Interregional economic impact analysis of the Wenchuan earthquake, China

Jidong Wu, Ning Li, Wei Xie
State Key Laboratory of Earth Surface Processes and Resources Ecology, MOE Key Laboratory of Environmental Change and Natural Disaster, Beijing Normal University, Beijing, China
(wujidong@bnu.edu.cn)

Abstract: Loss and damage induced by catastrophic earthquakes have significant impacts not only on the disaster-affected area's economy but also on other regions outside the disaster area, which is adverse to regional sustainable development. The ripple effects, originate from imbalance between supply and demand in the regional economic system, can spread far beyond the region, and could have considerable impacts on other regions. The recovery measurement framework proposed by Chang (2010) was applied to evaluate the indirect losses in and outside the disaster areas caused by the Wenchuan earthquake, occurred in 2008. The magnitude and the extent of the indirect impacts in different spatial scale from this quake were analyzed, the impact mechanisms and economic vulnerability of the indirect loss in different provinces were also identified. The results show that, for worst-hit region, the recovery time need more than three years, but it has a blooming trend in other regions surrounding the disaster-hit areas just after this quake. These analytical results may be used to propose risk management strategies in the recovery and reconstruction periods in the following years.

Key Words: Wenchuan earthquake; Interregional economic impact; Recovery

1 Introduction

The question of whether the economic effects of a disaster are negative or positive has been the focus of traditional economic analysis of disasters (Dacy and Kunreuther 1969, Cochrane 1975). In a short-run study of the effects of disasters, Albala-Bertrand (1993) claimed that the indirect economic effects of disasters are "*more a possibility than a reality*". A localized disaster may not have a negative net effect on the macro-economy if negative impacts from damages are cancelled out by the positive impacts of recovery and reconstruction activities (Albala-Bertrand 2007). Interestingly, Noy (2009) finds a negative correlation between disasters and the long-run economic growth rate: natural disasters will typically cause a drop in output of 9 percentage points in developing countries. A long-run empirical study by Skidmore and Toya (2002) showed that climatic disasters are positively associated with higher long-run economic growth, while geologic disasters are negatively correlated with growth.

In the studies described above, the quantitative estimates of the size of the macroeconomic impact of disasters are questionable. First, the authors model natural disasters and countries as homogenous when economic consequences induced by disasters will vary across the affected region (Ellson et al. 1984, Steenge and Bočkarjova 2007, Strobl 2012). The low quality and the inconsistency of the disaster data are also a concern. Moreover, most of the macroeconomic impact studies were based on cross-country data; while a positive or negative impact of disasters for developing or developed countries can be estimated, this is insufficient for regional disaster risk management because such estimations cannot provide differential predictions at the sectoral or interregional scale to local governors.

Fortunately, significant progress has been made in recent years in regional economic impact modeling of disasters, especially "*Modeling Spatial and Economic Impacts of Disasters*", edited by Okuyama and Chang (2004). This book shows how to use economic models, such as input–output and computable general equilibrium models, to estimate the economic impact of disasters. Santos and Haimes (2004) proposed a modified input-output model able to reflect the extent of an economy's inoperability post-disaster. Rose and Liao (2005) illustrated how a computable general equilibrium model can be used to estimate the sectoral and regional economic impacts of a lifeline supply disruption in the aftermath of a major earthquake. Tatano and Tsuchiya (2008) further developed a spatial computable general equilibrium model to estimate the economic loss due to seismic transportation network disruption. Hallegatte (2008) proposed the Adaptive Regional Input–Output (ARIO) model and demonstrated that indirect losses increase nonlinearly with direct losses. The ARIO model was also used to estimate the economic impacts of Hurricane Katrina, the storm surge risks in port cities (Hallegatte et al. 2011), and the Wenchuan earthquake (Wu et al. 2012).

The results from input-output models and computable general equilibrium models can reflect the heterogeneous effects of disasters well. Such models have estimated that the economic impact on the disaster-affected areas is usually negative; the indirect economic losses were several times larger than the direct losses in a disaster scenario analysis (Hallegatte 2008). However, these economic impact estimation models usually lack sufficient validation due to scarcity of observed economic statistics and disaster impact data. Moreover, the estimated economic impact was usually a net total impact, i.e., it did not distinguish between the negative impacts from disaster damages and the positive impacts from recovery and reconstruction activities.

