specializes in the time series analysis in this study.[1] Moreover, it suggests the analysis by the very simple system which is a method that leads from the characteristic of data, and that is called the vector-autoregressive (VAR) model in econometrics world (Sims, 1980). This is a model which each dependent variable are explained by these lag, it is often handled in economics as the data analysis though its economics meaning is very few.

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

Then, this study applies the framework of VAR to a regional economic analysis, and the change of the variable between regions is measured. The application of VAR to the regional economic analysis is not few and it only expands the case study even if it only applies this technique to the data of Fukuoka Prefecture.[2] Therefore, this study introduces VAR estimation by the Markov chain before VAR model analyzed by usual econometrics, and compares both two analyses. As for the Markov chain, it is thought that the Markov chain is a kind of the VAR model in the meaning that past data forecasts the future. The Markov chain corresponds to the VAR model of the first order. Therefore, the readers may think that it is in the extension of the research of the VAR model. However, it is not possible to correspond to a complex auto regression of higher-order. It has the problem that an appropriate estimate method of the transition probability matrix has not been established. Therefore, this study separately introduces the estimate method by the Markov chain.

2. VAR Model by Markov Chain

Before introducing econometrical VAR model, we propose another option for estimating VAR system that is Markov chain.

First, we remember the model of Markov chain. It is the classical well-known tool for the derivation of probabilistic chains (Romanovski, 1948). For each Markov transition matrix M = (p_{ij}) with transitional probabilities, $0 \le p_{ij} \le 1$, $\sum_{i=1} p_{ij} = 1$ the linear probabilistic chain can be derived as $p_{t+1} = M p_t$, t=0,1,2,... (Sonis and Dendrinos, 2009). If we apply it, the Markov transition matrix can also be used to model the dynamics of the economic growth. Let F_t is the vector comprising of the GDP in industrial sector in the period t, and F_{t+1} is the same for the period t+1. Suppose M_t is the matrix that maps F_t onto F_{t+1}, so that we have

$$F_{t+1} = M_t \cdot F_t . \quad (1)$$

Assuming that the transition matrix M_t is time specific, the share vector after s period, F_{t+s} will be given by

$$F_{t+s} = M_t \cdot M_{t+1} \cdot\cdot\cdot\cdot M_{t+s-1} \cdot F_t = \prod_{i=0}^{s-1} M_{t+i} \cdot F_t . \quad (2)$$

Therefore, current level of GDP is modeled by Markov chain.

Second, we will introduce how to estimate transition matrix M_t by using actual data. In

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

this case, M_t cannot be obtained directly from actual data. Hence an estimation procedure is necessary. The procedure implemented in this study runs along the following lines.

If F_t is (3 x 1), the transition matrix M_t for time t will be (3 x 3) and will look as follows:

$$M_t = \begin{pmatrix} a_{t,11} & a_{t,12} & a_{t,13} \\ a_{t,21} & a_{t,22} & a_{t,23} \\ a_{t,31} & a_{t,32} & a_{t,33} \end{pmatrix} \quad (3)$$

Suppose $F_t' = (b_{t,1}\ b_{t,2}\ b_{t,3})$ and $F_{t+1}' = (b_{t+1,1}\ b_{t+1,2}\ b_{t+1,3})$. According to equation (1), we therefore have

$$b_{t+1,1} = a_{t,11}*b_{t,1} + a_{t,12}*b_{t,2} + a_{t,13}*b_{t,3} \quad (4\text{-}1)$$
$$b_{t+1,2} = a_{t,21}*b_{t,1} + a_{t,22}*b_{t,2} + a_{t,23}*b_{t,3} \quad (4\text{-}2)$$
$$b_{t+1,3} = a_{t,31}*b_{t,1} + a_{t,32}*b_{t,2} + a_{t,33}*b_{t,3} \quad (4\text{-}3).$$

However, in this formula we may not keep property of Markov chain which sum of column of probability matrix M_t becomes equal to 1.

$$\sum_{k=1}^{3} a_{t,jk} = 1 \quad \forall j \quad (5)$$

Therefore, we assume adjustment parameter which will keep the property. Several ideas can be considered, but we adopt total growth rate of GDP g_t for using an adjustment parameter. g_t is simply defined by,

$$g_t = \sum_{j=1}^{3} b_{t+1,j} \Big/ \sum_{j=1}^{3} b_{t,j} \quad (6)$$

Then we modify equations to be

$$b_{t+1,1} = g_t\,(a_{t,11}*b_{t,1} + a_{t,12}*b_{t,2} + a_{t,13}*b_{t,3}) \quad (4'\text{-}1)$$
$$b_{t+1,2} = g_t\,(a_{t,21}*b_{t,1} + a_{t,22}*b_{t,2} + a_{t,23}*b_{t,3}) \quad (4'\text{-}1)$$
$$b_{t+1,3} = g_t\,(a_{t,31}*b_{t,1} + a_{t,32}*b_{t,2} + a_{t,33}*b_{t,3}) \quad (4'\text{-}1).$$

These three restrictions are however not enough to solve uniquely for the nine elements of the matrix M_t. We need more restrictions. In this regard, we note that one trivial solution of M_t is the identity matrix. The trivial solution of M_t is not the desired solution. However, it can provide the source of necessary restrictions. Assuming that the distribution does not change that much from one period to the next, it will indeed be case that the elements of M_t will be such that the matrix will mimic the identity matrix. Using this idea and generalizing M_t to be n x n, we can estimate the elements of M_t based on the following minimization procedure:

$$\text{Minimize} \qquad \sum_{j=1}^{n}\sum_{k=1}^{n}\left(a_{t,jk} - i_{jk}\right)^2$$

$$\text{Subject to} \qquad b_{t+1,j} = g_t \cdot \sum_{k=1}^{n} a_{t,jk} \cdot b_{t,k}\ ,\ \ \forall j\text{, and } \sum_{k=1}^{n} a_{t,jk} = 1,\ \ \forall j \qquad (7)$$

where i_{jk} is an element of identity matrix I and g_t is total growth rate of GDP as before mentioned ($g_t = \sum_{j=1}^{n} b_{t+1,j} \Big/ \sum_{j=1}^{n} b_{t,j}$). This minimization problem can be solved using non-linear programming to produce unique solution for the elements $a_{t,jk}$.

