Extended Input-Output Model of Regional Economy: A Case Study in Fukuoka Prefecture

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***ABSTRACT*:** Input-output (IO) analysis is used for many years as a tool which estimates an economic effect when economical shocks, such as an increase of demand, a disaster are given. There are two basic models in the IO analysis: one is the quantity model which estimates production and the other is the price model which estimates prices. This study investigates a possibility of extension which combined these two models. As an example, economical influencing between industry and the region is analyzed using the inter-regional IO table by two regions of Fukuoka Prefecture and other prefectures. The study conducts analysis on the theme of a disaster. In that case, an unexpected thing may happen. The study analyzes also about uncertainty after the disaster through Monte Carlo experiment.

KEYWORDS: Extended Input-Output Model, Regional Economy, Monte Carlo Experiment

1. INTRODUCTION

Input-output (IO) analysis is used for many years as a tool which estimates an economic effect when economical shocks, such as an increase of demand, a disaster, and so on are given. There are two basic models in the IO analysis: one is the quantity model which estimates production and the other is the price model which estimates prices (Miller and Blair, 2009). Since the quantity model fixes a price and the price model fixes quantity, it does not usually treat these models simultaneously. One of the purposes of this study is to investigate a possibility of extension which combined these two models.

As one possibility, we are considering an applied/computable general equilibrium (CGE) model which is more sophisticatedly constructing (Hosoe et al., 2010). It can be said CGE model is one direction of the extension of the IO model. However, this model is generally complicated for users. Therefore, the study suggests the moderate model that IO model is extended, but not to extend to the CGE model.

As an example, economical influencing between industry and the region is analyzed using the inter-regional IO table by two regions of Fukuoka Prefecture (*Fukuoka-ken*) and other prefectures. Fukuoka Prefecture is located in Kyushu of a southwest part of Japan. Japan is known as a quake-prone country. Therefore, there are many researches which analyze the bad influence to the economy by the disaster using IO or CGE model[1]. This study also conducts analysis on the theme of the disaster. The big earthquake has also occurred in Fukuoka Prefecture in 2005 (*Fukuoka Prefecture*

[1] Since there is dozens of literature, we do not introduce them tentatively. However, Okuyama (2009) is arguing about the difference from IO analysis and CGE analysis in disaster research.

Western Offshore Earthquakes), however, the study analyzes the influence on the Fukuoka economy to the supply shock by the disaster of other prefecture where the probability that the disaster will occur more is high. Through these analyses, we suggest some implication about the disaster shock to the Fukuoka economy and the possibility of the model.

2. THE MODEL

As known well, IO analysis consists of two basic models, quantity and price. The quantity model is $X=(I-A)^{-1}F$, where A is a matrix of direct-input coefficient[2], X and F are vectors of output and final demand in monetary values. The price model is $P=(I-A')^{-1}V$, where A' is a transposing of A, P and V are vectors of price and value-added. Various analysis are developed by making one of these two models (those many being the quantity models) decompose intricately. In this study, we suggest a model which makes the Input-output model extend but is not complicated as the CGE model. First, it considers treating these two models simultaneously here. It can be said the quantity model is featured the demand side and the price model is the supply side[3]. However, since the quantity model is constructed by quantity variables only (product-determining mechanism) and the price model is constructed by price variables only (price-determining mechanism), they cannot be combined as it is. Then, some idea will be added to a model.

First, the demand side sets up a model as follows, taking into consideration the data used by this study.

