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Natural Disasters Caused by Climate Change and Agricultural Products Loss in Cross-Strait Industry: An Input-Output Analysis

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ABSTRACT

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In order to estimate the direct and indirect losses caused by natural disaster, this study conducts an Inter-Country Input-Output (ICIO) analysis to discuss the impacts on cross-strait industries in the face of disasters losses. The present study includes data from 96 sectors' cross-strait Inter-Country Input-Output table and the statistics of agriculture during 2005-2011 in Taiwan and the period 2005-2010 in Mainland China. The results indicate the total value-added effect in Mainland China is larger than Taiwan, whereas the multiplier of agriculture losses in Taiwan is larger than Mainland China. This indicates that the losses caused by natural disasters are larger in Taiwan is than in Mainland China.

ADDITIONAL INDEX WORDS: *Agriculture, products loss, climate change, inter-country input-output (ICIO) model, cross-strait.*

INTRODUCTION

Mainland China and Taiwan have followed different patterns of political and economic development since 1949, resulting in significant differences in economic activities, social environments and developmental trajectories between Mainland China and Taiwan. Nevertheless, both of them has suffered from great damage caused by natural disasters, which would seriously affect economic systems, traffic infrastructure, agricultural industry and so on. More specifically, Taiwan depends largely on imports from and exports to Asian countries. Dominated by sub-tropical and tropical climate, Taiwan is often affected by Typhoons during summer and autumn. Although typhoons bring abundant rainfall, they also trigger natural disasters such as floods and landslides, which threaten residents' lives and cause losses in economic activities. For instance, typhoon Morakot caused death of more than 600 people and losses of 164 billion in agricultural productions and infrastructure in 2009.

In recent years, Mainland China also suffers from disasters such as typhoon and drought. In Mainland China, there is not much variance in the total annual rainfall across years, whereas the amounts of monthly rainfall vary greatly within a year. According to the statistics of the National Office of Flood Control and Drought Management, in 2009, there were 43% drought-stricken in wheat-field and 429 million people faced the problem of lacking drinking water.

To summarize, although Mainland China and Taiwan share different industrial structures, they both suffer from natural disasters and the losses caused by these disasters in agriculture and related industries. Therefore, in order to investigate the direct and indirect impacts of the natural disaster on agricultures in Taiwan and China, the present study employ an supply-side Inter-Country Output Analysis proposed by Miller and Blair (2009). To this end, this paper uses data from cross-strait Inter-Country Input-Output table of 96 sectors in 2006 reported in Lin's (2013) and the statistics of Agricultural natural disasters published by the Council of Agriculture Statistics in Taiwan during 2005 to 2011 and the database of agricultural productivity in China in 2005 to 2010.

LITERATURE REVIEW

Climate change may cast influence on environments in various ways. For instance, Ahmed *et al*. (2015) concluded that 33% of farmers in the Province of Punjab, Pakistan, were unwilling to pay for a planned climate change adaptation program, whereas 67% were willing to pay (WTP). The predominant reasons for this willingness included 'having impacts on agricultural production', 'feeling responsible for my contribution to climate change' and 'concern for the risk posed by climate change'. Ahmed *et al* (2015) and McElhinney (2016) further found farmers who were more WTP for a climate change adaptation program were more highly-educated, had higher incomes and had greater concern for climate change. In short, climate change not only affects the natural environment but also affects social awareness about the environmental sustainability.

Furen *et al*. (2005) argued that climate change would affect growth in population and economic development. A decrease in the amount of rainfall would increase the risk of drought, which would in turn affect the productivity of related industries. The authors use Social Accounting Matrix (SAM) and simulate six situations to explore the economic impacts of water restrictions and conclude that the food and beverage sectors undergo most

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Table 1. *The losses in value-added by natural disasters in Taiwan.*