Third, we construct transition matrix $\overline{M}$ for forecasting. Since the above estimated transition matrix M_t is time specific, we consider the average of the elements.

$$\overline{M} = \sum_{t=1}^{s} M_t \Big/ s \qquad (8)$$

We estimate VAR system by using this matrix.

3. Vector Error-Correction Model

A set of time-series variables are said to be cointegrated if they are integrated of the same order and a linear combination of them is stationary. 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 next goal of this study is to use Johansen's (1988) vector error-correction model (VEC model) to formulate regional output variables. Although Engle and Granger's (1987) two-step error-correction model may also be used in a multivariate context, the VEC yields more efficient estimators of cointegrating vectors. This is because the VEC is a full information maximum likelihood estimation model, which allows for testing for cointegration in a whole system of equations in one step and without requiring a specific variable to be normalized. This allows us to avoid carrying over the errors from the first step into the second, as would be the case if Engle-Granger's methodology is 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

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{k-1} \Delta X_{t-k+1} - \alpha_1 Z_{t-k} + \mu + e_t \quad (9)$$

$$Z_t = \beta_1 X_t \quad (10)$$

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 vector autoregressive (VAR) component in first differences and error-correction components, respectively, in levels of Eq. (9). X_t is a p x 1 vector of variables and is integrated of order one. μ is a p x 1 vector of constants. k is a lag structure, while e_t is a p x 1 vector of white noise error terms. Γ_j is a p x p matrix that represents short-term adjustments among variables across p equations at the jth lag. β is a p x r matrix of cointegration vectors, and Δ denotes first differences. α is a p x r matrix of speed of adjustment parameters representing the speed of 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 through 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, and 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 vector using by Johansen's (1988) test. If there are no cointegration vectors among the variables, we should use VAR model to estimate system.

4. Data

First of all, Fukuoka Prefecture that is the object region has two direct control cities, and is independent on an administrative side. The two are Fukuoka City and Kitakyushu City. Moreover, we assume the rest of Fukuoka Prefecture except the income of Fukuoka City and Kitakyushu City then these three regions were used. The economy of Fukuoka Prefecture is not closed only within own prefecture though it is the region where economy is developed comparatively in Japan. Then, the region that influences these three regions is set into the analysis. Needless to say, one is other prefectures in Japan (the rest of Japan). We want to investigate what influence an economic dependence in three regions gives the rest of Japan. Next, it should examine the relation to the surrounding country because Fukuoka Prefecture is geographically near East Asia. Therefore, China and South Korea comparatively near Fukuoka Prefecture are added to the system of the model.

The data of the rest of Fukuoka Prefecture, Fukuoka City, and Kitakyushu City are used "*Kenmin Keizai Keisan*" published by the Cabinet Office of Japan on their homepage. The data of Japan, China, and South Korea are used "*World Development Indicators* (WDI) 2009" by the World Bank. Both are the total quantity of GDP and GRP (gross regional product), these were assumed the comparable one by the 2000 price of US dollar conversion. The estimation period is assumed from 1976 to 2007.

5. Estimation Result

5.1. Results of Markov Chain

First of all, the result of VAR model by using the Markov chain is shown. Table 2 shows the estimated transition probability matrix by using the method of chapter 2 for all of the six regions.[3] For instance, it is found that the spillover from lag in other region is very small though the value of lag in own region is the largest when the row of Kitakyushu City is seen. The spillover effect exists slightly in Fukuoka City and the rest of Fukuoka Prefecture. There is no effect from the region of the remainder at all. It slightly receives effect only from South Korea besides though Fukuoka City has received the spillover from Kitakyushu City and the rest of Fukuoka Prefecture. The rest of Fukuoka Prefecture is receiving the spillover from Kitakyushu City and Fukuoka City, and it also has the effect slightly also excluding China. The spillover to China is the largest though the rest of Japan, South Korea, and China have received the effect from all regions. When these are seen, it has the possibility of concentrating on China in the economy for the long term. The economy of Kitakyushu City, Fukuoka City, and the rest of Fukuoka Prefecture are declining tendency each other.

The result of forecasting this until 2020 based on 2007 is Table 3. It is assumed that the average growth rate is 3% during the period. However, only the economy in China is increasing almost twice because the economy concentrates on China. Because it is an economic growth rate of about 8% in the current of China, the validity of forecast is seen.

Figure 1 shows the situation of China in which economy is concentrated in the super long-run. It is examined that how the distribution changed by assuming Kitakyushu City as 1 (100%) at the initial stage, and multiplying the Markov chain in Table 2 continuously. There is ergode character which the distribution converges to certain state as a feature of the Markov chain.[4] However, the model in Table 2 is very long the attainment terms to the ergodic distribution, and has not reached even 1,000 times completely. Still, the situation in which Kitakyushu City had all the incomes changes completely, and the greater part of incomes are of China. South Korea is secondarily and the following is the rest of Japan, and three regions of Fukuoka Prefecture are situations which with the income hardly. In a word, it can be said that there is a possibility of concentrating only on China for the future in this system.

