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Conference Paper

Future Prediction of the Prefectural Economy in Japan: Using a Stochastic Model

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Sakamoto, Hiroshi (2012) : Future Prediction of the Prefectural Economy in Japan: Using a Stochastic Model, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

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Future Prediction of the Prefectural Economy in Japan: Using a Stochastic Model

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2012 June

Draft version, do not quote.

[♦] The authors would like to thank for their useful comments the participants of Applied Regional Science Conference (ARSC) 2011 meeting (Toyama University, Japan in 2011) and the 52nd European Regional Science Association (ERSA) conference (Bratislava, Slovakia in 2012), where this paper was presented. The authors are entirely responsible for all remaining errors.

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Abstract

This study develops an easy forecasting model using prefectural data in Japan. The Markov chain known as a stochastic model corresponds to the vector auto-regressive (VAR) model of the first order. If the transition probability matrix can be appropriately estimated, the forecasting model using the Markov chain can be constructed. Therefore, this study introduces the methodology to estimate the transition probability matrix of the Markov chain using the least-squares optimization. For application, firstly change of the all-prefectures economy by 2020 is analyzed using this model. Secondly, in order to investigate the influence to other prefecture, a specific prefecture's shock is put into a transition probability matrix. Lastly, in order to take out the width of prediction, the Monte Carlo experiment is conducted. Despite this model is very simple, we provide the more sophisticated forecasting information of the prefectural economy in Japan through the complicated extension.

JEL classification: C15, C53, C61, O53, R12

Keywords: Prefectural economy, Japan, Stochastic model, Markov chain

1. Introduction

This study develops an easy forecasting model using prefectural data in Japan. In and after 1990 of the collapse of the 'bubble' economy, Japanese economy has changed neither extreme growth nor a downturn. But if it says whether Japanese economy is fine by international comparison, it will be answered that many people are not so, particularly, local areas. It is considered some factors that the low birthrate and longevity and the decrease-in-population tendency which have been said since around 2000 and the concentration of too much power and too many people in Tokyo which continued from the bubble or before. On the other hand, the opinion that economic growth is from local areas is also heard. It is better for there to be a tool which will analyze such information quantitatively if it can do, although it is a key how economic resources, such as a person, material, capital, and information, are distributed to the area. Here is the starting point of this study.

It is considered that it is better to build the model based on economics in the viewpoint of distribution between the regions of previous economic resources in the ability to be considered.¹ On the other hand, another model can be considered if a model is built about change of only the macro index of GDP of all prefectures. Then, in order to explain change of all-prefectures economy, we would like to advocate using the stochastic model which used the Markov chain in this study. It is a very simple forecasting model which will determine the next term by only the information on this term. Moreover, it is thought that it is one form of the vector auto regressive (VAR) model structurally which Sims (1980) who won the Nobel Prize for Economics in 2011 advocates.²

Although the forecasting model using a Markov chain exists for many years, In order to measure the convergence of the economy between countries or between the regions in economics as part of the application, the distribution approach which used the Markov chain came to be advocated.³ Moreover, in Sakamoto (2010b), the Chinese demographic shift between prefectures is predicted using a Markov chain. Although the prediction by such stochastic models can be referred to as very easy compare with an economic model, the prediction result is not necessarily realistic in sometimes. Then, in order to make a prediction result more realistic, the Monte Carlo experiment is used and width is given to a result.⁴

¹ Sakamoto (2011) is considering the research from for this viewpoint.

² However, in the character and estimation of a parameter (transition probability matrix), both differ deterministically.

³ For example, see Quah (1993, 1996a and b) Sakamoto and Islam (2008).

⁴ The Monte Carlo experiment has related research by Sakamoto (2010a).

2. The Model

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

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

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

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

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

Second, we will introduce how to estimate the transition matrix M_t by using actual data. In the research which measures convergence distribution of income, such as Quah, The income data of each country or each region is collected, a suitable grid line is assumed to the whole sample, a sample is classified for every state of income based on the grid line, and the method of estimating a matrix by totaling the temporal response of the state in each country or each region is adopted. In this case, the state of income is summarized to several states (around five states) from low income to high income. However, this cannot express an individual change in each or each region. Therefore, in this study, in order to investigate an individual change of each prefecture, the following processes perform the estimation method.