[2] $A=Zx^{-1}$, where Z is a matrix of inter-industry sales in monetary values and x is a diagonal matrix with the elements of the vector X along the main diagonal.
[3] This argument is based on Leontief model (Leontief, 1936, 1941, and 1986). As a model which treats a supply side quantitatively, Ghosh (1958) suggests other model using direct-output coefficient ($B=x^{-1}Z$).

$$\begin{aligned} X_{r,i} &= \sum_s \sum_j \alpha^A_{s,r,i,j} X_{r,i} \\ &+ \sum_s \sum_d \alpha^F_{s,r,i,d} F_{s,d} \big/ P_{r,i} \\ &+ \alpha^E_{r,i} E \big/ P_{r,i} \\ &- \alpha^M_{r,i} X_{r,i} \big/ PM_{r,i} \end{aligned} \quad . \qquad (1)$$

This is what is called the quantity model. The production-goods demand X consists of the intermediate-goods demand AX (αX), the final demand F, export E, and import (function of production goods). α is a parameter to each demand and it is calibrated from the database. Moreover, it is assuming to be subject to the influence of the prices of production goods for final demand and export. The demand function based on a Cobb-Douglas type utility function is the background for this. Subscript at the lower right of each variable r and s are represented region, i and j are represented industry, d is represented demand item, and v is represented value-added item, respectively.

$$\begin{aligned} P_{r,i} X_{r,i} &= \sum_s \sum_j \alpha^A_{r,s,j,i} P_{s,j} X_{r,i} \\ &+ \sum_v PV_{r,v} W_{r,v,i} \end{aligned} \quad . \qquad (2)$$

This is the model of the supply side. To the price model, the quantity variable was added, and it set up so that the amount of money might be balanced. Eq (1) and Eq (2) turn into simultaneous equations now, and it can decide the price P and quantity X simultaneously. PV is the factor price and W is quantity of the production factor and $PV*W$ shows the monetary values of value-added.

$$\sum_i W_{r,v,i} = \sum_i \alpha^V_{r,v,i} X_{r,i} \left(P_{r,i} \big/ PV_{r,v} \right)^{\sigma} \quad . \qquad (3)$$

This shows the relation between supply and demand of the production factor. It is determined by

Table 1 Industry Classification

	Industry		Industry
a001	Agriculture	i021	Construction
a002	Forestry	i022	Electricity and gas supply
a003	Fishing	i023	Water supply and waste treatment
i004	Mining	s024	Wholesale and retail trade
i005	Food products and beverages	s025	Finance and insurance
i006	Textiles	s026	Real estate
i007	Pulp, paper and paper products	s027	Transport
i008	Chemicals	s028	Communications
i009	Petroleum and coal products	s029	Public administration
i010	Non-metallic mineral products	s030	Education and research
i011	Iron and steel	s031	Medical-treatment, health, social security and care
i012	Non-ferrous metals	s032	Other public service
i013	Fabricated metal products	s033	Business services
i014	Machinery	s034	Entertainment
i015	Electrical machinery, equipment and supplies	s035	Restaurant
i016	Information and communication facility	s036	Hotel
i017	Electronic components	s037	Other service
i018	Transport equipment	s038	Stationery for an individual
i019	Precision instruments	s039	Others
i020	Others		

(Source) Inter-regional IO table of Fukuoka prefecture

the function of production goods, the goods price, and the factor price. However, the reaction to the factor demand for price fluctuation presupposes that it is flexible. Therefore, the elasticity parameter σ was added here. It is what is called CES type demand function. Moreover, the production factor is enabling movement between industries in the each region from the above-mentioned specification. Therefore, the factor price is unified between industries.

$$F_{r,d} = \alpha^{D}_{r,d} \sum_{i} \sum_{v} PV_{r,v} W_{r,v,i} \ . \quad (4)$$

It is a conditional equation showing that the sum total of factor incomes corresponds with final demand. Although the model closes by this, this assumption is not used in the usual input-output analysis. Moreover, by the CGE model, it is set up in distribution of the items (consumption, investment, etc.) of final demand about closing of the model in many cases. However, in order to simplify the model here, parameter α is set and are making it simplified.