Then, we propose the system in Japan by removing China and South Korea from the six regions system. Table 4 shows of the measurement result of VAR system that uses the

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[3] The GAMS (General Algebraic Modeling System) minimization program is used to carry out the estimation.

[4] Therefore, even if it is started from which variable, the shock that corresponds to the following impulse response functions becomes to the same ergodic distribution finally.

Markov chain by four regions of Kitakyushu City, Fukuoka City, the rest of Fukuoka Prefecture, and the rest of Japan. It can be said that the result is not very different from the system in Table 2. It is a result of the large concentration on the rest of Japan though the analysis similar to six regions' model was done to Table 4 and Table 5.[5]

It was shown that the economy of Fukuoka Prefecture was a deceleration tendency in the system from the above-mentioned two models. For the model which uses the Markov chain, a past growth rate difference is connected with concentrated tendency and non-concentrated tendency in the future. In a word, the region where the growth rate is comparatively high concentrates, and other regions become non-concentrations. It was evidence in this model that becoming concentrated tendency even if China extended for the future because China had accomplished remarkable economic growth for the measurement period. On the other hand, it means the growth rate of Fukuoka Prefecture for the measurement period had fallen below (the rest of) Japan that Japan concentrates by the model in four domestic regions. Therefore, to break this tendency, should do the economic growth of Fukuoka Prefecture.

5.2. Results of VEC model

Next, we will show the analysis result based on usual econometric model of VAR and/or VEC. First of all, if it is excluded that the rest of Japan slightly exceeds 10% by the unit root test, it can be read that all series become stationary at the first order difference in Table 6. This is also stationary at the first order difference if it is estimated that the rest of Japan is about 10%. Therefore, we can test of the cointegration at the series of $I(1)$. In the cointegration test in Table 7, three models were examined. First is a system in six regions. Second is a system in four regions of Japan with China and South Korea as the exogenous variables. 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.[6] It reaches the conclusion that all systems should be estimated by the VEC model with one cointegration vector rather than VAR model because they have cointegration vector.[7]

As regards three models estimated with VEC, showing of the impulse response function (one unit innovations) when giving a shock to each variable since Figure 3. Lag to the endogenous variable of VEC assumes the first order. The purpose of this lag structure is to make them deal with the model of the Markov chain. Each model also comparatively reaches the next equilibrium at early time, and the error correction is demonstrated greatly.

Figure 3 is a response of each variable to the shock of Kitakyushu City. The influence that it has on the rest of Japan is large, and another region changes in the direction of the

[5] The economic growth rate in Table 4 was assumed to be 2%.
[6] Because P value is about 12%, it can have one cointegration vector in four regions system.
[7] There is a method of confirming stationary by the unit root test by using the time series that adds the structural change dummy because VAR can use if an original time series is stationary (Groenewold et al., 2007 and 2008).

positive, too. In the shock of Fukuoka City in Figure 4, it is the influence of the negative to another region, especially large in Kitakyushu City though it is a direction of the positive for Japan. Fukuoka City's developing has the possibility of becoming disadvantageous for Kitakyushu City. In the shock of the rest of Fukuoka Prefecture in Figure 5, positive effects are seen in adjacent Kitakyushu City and Fukuoka City furthermore South Korea, almost no effect in China and negative effect in Japan are seen. The big city of Fukuoka City and Kitakyushu City is expected to spillover for Fukuoka Prefecture at first. In the shock of the rest of Japan in Figure 6, another is some negative though it is a positive to Fukuoka City and South Korea. Because Fukuoka Prefecture is located to the fourth economic bloc in Japan, it can be thought that Japanese economy influences Fukuoka City that is the center of Fukuoka Prefecture easily. In the shock of China in Figure 7, it is a huge negative for the rest of Japan though some other regions are positive. It can be said that gaining power of China is undesirable for Japan. In the shock of South Korea in Figure 8, the positive effect on Fukuoka City of adjacent with sea is large. On the other hand, it seems that the two countries are competing from the negative effect for China.

It is thought that it conflicts between three regions of (the rest of) Japan, China, and South Korea when the change of shock by six regional model was analyzed. On the other hand, it has both influences of the positive on Japan though it conflicts Fukuoka City and Kitakyushu City in Fukuoka prefecture. Moreover, (the rest of) Fukuoka Prefecture is giving neighboring regions the influence of the positive.

It is since Figure 9 that the impulse response function of four regions model was shown based on this. There is neither six regional model nor a big difference if being possible to say excludes the result of Figure 12 different somewhat (Kitakyushu City is an effect of the positive against the shock of Japan). The antagonism in Fukuoka City and Kitakyushu City and supplementary to both cities in (the rest of) Fukuoka Prefecture are seen.

6. Concluding Remarks

The spillover effect between regions in Fukuoka Prefecture and surrounding regions was analyzed with the framework of VAR. Two of the model and usual econometric models (finally, VEC model) that applied the Markov chain were used about VAR. For the Markov chain and the econometric model, the change when giving a shock is different and it is difficult to compare both and to judge superiority or inferiority. The Markov chain is able to know a long-term distribution situation, and the result suggests the decline of Japan and Fukuoka Prefecture while the future of Chinese economy is more strongly. The econometric model shows a short-term change. This is because the error correction works. As a result, it can reach to the next equilibrium in the short span of time comparatively. As regards the influence between regions, it turned out that it is conflicted mutually with (the rest of) Japan, China, and South Korea, Fukuoka City and Kitakyushu City are in the antagonism in Fukuoka Prefecture, and Fukuoka Prefecture was supplementary to both cities.

It is effective to use a usual econometric model to analyze the spillover effect between regions. On the other hand, the Markov chain is different from the econometric model in the point that a long-term distribution situation can be analyzed.[8] Therefore, the analysis is different, and, as a result, it can be said that the obtained conclusion will also change even by the same VAR form.