Since M_t cannot be directly obtained from actual data, an estimation procedure will be necessary. The procedure implemented in this paper runs along the following lines:

If F_t is (3×1) , the transition matrix M_t for time t will be (3×3) and it 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 have

$$b_{t+1,1} = b_{t,1} * a_{t,11} + b_{t,2} * a_{t,12} + b_{t,3} * a_{t,13} \quad (4-1)$$

$$b_{t+1,2} = b_{t,1} * a_{t,21} + b_{t,2} * a_{t,22} + b_{t,3} * a_{t,23} \quad (4-2)$$

$$b_{t+1,3} = b_{t,1} * a_{t,31} + b_{t,2} * a_{t,32} + b_{t,3} * a_{t,33} \quad (4-3).$$

However, in this formula, the property of the Markov chain may not hold when the sum of the column of probability matrix M_t becomes equal to 1.

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

Therefore, since we assume that the adjustment parameter will hold the property, several ideas can be considered. However we adopt the total growth rate of GDP g_t when using an adjustment parameter. g_t is simply defined by

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

Then, we modify the equations to be

$$b_{t+1,1} = g_t (b_{t,1} * a_{t,11} + b_{t,2} * a_{t,12} + b_{t,3} * a_{t,13}) \quad (4'-1)$$

$$b_{t+1,2} = g_t (b_{t,1} * a_{t,21} + b_{t,2} * a_{t,22} + b_{t,3} * a_{t,23}) \quad (4'-2)$$

$$b_{t+1,3} = g_t (b_{t,1} * a_{t,31} + b_{t,2} * a_{t,32} + b_{t,3} * a_{t,33}) \quad (4'-3).$$

However, these three restrictions are insufficient to uniquely solve the nine elements of the matrix M_t . We will need more restrictions. In this regard, we note that one trivial solution of M_t is the identity matrix, although it is not the desired solution. However, it can provide the source of necessary restrictions. Assuming that the distribution does not greatly vary from one period to the next, the case will be where the elements of M_t are such that the matrix will mimic the identity matrix. Using this idea and generalizing M_t to be $n \times n$, we can estimate the elements of M_t based on the following minimization procedure:

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

$$\text{Subject to } b_{t+1,j} = g_t \cdot \sum_{k=1}^n b_{t,k} \cdot a_{t,jk}, \quad \forall j,$$

$$\text{and } \sum_{k=1}^n a_{t,jk} = 1, \quad \forall j \quad (7)$$

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

Third, we construct the transition matrix M for forecasting. Since the above estimated transition matrix M_t is time specific, we first consider the average of the elements:

$$\bar{M} = \sum_{t=1}^s M_t / s \quad (8)$$

In this study, prediction, a simulation, and the Monte Carlo experiment will be conducted based on this averaged transition matrix.

$$F_{t+1} = F_t \cdot \bar{M} \quad (9)$$

3. Data

Data used ‘the gross expenditure of prefecture’ of the Annual Report on Prefectural Accounts (*Kenmin Keizai Keisan*). The numbers of regions are all 47 prefectures. A real price is based on the chain price in 2000. Since the real GDP by the chain price in 2000 was released from 1996, it made data extend using the pace of expansion of the real GDP by the chain price in 1995 about 1995 or before. From 1990 after the bubble economy to 2007 is used during the period. Moreover, since it was officially announced in the fiscal year, in order to use calendar year, data was simply divided into four, and it is what added 1/4 in the last fiscal year, and 3/4 in the current fiscal year, and considered it as calendar year data.

Next, it is considered that the difference in the population in each prefecture became a problem in analysis. Since it was interested in change of the total amount of GDP of each prefecture, it was not referred to as per capita GDP, but changed into GDP of each prefecture by the population standard in 2007. This changes and analyzes this to GDP at the time of converting with the number of population as of 2007, although GDP of each year is formed of the population of each year. Therefore, if the population of the year concerned is smaller (larger) than 2007, GDP of the year concerned will also be estimated greatly (small) and the influence by change of the population in a measurement period will be eliminated.

4. Simulation

A simulation is divided in the three directions. First, we measure the future prediction using a Markov chain based on an equation (9). Here, the prediction from 2008 to 2020 is examined. Next, we analyze change of the prediction after giving a certain shock to the transition matrix of the Markov chain. Here, the shock of the disaster damage based on a big earthquake in March 2011 is examined. Finally, we put in an uncertain element to each element of the transition matrix before and after shocking, and conduct the Monte Carlo experiment, in order to investigate the robustness and prediction feasibility of an estimation result of the transition matrix of the Markov chain. Hereafter, we will divide into the Monte Carlo experiment before and after, and will introduce analytic details and a result.