We use a data of inter-regional IO table of Fukuoka prefecture in 2005. This table is constructed two regions of Fukuoka Prefecture and other prefectures and 39 industrial sectors (see, Table 1). The items of added value are “Consumer spending outside a household economy (row)”, “Wages and salary and Social insurance premiums (employer burden)”, “Other salaries and an allowance”, “Operating surplus”, “Capital depreciation”, “Indirect tax except customs duty”, and “Subsidy”, The items of final demand are “Consumer spending outside a household economy (column)”, “Private consumption”, “Government consumption”, “Government investment”, “Private investment”, and “Inventory”. The value added W is assumed to be exogenous variables, and has a role which gives a shock in a simulation. Although the factor price PV changes by shock, Consumer spending outside a household economy (row), Indirect tax except customs duty, and Subsidy are making the price fixation among *W*. This shows that these three items of total monetary amount does not change before and after a simulation. In addition, since the indirect tax and the subsidy were contained in this, it was possible to have modeled this as distortion of the price, but it omitted for the simplification of the model. In addition, the export demand *E* and the import price *PM* are made into exogenous variables. Neither shall consider the change of the circumstance of the international economy.

3. SIMULATION

When considering the influence of the economy on the shock by a disaster happens, a scenario of the exogenous increase in the final demand seen by the usual IO analysis cannot be drawn. When a disaster happens, collapse of private capital stock, such as a house and a factory, and collapse of infrastructures (social-capital stock) including traffic and a logistic network are expected and even if the final demand does not change, a negative shock in the supply side will be suffered. Therefore, if disaster analysis is considered by the framework of IO analysis, it can be said that the supply side model is more suitable than the demand side.

Here, the influence of the economy when capital stock decreases according to a disaster is analyzed. In performing this simulation, change of the capital price by the shock of capital stock poses a problem. When a negative shock was given to capital stock, if the case where elasticity was 1 (what is called a Cobb-Douglas type) considered elasticity by the formula (3), the capital price will going up to compensate the shock and it will have no influences on economy. Therefore, the cases where elasticity is high and low are assumed here, and the simulation is carried out in each case.

Furthermore, in this simulation, it assumes that the demand of production factors is unstable. Although it is useful for this to investigate the robustness of results, if unstable, in a certain degree, the influence on the economy to a disaster shock will become ambiguous.

It is as follows when these are shown concretely. About reduction in capital stock, it is assumed to decrease by 20% in other prefectures. Although this value may be a remarkable catastrophic disaster, it is because the influence on economy is not great even if it takes out a realistic number. Moreover, the problem examined here poses a problem which measures not the influence of the other prefectures' economy on the disaster occurs in Fukuoka Prefecture but the influence of the Fukuoka economy on the disaster occurs in other prefectures, such as the Great East Japan Earthquake, for example. Next, elasticity was set to 0.5 by the case where it is low, and was set to 2 by the case where it is high. The low (high) elasticity means that change of the capital price is slow (quick) to the shock of capital stock. About the instability of demand for production factor, the normal random number was put into the demand parameter of production factor, and Monte Carlo experiment was conducted. The number of times of the experiment is 400 times. Furthermore, in reduction of the capital stock by the disaster shock, the shock was given irregularly using the binominal random number of that whose probability of occurrence is 0.5.

4. RESULTS

Figure 1 shows the average of change of the quantity of production by the disaster shock when elasticity is low after Monte Carlo experiment. When the binominal random number was used, the number of times that capital stock decreased became 194 times.