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[8] It is unsuitable to measure a negative effect because the estimate values are originally positive of all though the effect is demonstrated in a short-term forecast.

Table 1 Economy of Fukuoka Prefecture and Japan

2000 price GRP (Billion yen)								
	2000	2001	2002	2003	2004	2005	2006	2007
Fukuoka	18,062	17,837	18,105	18,512	18,774	19,208	19,473	19,717
Fukuoka	6,943	6,840	6,863	6,885	7,026	7,237	7,127	7,270
Kitakyushu	3,682	3,606	3,613	3,668	3,685	3,803	3,780	3,865
Japan	522,030	515,897	521,556	529,949	539,189	552,666	562,455	567,833
per capita GRP (Thousand yen)								
	2000	2001	2002	2003	2004	2005	2006	2007
Fukuoka	3,601	3,546	3,593	3,669	3,718	3,804	3,853	3,900
Fukuoka	5,176	5,051	5,016	4,989	5,053	5,165	5,039	5,095
Kitakyushu	3,640	3,575	3,590	3,656	3,684	3,828	3,816	3,915
Japan	4,113	4,052	4,091	4,150	4,219	4,326	4,402	4,444
Population (10 thousand persons)								
	2000	2001	2002	2003	2004	2005	2006	2007
Fukuoka	502	503	504	504	505	505	505	506
Fukuoka	134	135	137	138	139	140	141	143
Kitakyushu	101	101	101	100	100	99	99	99
Japan	12,693	12,732	12,749	12,769	12,779	12,777	12,777	12,777
Workers (10 thousand persons)								
	2000	2001	2002	2003	2004	2005	2006	2007
Fukuoka	239	237	234	233	234	236	237	238
Fukuoka	83	83	83	83	84	84	82	82
Kitakyushu	49	48	48	47	47	46	46	46
Japan	6,435	6,389	6,342	6,303	6,278	6,276	6,284	6,294
Share of secondary industry (percent)								
	2000	2001	2002	2003	2004	2005	2006	2007
Fukuoka	21.83	20.51	20.33	20.23	20.01	20.05	20.18	20.22
Fukuoka	10.01	9.22	9.57	8.53	8.85	8.78	8.56	7.87
Kitakyushu	28.84	27.78	25.89	25.41	25.41	26.62	25.98	25.97
Japan	27.49	25.87	25.52	25.40	25.58	25.44	25.65	25.32

(Source) *Kenmin Keizai Keisan*, Cabinet Office, Government of Japan.

Table 2 VAR of Markov Chain (6 regions transition matrix)

	KK	FC	FP	JP	CN	KR
KK(-1)	0.9731	0.0011	0.0028	0.0077	0.0077	0.0077
FC(-1)	0.0001	0.9817	0.0015	0.0055	0.0058	0.0054
FP(-1)	0.0004	0.0020	0.9790	0.0062	0.0064	0.0059
JP(-1)	0.0000	0.0000	0.0001	0.9877	0.0101	0.0021
CN(-1)	0.0000	0.0000	0.0000	0.0004	0.9991	0.0004
KR(-1)	0.0000	0.0002	0.0005	0.0013	0.0021	0.9959

(Note) KK: Kitakyushu City; FC: Fukuoka City; FP; the rest of Fukuoka Prefecture; JP: the rest of Japan; CN: China (main land); KR: South Korea.
(Source) Author's calculation (all tables and figures except Table 1)

Table 3 GDP (GRP) Forecast from 2007 (2000 price USD, millions)

	KK	FC	FP	JP	CN	KR
2007	35,670	67,126	79,598	5,023,616	2,387,680	734,479
2008	35,809	68,366	81,353	5,113,868	2,512,237	766,382
2009	35,950	69,633	83,149	5,205,799	2,641,449	799,374
2010	36,092	70,930	84,989	5,299,443	2,775,471	833,490
2011	36,237	72,257	86,873	5,394,833	2,914,463	868,765
2012	36,384	73,613	88,802	5,492,004	3,058,592	905,235
2013	36,533	75,002	90,778	5,590,990	3,208,030	942,938
2014	36,684	76,422	92,802	5,691,827	3,362,951	981,911
2015	36,838	77,876	94,875	5,794,553	3,523,539	1,022,195
2016	36,994	79,363	96,998	5,899,204	3,689,982	1,063,830
2017	37,152	80,886	99,173	6,005,819	3,862,474	1,106,859
2018	37,313	82,444	101,402	6,114,437	4,041,214	1,151,324
2019	37,476	84,039	103,685	6,225,098	4,226,410	1,197,271
2020	37,642	85,671	106,024	6,337,841	4,418,274	1,244,745

Figure 1 Road to Ergodic Distribution

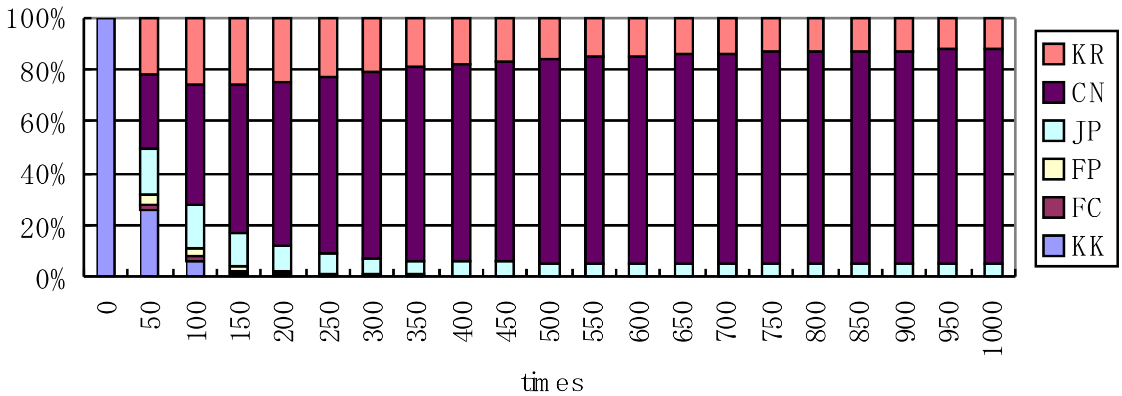

Table 4 VAR of Markov Chain (4 regions transition matrix)