4-1. Analysis of the deterministic path before Monte Carlo experiment

First, Table 1 shows the result (a part is omitted) of the transition matrix based on the equation (9). The transition matrix was estimated based on the optimization problem of the equation (7) during from 1990 to 2007, and the arithmetic average is taken. The table shows the probability that not changing from Hokkaido to Hokkaido at all is 0.991877 and change from Hokkaido to Aomori Prefecture is 0.000117 and so on at the next time of the total amount of GDP. Prediction by 2020 will be performed using this transition matrix. In addition, because it is unable to show growth of the whole Japanese economy only by multiplying a transition matrix, the simulation of the exogenous growth rate of 1% is put in and carried out to probability change.

Next, the disaster shock accompanying a big earthquake is considered. This East Japan great earthquake has also hung down direct and indirect damage to many prefectures. Also in it, the damage of northeast 3 prefectures in Iwate, Miyagi, and Fukushima is serious, and the place which requires considerable time also exists in revival. How this disaster shock is reflected on a transition matrix? One method is to change the element of a transition matrix. There have many factors which become negative to GDP such as use of capital stock becomes impossible destructively according to the disaster. Therefore, the direction of change also becomes negative. We multiply a number smaller than 1 to each element of a transition matrix and it is made to be set to little GDP rather than before shock. The items are the following and are set to Aomori: 0.95, Iwate: 0.90, Miyagi: 0.90, Fukushima: 0.90, Ibaraki: 0.95, Chiba: 0.97, and Tokyo: 0.97. Moreover, that prefecture makes this rate of the shock apply to all the affecting prefectures.

For example, since the probability of Iwate Prefecture to Hokkaido is 0.000071, Iwate Prefecture to Aomori Prefecture is 0.000050 and Iwate Prefecture to Iwate Prefecture is 0.997486 by Table 1, it will predict using the number which multiplies 0.90 on these at the time of the shock. In addition, the shock is performed only to the transition matrix in 2010 to 2011. It is because a big earthquake happens during the term of 2011 and the other year is not

subject to the influence of the earthquake itself.

Figure 1 and Figure 2 compare the deterministic path before the Monte Carlo experiment by the case where there is nothing with the case where there is a disaster shock. The prefecture which gave the disaster shock and the whole country are displayed in both two figures. It turns out that growth rates differ in each prefecture. It means that this does not grow in the growth rate with each same all prefectures, and it is expected that the regional disparity changes. On the other hand, when a disaster shock is given, it turns out that economic growth of the year which gave the shock falls but it is recovered after the shock. However, it cannot be compensated with the fall at the time of the shock. It is considered that changes the element of a transition matrix only one year and carries out a simulation with the same element again after next year.

Next, it is analyzed how all prefectures economy has changed as a result of the future prediction by a simulation. Table 2 shows change of GDP of each all prefectures. The table shows the total rate of change (it is not an annual average) from 2007 to 2020. Since the exogenous growth rate of 1% per year is given, the change during a period exceeds 13%. Below in an average, especially prefectures if 10% or less are Hokkaido, Chiba Prefecture, Kanagawa Prefecture, Osaka Prefecture, and Hyogo Prefecture. It turns out many leading economy prefectures except Aichi Prefecture are below an average if Hokkaido and Okinawa Prefecture are removed. Therefore, if economy changes by this model, it can say that the regional disparity is reducible.

On the other hand, about the change after a shock, although the prefectures which gave the shock have dropped the economic growth rate on the rate of the shock suitability, since they remain in the growth rate fall below the rate of the shock, some rally effect is seen about these prefectures. However, it turns out that all another prefectures have dropped the growth rate and they are also subject to the influence of the disaster shock. However, it can also be said that the difference was quite small and it was not almost influential.

4-2. Analysis of the indefinite path after the Monte Carlo experiment

Next, the case where these paths are not deterministic is considered. The Monte Carlo experiment asks for data required for an experiment based on the information acquired in the process in which the transition matrix of the equation (9) is estimated. The experiment is conducted on the assumption that the element of a transition matrix has uncertainty. That is, after giving width to the number of Table 1, it predicts by the transition matrix obtained based on the experiment. It assumes that the number of Table 1 has width according to a normal distribution with an average and standard deviation. The average is the number of Table 1. Standard deviation uses the standard deviation obtained from the result of the transition matrix of each year from 1990 to 2007. The result was shown in Table 3. That is, it experiments by generating the regular random number according to the average of Table 1, and the standard deviation of Table 3. Obviously, since it is applicable this experiment gives a

shock, the comparison of before the shock and after the shock is also attained. In addition, generating of the random number by the Monte Carlo experiment is assumed to be 300 times. Needless to say, the more experiment times, the more precise results are obtained. Since processing of calculation becomes complicated, the experiment has been stopped in the range which is a little easy to treat.