Figure 1 Change of output in low price elasticity

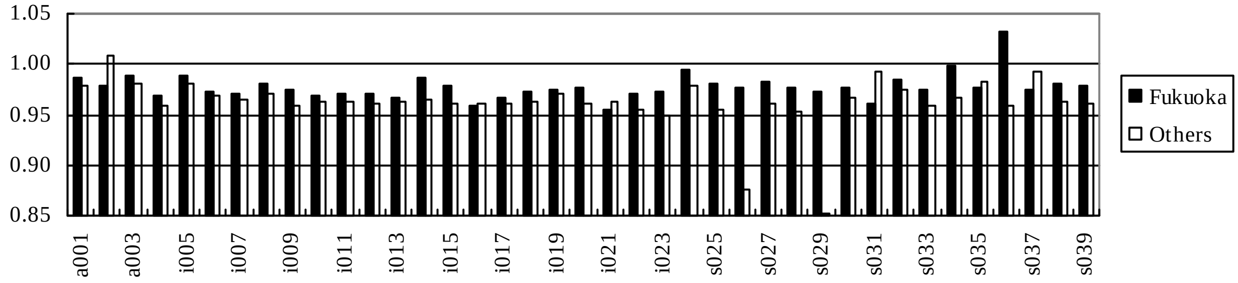


Figure 2 Change of output in high price elasticity

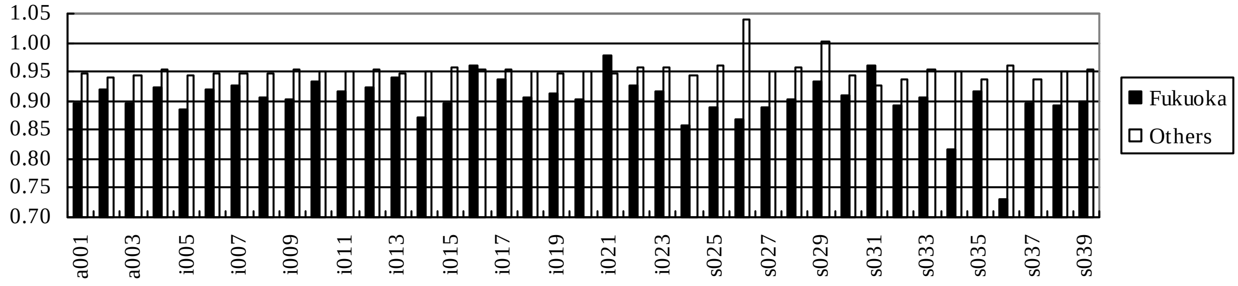


Figure 3 Change of price in low price elasticity

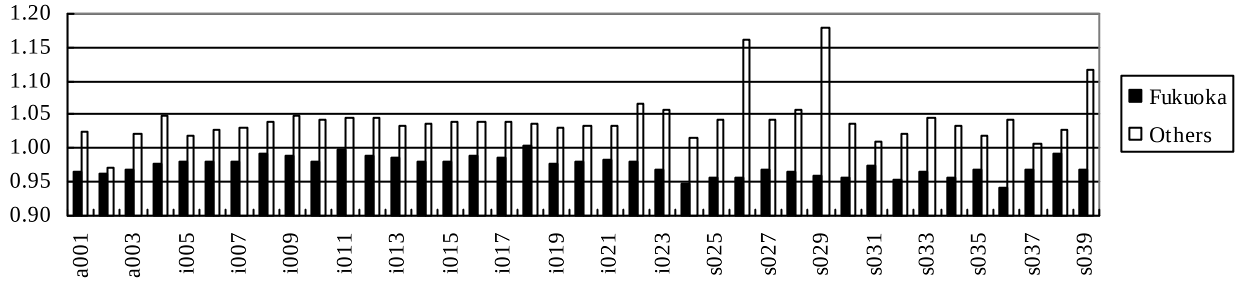
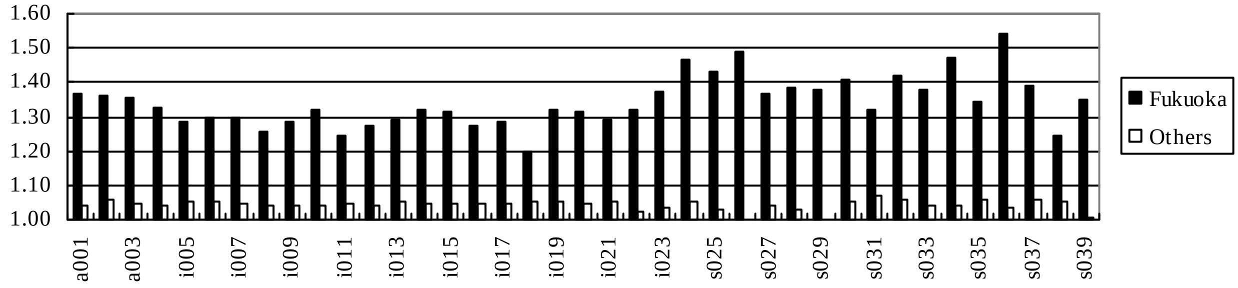