Sectors		2005 GDP effect	rank	2006 GDP effect	rank	2007 GDP effect	rank	2008 GDP effect	rank	2009 GDP effect	rank	2010 GDP effect	rank	2011 GDP effect	rank
001	Farming products	46,012	1	7,996	1	27,110	1	32,035	1	28,394	1	20,630	1	8,027	1
002	Livestock products	602	6	53	8	194	8	223	8	2,292	4	311	5	19	15
003	Forest products	778	5	37	11	147	9	79	15	9,305	3	112	10	19	14
004	Fishery products	3,710	2	147	4	567	3	1,441	3	9,913	2	1,633	2	538	2
005	Agricultural services	2,357	3	403	2	1,366	2	1,621	2	1,648	5	1,056	3	406	3
006	Crude petroleum and natural gas extraction	186	13	30	13	101	13	123	12	180	15	83	13	31	11
008	Other non-metallic minerals	249	11	42	9	142	10	169	10	197	14	111	11	43	9
013	Animal feeds	112	16							288	11	52	16		
026	Petrochemical raw materials and petroleum refining products	171	14	24	14	83	14	106	13	211	13	76	14	28	12
028	Basic chemical materials			15	19	51	19	61	19					15	19
029	Chemical fertilizers	527	7	91	5	308	5	365	5	357	8	236	6	91	5
032	Pesticides and herbicides	140	15	24	15	81	15	96	14	107	20	62	15	24	13
038	Plastic products	109	17	18	16	62	16	74	16			49	17	19	16
066	Electricity supply	363	9	57	7	195	7	238	7	345	9	162	8	61	7
070	Wholesale trade and retail trade	1,134	4	165	3	565	4	705	4	1,372	6	511	4	181	4
071	Railroad vehicle transportation and land transportation	267	10	41	10	139	11	170	9	311	10	118	9	44	8
081	Telecommunication services	108	18	16	17	56	17	69	17	121	18	48	19	18	17
083	Finance, securities, futures and other activities auxiliary to financial service activities	429	8	66	6	225	6	275	6	495	7	191	7	70	6
085	Real estate services	108	19	16	18	54	18	67	18	131	17	48	18	17	18
087	Professional, scientific and technologic services	223	12	35	12	119	12	145	11	233	12	100	12	37	10
094	Public administration and social association services	95	20	15	20	51	20	61	20	135	16	41	20		
095	Repair, domestic and personal services									111	19			15	20
	Total	59,140		9,504		32,347		39,038		57,817		26,279		9,943	

Unit: Million NT

losses in all situations. Okuyama (2007) discussed the advantages and disadvantages of Input-Output model, Computable General Equilibrium (CGE) model and Social Accounting Matrix (SAM). This paper concluded that the model estimation should be guided by economic theories to prevent overestimation or underestimation in empirical or simulated results.

Wu (2003) investigated the influence of the reconstruction budget for the 921 Earthquake on the industrial structure and the economic development of tourism in central Taiwan. After reviewing various related literatures, Wu (2003) found RAS method was the one with least measurable error to build Regional Input-Output model, and therefore it was found to explore the linkage contributions and the economic multiplier impacts.

Lin *et al*. (2010) combined the regional and supply side Input-Output analysis developed by Miller and Blair (2009) to evaluate the losses of agricultural productions caused by natural disasters in regional economy. They found the losses of agricultural productions from natural disasters substantially affected income and employment effect, as high as a loss accounting for 30% of Agriculture GDP.

METHODS

According to Miller and Blair (2009), natural disasters affect the supply of economic activities and result in output impairment in the economic system. This study uses the Inter-Country Input-Output model to estimate the influence of agricultural products loss caused by climate change in cross-strait industry as follows.

$$X = Z + F \tag{1}$$

X, Z and F are the output vector, middle demand matrix and the final demand. The multi-regional trade matrix is given below:

$$Z = \begin{bmatrix} Z_{ij}^{LL} & \mathrm{L} & Z_{ij}^{LK} \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ Z_{ij}^{KL} & \mathrm{L} & Z_{ij}^{KK} \end{bmatrix} \tag{2}$$

In equation (2), Z_{ij}^{LL} is the i-th commodity produced in the j-th industry in the L-th region. Z_{ij}^{LK} indicates the outputs in region K from the j-th industry and the inputs produced in region L.