Table 4 and Table 5 show an average and coefficient of variation of GDP of each all prefectures before the shock after the Monte Carlo experiment. The coefficient of variation, which is standard deviation divided by the average, is going up as it is set to 2020. In order to generate the random number to the transition matrix of each year, the more this tends toward the future, the more it means that uncertainty increases. However, this number itself is as small as about 2%. Since the number of Table 3 is also quite small, it is thought that uncertainty is small. However, growth of Japanese economy is less than 1% of present condition, and it is relatively considered to be uncertain that there is uncertainty for 2% by standard deviation. Moreover, the prefecture's feature about the difference in the coefficient of variation is not seen, it can be said that it is changing at random based on Table 3.

Table 6 and Table 7 show an average and coefficient of variation of GDP of each all prefectures after the shock after the Monte Carlo experiment. Since the shock was performed from 2010 to 2011, the result of 2010 is omitted because it is the same as Table 4 and Table 5. Moreover, the right half of the table shows comparison with before the shock. Since the difference in the prefectural average which gave the shock is falling from 2015 to 2020, regaining growth gradually after the shock is imagined. Although the prefecture which gave the shock is going up about the coefficient of variation, each other prefecture is falling slightly. It is possible that uncertainty increased it also in the recovery prospect of future prefectural economy by the disaster shock since the rise of the coefficient of variation meant the rise of uncertainty.

Finally, we investigate the degree of duplication of the Monte Carlo experiment sample for which has overlapped before the shock and after the shock. Here, the frequency table was created for the ratio of an experiment result and an average on the basis of each all prefectures by the Monte Carlo experiment before the shock in 2015 and 2020 by a logarithms and the width of 0.005. Then, the number of duplications of the frequency before the shock and after the shock is calculated. Table 8 is the result of multiplicity of distribution. It is shown that distribution is so the same before the shock and after the shock if it is close to 100%. Although the number near 100% in general has come out in the prefecture which did not give the shock, since it is not 100% completely, it turns out that it may suffer influence of the disaster shock slightly. On the other hand, about the prefecture which gave the shock, it turns out that Miyagi Prefecture and Fukushima Prefecture do not have an overlapping sample almost and their economy hangs low completely after the shock even if assuming uncertainly. The prefecture which shocking rates are not large, such as Tokyo, shows the suitable degree of duplication around 30%. Even if this has the shock, it shows that a negative effect may be negated by uncertainty.

5. Concluding Remarks

While this study expressed change of GDP for all prefectures economy of Japan by the stochastic model and searched for the future prediction, it operated the probability element of the stochastic model and also analyzed the prediction when there is a disaster shock which made the previous East Japan great earthquake the example. It was shown that the regional disparity may contract and the recovery tendency was slightly looked at by prediction also from the disaster shock in the future. Furthermore, the Monte Carlo experiment when uncertainty exists in this stochastic model was conducted, and, the possibility is showed that a negative effect such as the disaster shock might be negated by uncertainty.

About a stochastic model, it seems that there is still room for improvement. For example, the mutual effect between all prefectures is quite small. Although this may be appropriate one actually, it is considered that there may be influencing more in people, material, capital, and the present condition with prosperous traffic of information. However, it seems that the argument which was thought-provoking to some extent about the future of Japanese economy can be offered through this model.

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Table 1 Transition matrix (average)

	Hokkaido	Aomori	Iwate	Miyagi	Akita	...	Okinawa
Hokkaido	0.991877	0.000117	0.000055	0.000080	0.000144		0.000001
Aomori	0.000003	0.996611	0.000052	0.000033	0.000027		0.000027
Iwate	0.000071	0.000050	0.997486	0.000001	0.000048		0.000051
Miyagi	0.000034	0.000041	0.000037	0.996496	0.000049		0.000010
Akita	0.000032	0.000008	0.000027	0.000043	0.997642		0.000007
...						...	
Okinawa	0.000097	0.000106	0.000129	0.000106	0.000119		0.993580

Figure 1 Prediction before the Monte Carlo experiment (1) (Billion yen)