Figure 4 Change of price in high price elasticity



Therefore, although capital stock did not decrease by remainder 206 times, change of the quantity of production by Monte Carlo experiment hardly existed. Except for a part of industries, 5% is not filled the reduction in the quantity of production in general. In Fukuoka Prefecture and other prefectures, it can be said that the reduction on other prefectures is large and the influence on Fukuoka Prefecture is not so big.

Figure 2 shows the average of change of the quantity of production when elasticity is high. In this case, although the quantity of production on other prefectures is 5% of reduction in general, Fukuoka Prefecture serves as reduction beyond it. Therefore, it is shown that the influence which the disaster shock has on other regions (Fukuoka Prefecture) is great, if the reaction to the price is large.

Figure 3 and Figure 4 show the price change in each cases of elasticity. In any elasticity, while price change of each industry on other prefectures is about 5%, as for Fukuoka Prefecture, the case where the price falls (when elasticity is low) and the case where the price rises extremely (when elasticity is high), by the difference in elasticity has arisen. It turns out that the adjusted speed of the capital price accompanying reduction in capital stock is acting on a result greatly by this.

Table 2 and Table 3 show change of the weighted price index, nominal GDP, real GDP, and the quantity of production in each region and elasticity, respectively. The maximum, the minimum, an average, and standard deviation by the sample of pre and post shock are shown. As investigated about individual industry in Figure 1 to 4, it turns out that the influence on the Fukuoka economy changes greatly with differences in elasticity. That is, it can be said that the negative influence for the Fukuoka economy is great, if the price change is flexible.

Table 4 shows the same change, after uniting Fukuoka Prefecture and other prefectures with some recalculations. According to this, it turns out that the average is few influence of elasticity, but the standard deviation is so small when elasticity is high. The standard deviation of Fukuoka Prefecture is also so high when elasticity is high and this brings a very unstable result. However, since economy of other prefectures is comparatively large and stable, it is considered to be brought such result.

Finally, it is investigated whether remarkable change was shown by indices, such as the price, between pre and post shock. There is a test of difference between two means as a statistical indicator when investigating the independency between samples. When this test is performed by this research, it shows a significant difference between pre and post shock in many indices. Therefore, it can be said that there is a bad influence to the economy by the shock in general. However, about an individual sample, it cannot necessarily say. Here, the multiplicity between samples is analyzed. It is because the shocking influence of capital stock may be offset for the uncertainty of factor demand when a multiplicity is high. Table 5 is investigating the multiplicity in each cases of elasticity, its difference in the multiplicity by the difference in elasticity is clear. That is, if elasticity is low, many results which do not understand whether it is shocking influence and whether it is uncertainty are produced. If elasticity is high, the bad influence to economy is occurred certainly by the shock.

5. CONCLUSIONS

The model proposed by this research is the complicated model including price fluctuation for

Table 2 Monte Carlo result of regional macro variable in low price elasticity

			Price	Nominal GDP	Real GDP	Gross production
Fukuoka	Pre-shock	Max	1.1352	1.1769	1.0617	1.0314
		Min	0.8813	0.8557	0.9478	0.9651
		Average	0.9999	1.0001	0.9998	1.0004
		Std. dev	0.0429	0.0556	0.0187	0.0123
	Post-shock	Max	1.0788	1.0562	1.0097	1.0049
		Min	0.8673	0.7861	0.8974	0.9401
		Average	0.9694	0.9329	0.9621	0.9776
		Std. dev	0.0376	0.0465	0.0180	0.0128
Others	Pre-shock	Max	1.0495	1.0061	1.0596	1.0608
		Min	0.9378	0.9921	0.9570	0.9554
		Average	0.9999	1.0000	1.0005	1.0004
		Std. dev	0.0189	0.0026	0.0171	0.0176
	Post-shock	Max	1.1159	1.0067	1.0003	1.0005
		Min	0.9985	0.9942	0.9022	0.9011
		Average	1.0470	1.0004	0.9557	0.9564
		Std. dev	0.0192	0.0023	0.0161	0.0165