Table 2. *The losses in value-added by natural disasters in China.*

Sectors	2005 GDP effect	rank	2006 GDP effect	rank	2007 GDP effect	rank	2008 GDP effect	rank	2009 GDP effect	rank	2010 GDP effect	rank
01 Farming products	15,657	1	18,001	1	26,480	1	24,595	1	31,795	1	24,784	1
02 Livestock products	5,668	2	5,440	2	9,258	2	9,596	2	10,769	2	7,520	2
03 Forest products	1,281	4	1,528	4	2,255	4	2,119	4	2,560	4	1,976	4
04 Fishery products	2,417	3	2,522	3	3,622	3	3,439	3	4,401	3	3,275	3
05 Agricultural services	1,014	6	1,125	6	1,700	6	1,615	6	2,028	6	1,548	6
06 Crude petroleum and natural gas extraction	86	15	95	15	142	15	135	17	169	15	129	15
08 Other non-metallic minerals	104	13	117	13	175	13	165	13	209	13	160	13
11 Flour	82	17	81	17	134	17	137	16	157	17	112	17
13 Animal feeds	318	7	310	8	515	7	527	7	603	7	425	8
26 Petrochemical raw materials and petroleum refining products	91	14	98	14	148	14	142	14	177	14	133	14
29 Chemical fertilizers	194	9	221	9	328	9	307	9	393	9	304	9
32 Pesticides and herbicides			60	20	89	20			106	20	82	20
66 Electricity supply	188	10	204	10	311	10	299	10	370	10	279	10
70 Wholesale trade and retail trade	1,109	5	1,133	5	1,814	5	1,809	5	2,138	5	1,553	5
71 Railroad vehicle transportation and land transportation	168	11	180	11	277	11	269	11	329	11	245	11
81 Telecommunication services	63	19	68	19	104	19	100	19	123	19	92	19
83 Finance, securities, futures and other activities auxiliary to financial service activities	297	8	314	7	490	8	479	8	579	8	429	7
85 Real estate services	86	16	89	16	140	16	138	15	165	16	121	16
87 Professional, scientific and technologic services	157	12	165	12	259	12	254	12	306	12	226	12
94 Public administration and social association services	66	18	71	18	111	18	108	18	130	18	97	18
95 Repair, domestic and personal services	53	20					85	20				
Total	30,047		32,831		49,908		47,829		59,354		44,871	

Unit: Million NT

Assuming that the input coefficients are fixed, the relationship of input and output can be estimated and the coefficient of middle input in different regions can be expressed in equation (3):

$$A=\begin{bmatrix} A^{LL} & \mathrm{L} & A^{LK} \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ A^{KL} & \mathrm{L} & A^{KK} \end{bmatrix}=\begin{bmatrix} \left[z_{ij}^{LL}/X_j^{L}\right] & \mathrm{L} & \left[z_{ij}^{LK}/X_j^{K}\right] \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ \left[z_{ij}^{KL}/X_j^{L}\right] & \mathrm{L} & \left[z_{ij}^{KK}/X_j^{K}\right] \end{bmatrix} \quad (3)$$

For similarity consideration, this study defines the total output matrix X and the final demand matrix F as the balance equation between supply and demand, which is written as:

$$X = AX + F \quad (4)$$

$$(I - A)X = F \quad (5)$$

where $(I-A)$ is a Leontief matrix and X can be solved when the matrix is non-singular:

$$X = (I - A)^{-1}F \quad (6)$$

In equation (6), $(I-A)^{-1}$ is a direct and indirect requirements matrix, also called as the inter-industry interdependence coefficients matrix or Leontief inverse matrix. Equation (6) can explain the new equilibrium outputs when the final demand changes:

$$\Delta X = (I - A)^{-1}\Delta F \quad (7)$$

The input output table can make differences between domestic goods (Zd) and the imported goods (Zm), which can be expressed as Z=ZD+ZM, F=FD+FM and X=ADX+FD. The Leontief's Matrix in domestic goods $(I-A^D)$ can be solved as:

$$(I - A^D)X = F^D \quad (8)$$

X and the equation that analyze the changes of final demand can also be solved:

$$X = (I - A^D)^{-1}F^D \quad (9)$$

$$\Delta X = (I - A^{\mathrm{D}})^{-1}\Delta F^{\mathrm{D}} \quad (10)$$

The output effect on Equation (10) can be transformed to a value-added effect:

$$\Delta V = v(I - A^{\mathrm{D}})^{-1}\Delta F^{\mathrm{D}} \quad (11)$$

Likewise, the total output effect under differ situations such as when the final demand changes, the domestic goods output effect and the value-added effect can be calculated in equation (12) to equation (14).

$$\Delta X = (I - A^{*})^{-1}\Delta\overline{X} \quad (12)$$

$$\Delta X = (I - A^{D*})^{-1}\Delta\overline{X} \quad (13)$$

$$\Delta V = v(I - A^{D*})^{-1}\Delta\overline{X} \quad (14)$$

ANALYSIS

A supply-side Inter-Country Input-Output (ICIO) analysis was conducted to explore the impacts of natural disasters on the economic systems of Taiwan and Mainland China. The losses in value-added effects were estimated. Table 1 presents the value-added losses caused by natural disasters in Taiwan during 2005-2010. The effects range from 9.9 billion to 59.1 billion NT. The largest reduction was the damage to agricultural products, accounting for 80.7% of the total losses. The second largest industry suffering from natural disasters is wholesale trade and retail trade industry, followed by chemical fertilizers.