	KK	FC	FP	JP
KK(-1)	0.9836	0.0025	0.0045	0.0094
FC(-1)	0.0002	0.9896	0.0030	0.0072
FP(-1)	0.0011	0.0033	0.9857	0.0098
JP(-1)	0.0000	0.0001	0.0002	0.9998

Table 5 GDP (GRP) Forecast from 2007 (2000 price USD, millions)

	KK	FC	FP	JP
2007	35,670	67,126	79,598	5,023,616
2008	35,891	68,421	81,269	5,124,549
2009	36,116	69,740	82,971	5,227,506
2010	36,343	71,085	84,705	5,332,527
2011	36,573	72,455	86,472	5,439,653
2012	36,806	73,850	88,273	5,548,927
2013	37,043	75,272	90,107	5,660,392
2014	37,282	76,721	91,977	5,774,090
2015	37,525	78,198	93,881	5,890,068
2016	37,771	79,702	95,822	6,008,371
2017	38,021	81,235	97,799	6,129,045
2018	38,273	82,797	99,814	6,252,138
2019	38,530	84,388	101,866	6,377,698
2020	38,790	86,010	103,958	6,505,774

Figure 2 Road to Ergodic Distribution

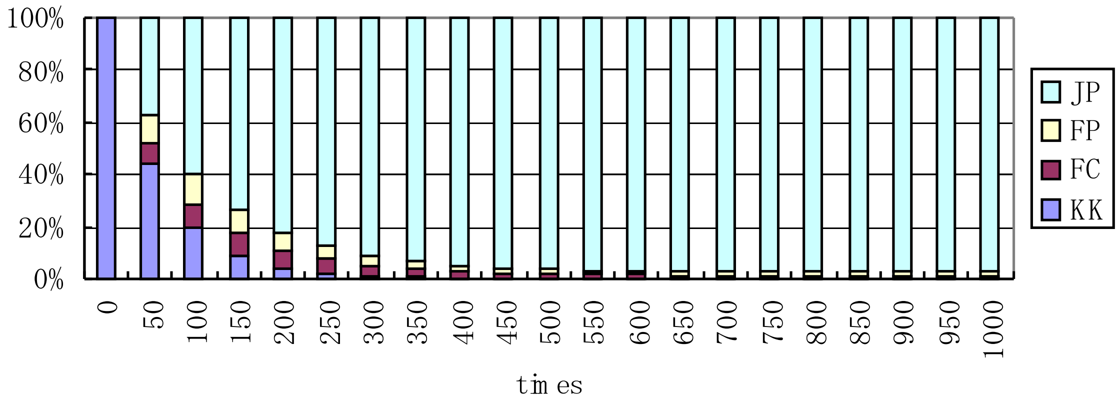

Table 6 Unit Root Test (ADF)

	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 7 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 3 Impulse Response Function of VEC 1 (one unit innovations, response of KK)

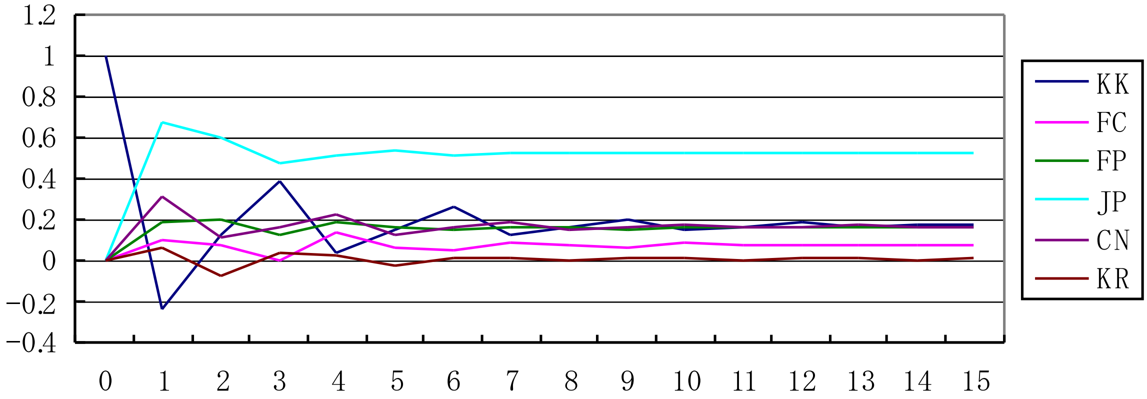

Figure 4 Impulse Response Function of VEC 1 (one unit innovations, response of FC)