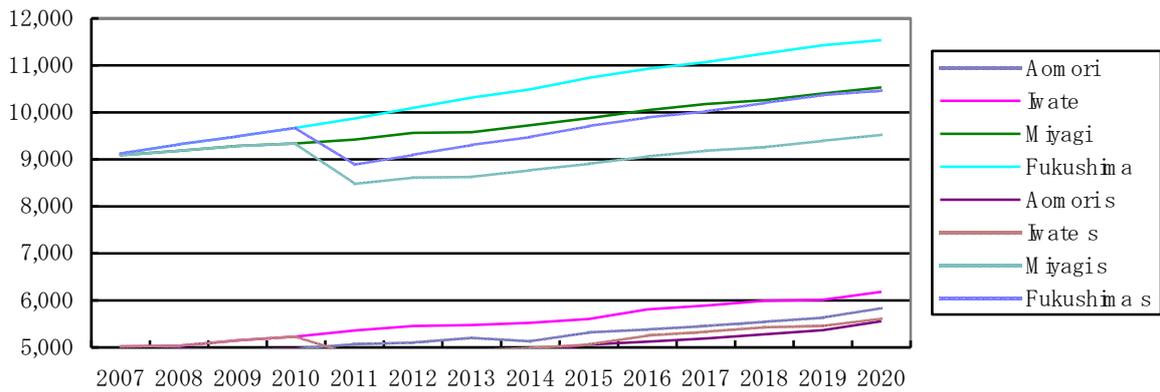
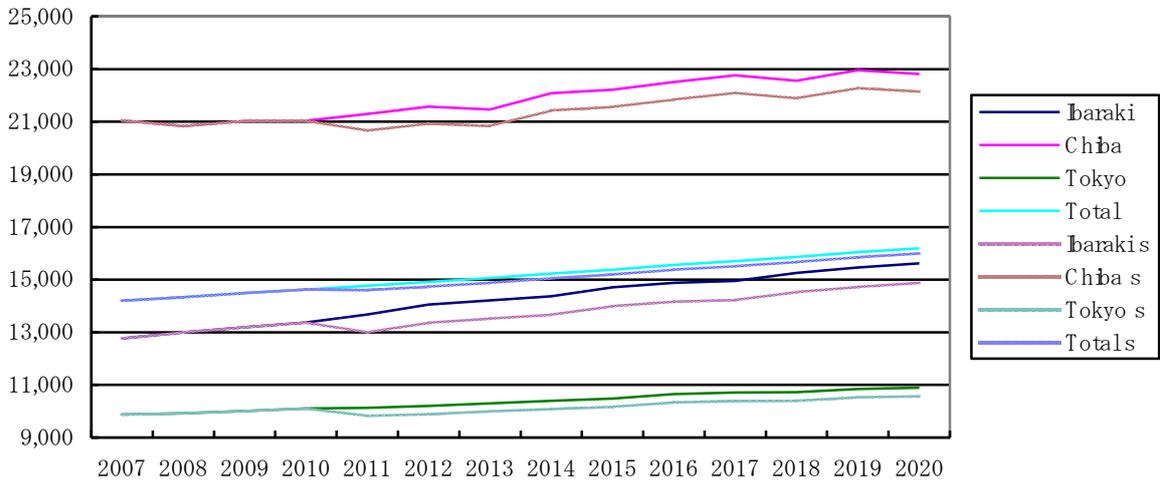


Figure 2 Prediction before the Monte Carlo experiment (2) (Billion yen)



(Note) Tokyo is reduced to 1/10 and the whole country (Total) is reduced to 1/40.

Table 2 Change of GDP of each prefecture (the rate of change from 2007 to 2020, %)

	Without shock	With shock	Change		Without shock	With shock	Change
Hokkaido	7.85	7.78	-0.07	Shiga	12.05	12.01	-0.04
Aomori	18.18	12.63	-5.55	Kyoto	14.89	14.85	-0.04
Iwate	23.11	11.79	-11.31	Osaka	3.58	3.56	-0.02
Miyagi	15.92	4.78	-11.14	Hyogo	6.63	6.55	-0.08
Akita	24.58	24.52	-0.06	Nara	12.09	12.03	-0.06
Yamagata	26.74	26.64	-0.10	Wakayama	12.63	12.60	-0.02
Fukushima	26.51	14.75	-11.76	Tottori	18.28	18.21	-0.07
Ibaraki	22.41	16.61	-5.80	Shimane	21.12	21.05	-0.07
Tochigi	14.86	14.81	-0.05	Okayama	12.09	12.03	-0.06
Gunma	15.18	15.15	-0.03	Hiroshima	14.93	14.90	-0.02
Saitama	11.18	11.15	-0.03	Yamaguchi	19.29	19.20	-0.09
Chiba	8.36	5.17	-3.19	Tokushima	23.72	23.66	-0.07
Tokyo	10.31	7.05	-3.27	Kagawa	18.23	18.18	-0.04
Kanagawa	-0.68	-0.68	0.00	Ehime	24.68	24.64	-0.04
Niigata	23.36	23.25	-0.12	Kochi	23.57	23.55	-0.02
Toyama	18.59	18.53	-0.06	Fukuoka	14.37	14.31	-0.06
Ishikawa	19.16	19.11	-0.05	Saga	30.45	30.38	-0.07
Fukui	22.57	22.51	-0.06	Nagasaki	15.65	15.64	-0.01
Yamanashi	16.38	16.33	-0.05	Kumamoto	16.04	16.00	-0.03
Nagano	20.76	20.70	-0.06	Oita	31.39	31.31	-0.08
Gifu	13.43	13.39	-0.04	Miyazaki	17.55	17.54	-0.02
Shizuoka	25.14	25.03	-0.11	Kagoshima	26.66	26.60	-0.06
Aichi	20.94	20.72	-0.21	Okinawa	13.98	13.95	-0.03
Mie	31.89	31.69	-0.20	Total	14.02	12.64	-1.38