Table 3 Monte Carlo result of regional macro variable in high price elasticity

			Price	Nominal GDP	Real GDP	Gross production
Fukuoka	Pre-shock	Max	1.1574	1.1479	1.0209	1.0339
		Min	0.8918	0.8985	0.9708	0.9482
		Average	1.0036	1.0028	0.9995	0.9994
		Std. dev	0.0499	0.0435	0.0084	0.0160
	Post-shock	Max	1.7933	1.6707	0.9699	0.9558
		Min	1.1065	1.0732	0.9193	0.8537
		Average	1.3631	1.2873	0.9449	0.9018
		Std. dev	0.1124	0.0969	0.0088	0.0177
Others	Pre-shock	Max	1.0252	1.0043	1.0191	1.0190
		Min	0.9817	0.9936	0.9705	0.9715
		Average	1.0001	0.9999	0.9998	0.9998
		Std. dev	0.0071	0.0019	0.0083	0.0080
	Post-shock	Max	1.0523	0.9985	0.9790	0.9787
		Min	1.0189	0.9722	0.9339	0.9371
		Average	1.0361	0.9891	0.9547	0.9566
		Std. dev	0.0068	0.0043	0.0074	0.0070

researchers of IO analysis, and is the model simplified more for CGE modelers. As a result, the model consisting of four blocks of equations was developed. Although it is also possible to increase or decrease the block of this equation, considering analytic accuracy and the advanced nature of academics, the model tends to become complicated. It is important to develop complicated model, however, it is also important to develop more operative and simple model.

The bad influence to the economy by the disaster shock was measured using this model. It turns out that economy gets worse about 5% with the negative shock of 20% of capital stock to other prefectures. It is important finding that the influences on Fukuoka Prefecture differ greatly by the difference in the elasticity in price adjustment. Therefore, in order to produce a more exact measuring result, it should be estimate elasticity correctly. However, it is not easy, and since this estimation has the problem same as the CGE model development which uses a CES function abundantly, it is very large as a subject.

Table 4 Monte Carlo result of total macro variable

			Price	Nominal GDP	Real GDP	Gross production
Low	Pre-shock	Max	1.0469	1.0017	1.0602	1.0598
		Min	0.9428	0.9983	0.9566	0.9558
		Average	0.9999	1.0000	1.0005	1.0004
		Std. dev	0.0175	0.0006	0.0173	0.0174
	Post-shock	Max	1.1070	1.0001	1.0004	1.0007
		Min	0.9981	0.9962	0.9020	0.9029
		Average	1.0442	0.9978	0.9559	0.9572
		Std. dev	0.0180	0.0007	0.0161	0.0163
High	Pre-shock	Max	1.0297	1.0007	1.0189	1.0191
		Min	0.9813	0.9992	0.9708	0.9707
		Average	1.0003	1.0000	0.9998	0.9998
		Std. dev	0.0081	0.0003	0.0082	0.0082
	Post-shock	Max	1.0689	1.0013	0.9789	0.9779
		Min	1.0229	0.9980	0.9353	0.9344
		Average	1.0469	1.0002	0.9554	0.9547
		Std. dev	0.0076	0.0006	0.0072	0.0072

Table 5 Multiplicity of distribution pre and post shock (%)

		Price	Nominal GDP	Real GDP	Gross production
Low	Fukuoka	98.45	94.85	80.41	82.99
	Others	51.94	97.09	46.39	51.55
	Total	55.34	27.84	47.42	51.55
High	Fukuoka	4.37	6.31	0.00	0.52
	Others	0.97	10.82	1.55	1.55
	Total	0.97	94.85	1.55	1.55

The necessity of offering the quantitative argument on various economic effects increases. Therefore, it is important that various model analyses are proposed.

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