As an industry with second largest losses caused by natural disasters, the wholesale and retail industry undertakes 0.07 units of the agricultural production. Given that the forward linkage is stronger in wholesale and retail, the economic effect on this industry accounts for 0.5% on average.

In addition, 0.10 units of agricultural production input were offered to chemical fertilizers industry, making it the third largest industry suffering from natural disasters. As the chemical fertilizers industry has a larger backward linkage with agriculture, the chemical fertilizers industry bears the production losses and the losses in value-added effects.

Table 2 presents the value-added losses by natural disasters in Mainland China from 2005 to 2010. The effects range from 30,047 to 59,354 billion RMB. Similarly, agriculture industry was the mostly affected, with a loss of 55.2% in 2010, followed by wholesale trade and retail trade, and animal feeds.

The input coefficient of agriculture is 1.14, which means the losses will bring damage through forward linkage. The losses of productions and the value-added in agriculture account for more than 65% in both cases.

To summarize, both in Taiwan and Mainland China, agriculture, wholesale trade and retail trade, animal feeds, and chemical fertilizers industry are the industries mostly affected by natural disasters. Comparing the multipliers in Taiwan (2.9) and the multiplier in Mainland China (2.6), it can be found that the losses in Taiwan is larger than Mainland China in the face of the same natural disaster.

CONCLUSION

This study used supply-side Inter-Country Input Output analysis to explore the impacts of natural disasters on the economic systems of Taiwan and Mainland China. Two main results emerge from the present study. First, the losses in value-added caused by natural disasters mainly occur in agriculture, forestry, fishery, wholesale trade and retail trade, animal feed and chemical fertilizers industries. These sectors account for 90% (Mainland China) and 87% (Taiwan) of total losses respectively. Second, the losses in agricultural products caused by natural disasters may result in losses in other industries through industrial linkage. The empirical results show that the agricultural loss in Mainland China (2.6) is smaller than the loss in Taiwan (2.9).

LITERATURE CITED

Ahmed, A.; Masud, M.; Al-Amin, A.; Yahaya, SRB.; Rahman, M., and Akhtar, R., 2015. Exploring factors influencing farmers' willingness to pay (WTP) for a planned adaptation programme to address climatic issues in agricultural sectors. *Environmental Science of Pollution Research*, 22, 9494–9504.

Albert, E. and Steenge, M., 2007. Thinking about imbalances in post-catastrophe economies: An input-output based proposition. *Economic Systems Research*, 19, 205-223.

Furen, J.; Hirokazu, T.; Yasuhisa, K., and Tomonori, M., 2005. *Economic loss estimation of water supply shortage based on questionnaire survey in industrial sectors*. Japan: Disaster Prevention Research Group of National Research Institute for Earth Science and Disaster Prevention (NIED), 50p.

Lin, H.C., 2013. The Taiwan's economic impact of cross-strait agricultural trade: Regional input-output analysis. *Taiwanese Agricultural Economic Review*, 19(1), 81-127.

Lin, H.C.; Kao, T.; Chou, L., and Chang, C., 2010. The economic impact from agricultural products loss caused by natural disasters and regional input-output analysis in Taiwan. *Proceedings of the 1st Congress of East Asian Association of Environmental and Natural Resource Economics* (Hokkaido University, Sapporo, Japan), pp. 10-75.

McElhinney, J., 2016, Influencing the agricultural sector to embrace adaptation to climate change, for the sake of global food security. *Environmental Science of Pollution Research*, 23, 9245–9246.

Miller, R.E. and Blair, P., 2009. *Input–Output Analysis: Foundations and Extensions*. Cambridge: Cambridge University Press, 259p.

Okuyama, Y., 2007. Economic modeling for disaster impact analysis past present and future. *Economic Systems Research*, 19, 115-124.

Wu, Y.W., 2003. After the 921 earthquake reconstruction tourist attractions in central Taiwan's economic impact analysis. China: National Taiwan University, Master's thesis, 160p.