Table 3 Standard deviation of a transition matrix

	Hokkaido	Aomori	Iwate	Miyagi	Akita	...	Okinawa
Hokkaido	0.009272	0.000330	0.000139	0.000217	0.000366		0.000000
Aomori	0.000005	0.005170	0.000138	0.000127	0.000104		0.000086
Iwate	0.000274	0.000170	0.005833	0.000000	0.000174		0.000198
Miyagi	0.000071	0.000116	0.000099	0.004646	0.000164		0.000035
Akita	0.000100	0.000019	0.000075	0.000112	0.003158		0.000018
...						...	
Okinawa	0.000211	0.000187	0.000208	0.000207	0.000188		0.006972

Table 4 Average and coefficient of variation of GDP of each prefecture before the shock after the Monte Carlo experiment (1)

	2010		2015		2020	
	Average	CV	Average	CV	Average	CV
Hokkaido	20102.67	0.016995	20616.20	0.027946	21149.83	0.035109
Aomori	5162.40	0.015976	5554.39	0.024648	5972.96	0.029269
Iwate	5262.26	0.011921	5683.56	0.021108	6130.25	0.025444
Miyagi	9347.59	0.008341	9812.48	0.013795	10311.74	0.017530
Akita	4309.61	0.010410	4662.53	0.016434	5039.93	0.019850
Yamagata	5193.04	0.010709	5700.16	0.016941	6237.31	0.020651
Fukushima	9648.00	0.009602	10582.54	0.013522	11561.13	0.016920
Ibaraki	13264.11	0.011575	14153.98	0.017416	15118.57	0.022093
Tochigi	9739.26	0.009999	10386.34	0.015685	11063.41	0.018918
Gunma	8690.66	0.012525	9109.75	0.020279	9541.39	0.025551
Saitama	23601.54	0.010762	24540.60	0.018035	25555.31	0.023007
Chiba	21511.46	0.015375	22202.99	0.023933	22932.97	0.030810
Tokyo	101085.10	0.009190	105220.60	0.014007	109407.76	0.017464
Kanagawa	34619.17	0.010367	34876.32	0.017364	35157.53	0.022615
Niigata	10460.88	0.009526	11215.69	0.015782	12019.55	0.019572
Toyama	5299.22	0.009969	5622.46	0.017205	5965.89	0.022520
Ishikawa	5405.25	0.009106	5737.48	0.014332	6092.96	0.017526
Fukui	4023.59	0.009050	4356.11	0.015033	4704.45	0.018658
Yamanashi	3937.22	0.014793	4228.66	0.022723	4534.47	0.030119
Nagano	10211.98	0.011136	11128.13	0.016536	12076.97	0.019782
Gifu	8438.48	0.007904	8890.68	0.013344	9383.27	0.017124
Shizuoka	19946.56	0.008956	21466.43	0.014431	23074.61	0.018017
Aichi	42367.07	0.011383	45291.32	0.017465	48386.63	0.021943
Mie	10211.41	0.014147	11378.67	0.020190	12610.94	0.024033

Table 5 Average and coefficient of variation of GDP of each prefecture before the shock after the Monte Carlo experiment (2)