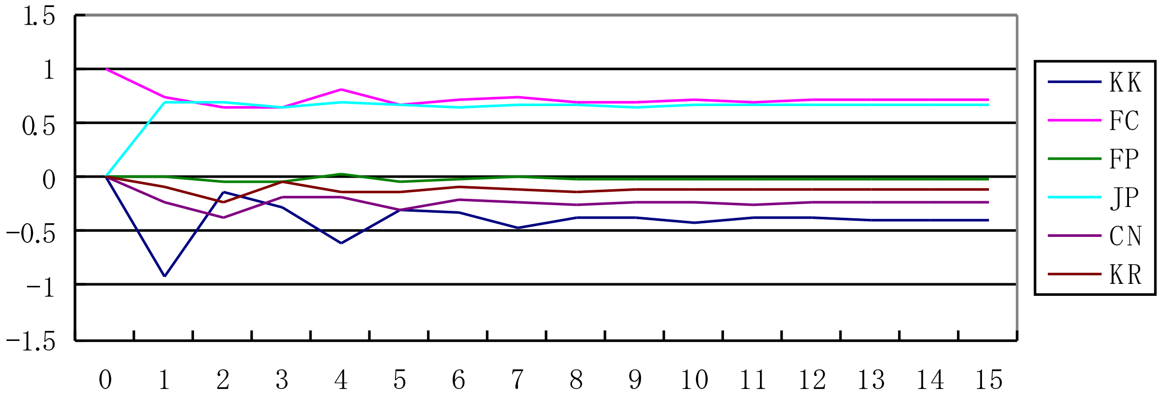

Figure 5 Impulse Response Function of VEC 1 (one unit innovations, response of FP)

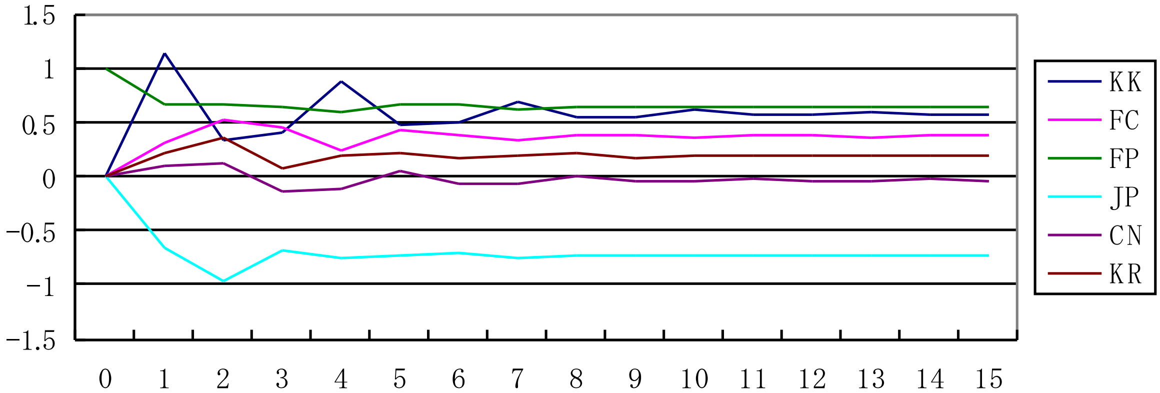

Figure 6 Impulse Response Function of VEC 1 (one unit innovations, response of JP)

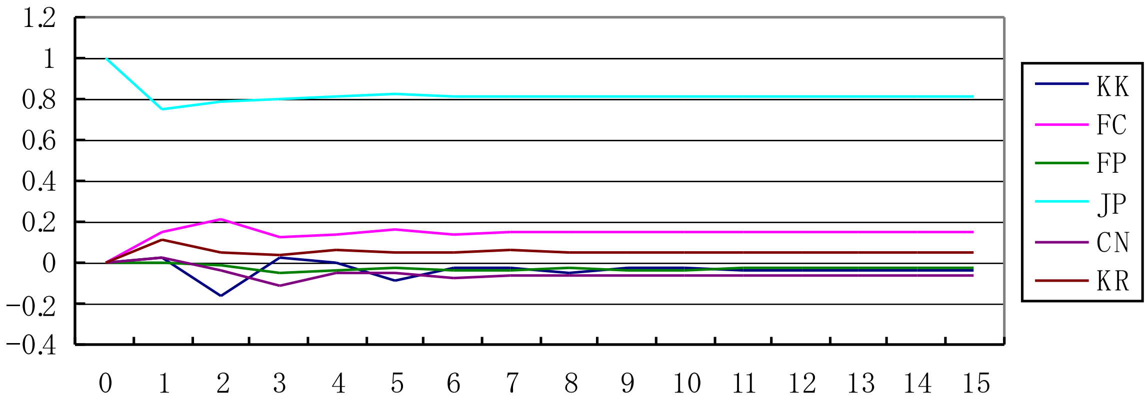

Figure 7 Impulse Response Function of VEC 1 (one unit innovations, response of CN)

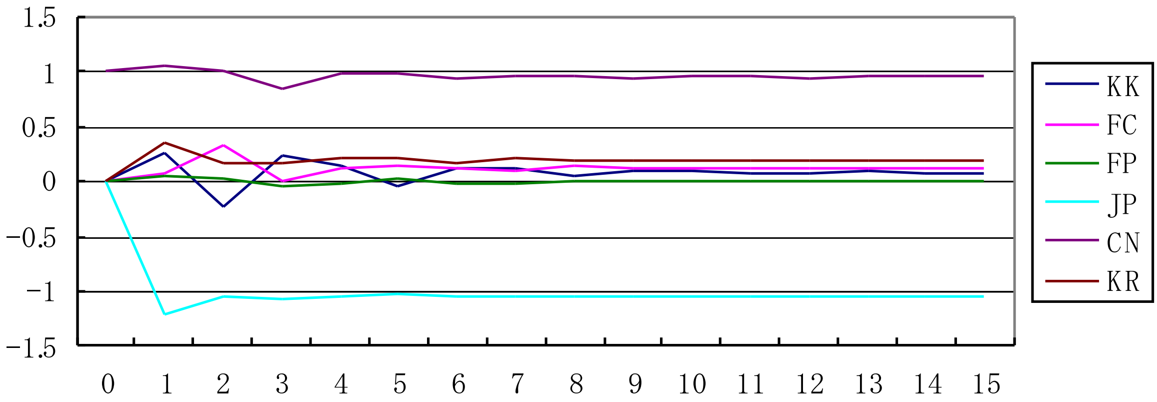

Figure 8 Impulse Response Function of VEC 1 (one unit innovations, response of KR)