	2010		2015		2020	
	Average	CV	Average	CV	Average	CV
Shiga	7253.40	0.017691	7748.94	0.029712	8283.94	0.034432
Kyoto	11307.93	0.010584	11885.97	0.017107	12513.07	0.020585
Osaka	41868.23	0.010208	42788.31	0.017852	43735.95	0.022156
Hyogo	21364.67	0.020009	21648.06	0.032491	21991.39	0.038387
Nara	4261.61	0.013099	4478.86	0.021409	4702.97	0.026200
Wakayama	3615.14	0.010032	3794.14	0.017336	3985.55	0.021982
Tottori	2408.97	0.010327	2567.31	0.015867	2735.41	0.020235
Shimane	2921.05	0.010227	3184.20	0.017355	3464.79	0.021101
Okayama	8417.42	0.016099	8845.91	0.026216	9295.51	0.033781
Hiroshima	13178.64	0.011002	13761.46	0.019088	14363.01	0.022861
Yamaguchi	6503.31	0.009017	7005.37	0.014122	7525.86	0.017138
Tokushima	3071.20	0.014610	3303.91	0.023450	3550.39	0.028203
Kagawa	4054.65	0.015487	4270.07	0.023386	4487.23	0.029808
Ehime	5687.90	0.012421	6096.04	0.019056	6516.00	0.022752
Kochi	2589.73	0.016447	2754.53	0.028454	2926.80	0.035202
Fukuoka	20257.22	0.007947	21307.12	0.011927	22401.28	0.015058
Saga	3498.44	0.009849	3820.41	0.016822	4168.38	0.020541
Nagasaki	4876.74	0.008758	5220.48	0.013794	5583.50	0.017835
Kumamoto	6549.65	0.007707	6966.47	0.011425	7394.57	0.014735
Oita	5390.17	0.008714	5911.70	0.013523	6463.30	0.015951
Miyazaki	4024.63	0.010624	4287.43	0.017217	4563.30	0.020886
Kagoshima	6337.23	0.009998	6876.77	0.015005	7454.04	0.018592
Okinawa	3974.99	0.012712	4130.88	0.020988	4290.66	0.026985
Total	585251.44	0.002407	615072.41	0.003910	646426.68	0.005075

Table 6 Average and coefficient of variation of GDP of each prefecture after the shock after the Monte Carlo experiment (1)

	Result				Change of before shock			
	2015		2020		2015		2020	
	Average	CV	Average	CV	Average	CV	Average	CV
Hokkaido	20613.38	0.027929	21143.41	0.035081	-0.01	-0.06	-0.03	-0.08
Aomori	5283.75	0.025062	5690.75	0.029739	-4.87	1.68	-4.72	1.60
Iwate	5132.27	0.021771	5557.15	0.026208	-9.70	3.14	-9.35	3.00
Miyagi	8843.79	0.014089	9309.63	0.017811	-9.87	2.14	-9.72	1.60
Akita	4661.56	0.016391	5037.67	0.019783	-0.02	-0.26	-0.04	-0.33
Yamagata	5698.12	0.016853	6232.39	0.020490	-0.04	-0.52	-0.08	-0.78
Fukushima	9560.61	0.014172	10488.73	0.017857	-9.66	4.80	-9.28	5.54
Ibaraki	13460.57	0.017608	14396.59	0.022306	-4.90	1.10	-4.78	0.96
Tochigi	10383.91	0.015674	11057.90	0.018903	-0.02	-0.07	-0.05	-0.08
Gunma	9108.30	0.020260	9538.09	0.025535	-0.02	-0.09	-0.03	-0.06
Saitama	24537.36	0.018026	25547.86	0.022993	-0.01	-0.05	-0.03	-0.06
Chiba	21541.01	0.024002	22254.36	0.030864	-2.98	0.29	-2.96	0.17
Tokyo	102100.05	0.014092	106205.54	0.017547	-2.97	0.61	-2.93	0.47
Kanagawa	34875.89	0.017364	35156.47	0.022615	0.00	0.00	0.00	0.00
Niigata	11212.80	0.015711	12012.48	0.019462	-0.03	-0.45	-0.06	-0.56
Toyama	5621.49	0.017189	5963.56	0.022475	-0.02	-0.09	-0.04	-0.20
Ishikawa	5736.78	0.014321	6091.27	0.017506	-0.01	-0.08	-0.03	-0.11
Fukui	4355.14	0.015013	4702.27	0.018632	-0.02	-0.13	-0.05	-0.14
Yamanashi	4227.19	0.022689	4531.06	0.030086	-0.03	-0.15	-0.08	-0.11
Nagano	11124.11	0.016483	12067.83	0.019708	-0.04	-0.32	-0.08	-0.38
Gifu	8889.58	0.013335	9380.58	0.017109	-0.01	-0.06	-0.03	-0.08
Shizuoka	21458.73	0.014323	23056.80	0.017831	-0.04	-0.75	-0.08	-1.03
Aichi	45268.99	0.017380	48334.39	0.021810	-0.05	-0.49	-0.11	-0.61
Mie	11370.64	0.020019	12592.62	0.023747	-0.07	-0.85	-0.15	-1.19

Table 7 Average and coefficient of variation of GDP of each prefecture after the shock after the Monte Carlo experiment (2)