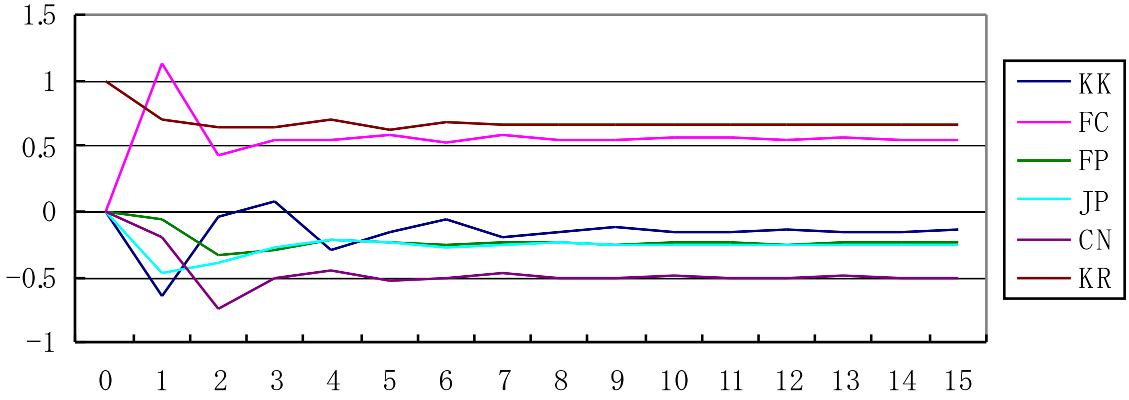

Figure 9 Impulse Response Function of VEC 2 (one unit innovations, response of KK)

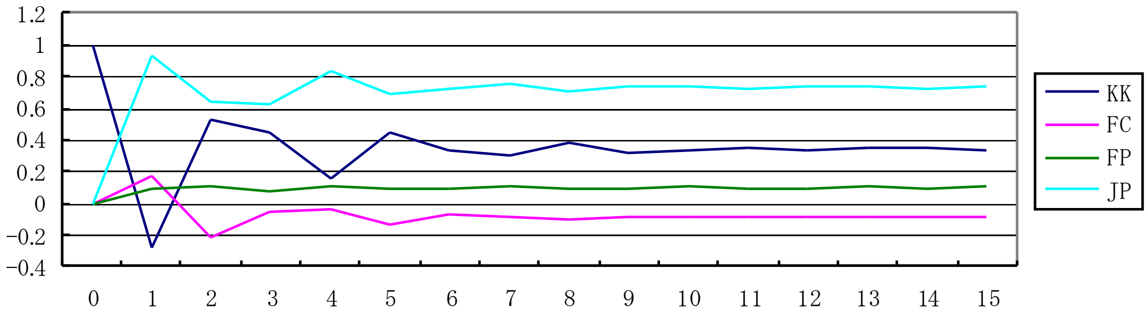

Figure 10 Impulse Response Function of VEC 2 (one unit innovations, response of FC)

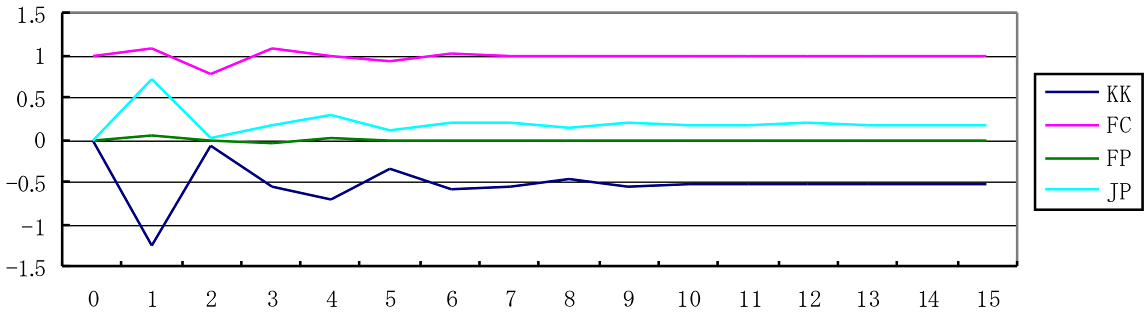

Figure 11 Impulse Response Function of VEC 2 (one unit innovations, response of FP)

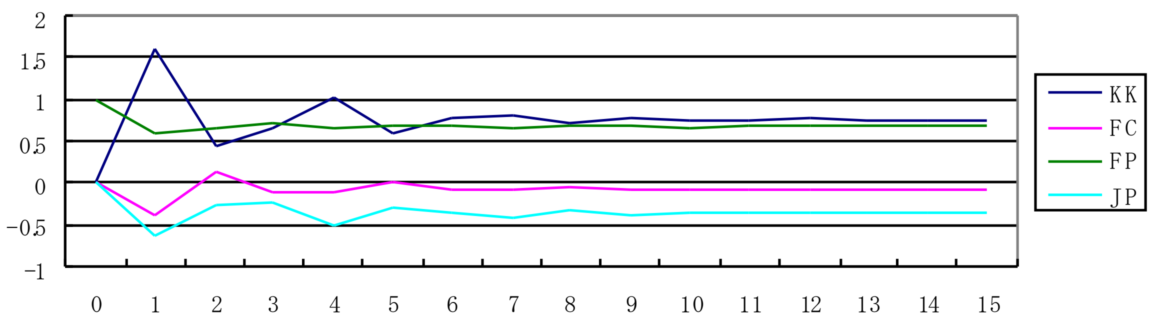

Figure 12 Impulse Response Function of VEC 2 (one unit innovations, response of JP)

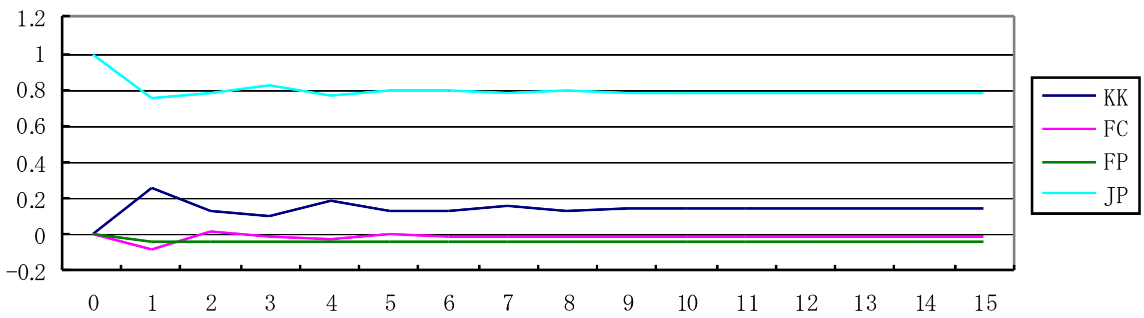

Figure 13 Impulse Response Function of VEC 3 (one unit innovations, response of KK)

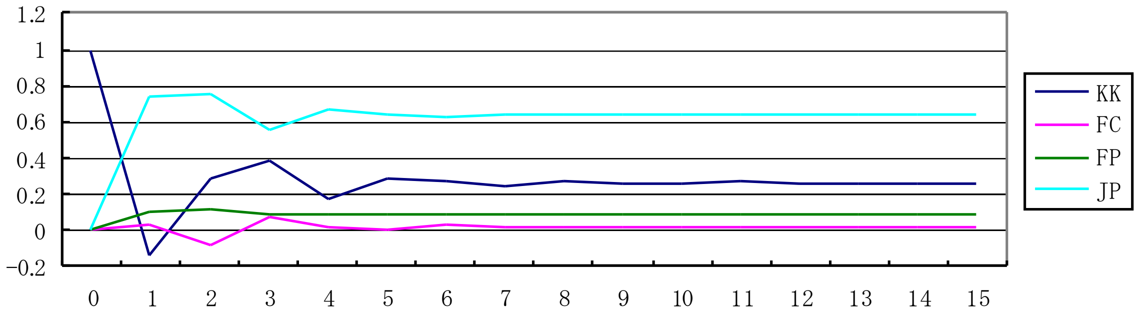

Figure 14 Impulse Response Function of VEC 3 (one unit innovations, response of FC)

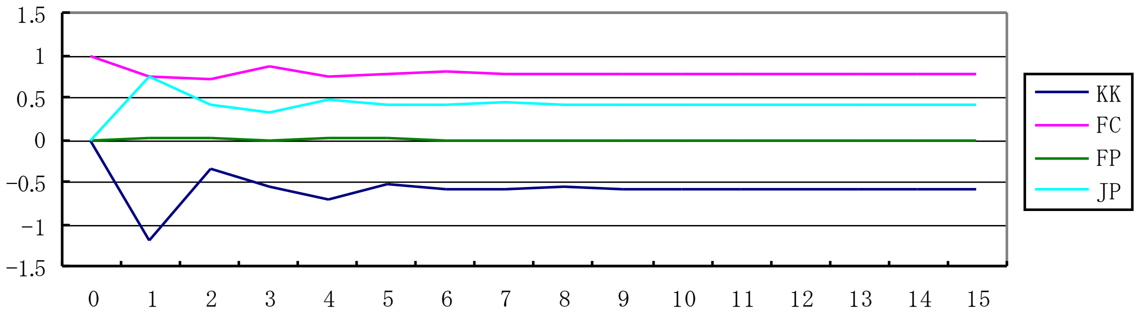

Figure 15 Impulse Response Function of VEC 3 (one unit innovations, response of FP)

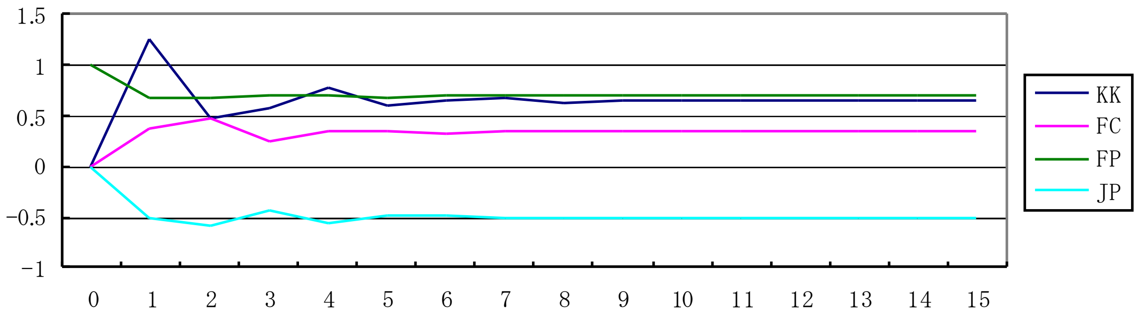

Figure 16 Impulse Response Function of VEC 3 (one unit innovations, response of JP)