	Result				Change of before shock			
	2015		2020		2015		2020	
	Average	CV	Average	CV	Average	CV	Average	CV
Shiga	7746.28	0.029664	8277.58	0.034395	-0.03	-0.16	-0.08	-0.11
Kyoto	11883.53	0.017074	12507.26	0.020541	-0.02	-0.19	-0.05	-0.21
Osaka	42784.28	0.017802	43727.12	0.022065	-0.01	-0.28	-0.02	-0.41
Hyogo	21642.32	0.032464	21979.01	0.038322	-0.03	-0.08	-0.06	-0.17
Nara	4477.98	0.021391	4701.04	0.026169	-0.02	-0.09	-0.04	-0.12
Wakayama	3793.70	0.017328	3984.50	0.021978	-0.01	-0.04	-0.03	-0.02
Tottori	2566.87	0.015865	2734.37	0.020225	-0.02	-0.01	-0.04	-0.05
Shimane	3183.52	0.017328	3463.23	0.021080	-0.02	-0.16	-0.04	-0.10
Okayama	8843.48	0.026146	9290.08	0.033655	-0.03	-0.27	-0.06	-0.37
Hiroshima	13758.88	0.019019	14356.98	0.022735	-0.02	-0.36	-0.04	-0.55
Yamaguchi	7003.39	0.014043	7521.13	0.017011	-0.03	-0.56	-0.06	-0.74
Tokushima	3303.00	0.023435	3548.21	0.028180	-0.03	-0.06	-0.06	-0.08
Kagawa	4269.34	0.023378	4485.50	0.029801	-0.02	-0.04	-0.04	-0.02
Ehime	6094.82	0.019042	6513.26	0.022714	-0.02	-0.08	-0.04	-0.17
Kochi	2754.20	0.028455	2926.02	0.035205	-0.01	0.00	-0.03	0.01
Fukuoka	21303.86	0.011892	22393.75	0.015006	-0.02	-0.29	-0.03	-0.35
Saga	3819.44	0.016779	4166.11	0.020495	-0.03	-0.25	-0.05	-0.22
Nagasaki	5219.79	0.013784	5581.88	0.017815	-0.01	-0.07	-0.03	-0.12
Kumamoto	6965.57	0.011415	7392.42	0.014712	-0.01	-0.09	-0.03	-0.16
Oita	5910.23	0.013494	6459.91	0.015912	-0.02	-0.22	-0.05	-0.25
Miyazaki	4286.71	0.017212	4561.59	0.020876	-0.02	-0.03	-0.04	-0.05
Kagoshima	6875.79	0.014995	7451.74	0.018581	-0.01	-0.06	-0.03	-0.06
Okinawa	4130.53	0.020992	4289.80	0.026985	-0.01	0.02	-0.02	0.00
Total	607683.54	0.003907	638661.93	0.005068	-1.20	-0.07	-1.20	-0.14

Table 8 Multiplicity of distribution before and after shock (%)

	2015	2020		2015	2020
Hokkaido	97.67	97.00	Shiga	96.33	94.67
Aomori	30.00	36.33	Kyoto	98.00	95.67
Iwate	1.67	5.67	Osaka	99.00	97.00
Miyagi	0.00	0.33	Hyogo	97.33	94.33
Akita	96.00	96.33	Nara	98.00	95.00
Yamagata	96.00	95.33	Wakayama	97.33	96.33
Fukushima	0.00	0.67	Tottori	98.00	96.33
Ibaraki	15.67	25.67	Shimane	99.00	95.33
Tochigi	98.67	97.33	Okayama	97.00	96.00
Gunma	98.00	96.67	Hiroshima	97.00	94.33
Saitama	98.67	97.33	Yamaguchi	97.67	93.67
Chiba	50.33	63.33	Tokushima	96.00	93.33
Tokyo	30.00	38.67	Kagawa	97.00	96.67
Kanagawa	100.00	99.00	Ehime	95.67	96.33
Niigata	97.33	94.67	Kochi	97.67	96.00
Toyama	98.33	95.67	Fukuoka	98.33	98.33
Ishikawa	97.67	97.67	Saga	97.33	95.33
Fukui	97.67	98.33	Nagasaki	98.33	96.33
Yamanashi	97.00	93.67	Kumamoto	97.67	97.00
Nagano	96.00	95.67	Oita	97.33	97.00
Gifu	98.33	97.00	Miyazaki	98.00	97.33
Shizuoka	97.33	94.33	Kagoshima	98.00	96.67
Aichi	97.67	91.33	Okinawa	99.33	98.00
Mie	96.00	92.67			