Empirical measurement of positive and negative disaster impacts on different spatial scales is necessary and critical for improving the accuracy of the estimates from these economic models. Few studies have made such an effort, especially in the context of developing countries. A successful empirical disaster recovery study should remedy this deficiency. The recovery time frame is the focus of most studies on disaster loss, as the duration of disaster recovery is directly related to the value of indirect economic losses and the total economic costs caused by the disaster (Brookshire et al. 1997, Rose et al. 1997). Disaster recovery research has transformed the development history from one that uses qualitative descriptions (Hass et al. 1977) to one that involves quantitative statistics (Chang 2010). Hass et al. (1977) were the first to propose a conceptual framework for describing the disaster recovery process. They divided it into four stages: the emergency period, restoration phase, replacement-reconstruction phase, and developmental reconstruction period. This framework was used to predict the post-disaster recovery timeframe of Hurricane Katrina in New Orleans (Kates et al. 2006). Porter et al. (2001) attempted to estimate the repair time given various levels of building damage. Burton et al. (2011) tried to evaluate the spatial recovery of the rebuilt environment in Mississippi after Hurricane Katrina using repeated photography and found recovery disparities across different communities. Chang (2010) proposed an exact quantitative measurement framework for urban disaster recovery using statistical data; this framework allows an estimation of the recovery duration of a given disaster. A comparison of "with- and without-" disaster values for various economic variables (e.g., per capita income) can also trace the effects of disasters in the recovery timeframe (Ellson et al. 1984). McComb et al. (2011) suggest that the adjacent regions surrounding the area affected by Hurricane Katrina may sustain lasting negative economic consequences. This persistence exists even though these surrounding areas can benefit from providing substitute production and shelter for the disaster-hit area in the short run. Ewing et al. (2005) find that the natural rate of unemployment decreased after Hurricane Bret of 1999 in Corpus Christi, Texas. Xiao (2011) examined the local economic impacts of the 1993 Midwest flood using time-series analysis and found that significant drops in personal income can be observed in the year of the event; however, the long-run effects seemed to be negligible.

This article contributes to the literature on the economic effects of natural disasters by estimating the economic impacts of the 2008 Wenchuan earthquake in worst-hit area and surrounding area. The disaster impact mechanisms are also decomposed to provide guidance for disaster risk management. This case study can be considered a supplement to other disaster case studies focused on developing countries where there is no insurance.

2 Methods and Data

The 8.0Ms Wenchuan earthquake occurred on May 12, 2008 in Sichuan province, China (Figure 1). This earthquake killed 69,226 people, left 17,923 missing, and caused a direct economic loss of 845 billion Chinese Yuan in 2008. Of these losses, 97.2% of the total dead and missing people, 42.9% of the collapsed houses and 39.5% of the direct economic losses were from the worst-hit area (NCDR and MOST 2008, pp. 97-103).

Figure 1. Study area.

The disaster recovery measurement framework proposed by Change (2010) was used to identify the disaster recovery process of Sichuan province using the statistical data mentioned above. The quantitative indicators, including population, sex ratio, GRP and per capita GRP, were used to measure various dimensions of the social and economic recovery of Sichuan and to provide some insight into the impact of this quake. Population and sex ratio are 'stock' variables (quantities measured at a specific point in time), which do not have an inherent temporal dimension, while the other two indicators are 'flow' variables (quantities that are measured per unit of time, e.g., per year).

Disasters usually cause a decline in production capacity but also an increase in demand for the reconstruction sector and goods due to direct damage of capital stock and other crucial infrastructure (Hallegatte and Przyluski 2010). Hence, there are negative and positive disaster effects on the disaster-affected area and surrounding region. ***Indirect losses*** refer to 'output losses' (negative effects), which can be defined as the economic production reduction resulting from the disaster. ***Indirect gains*** are the additional output (positive effects) due to reconstruction stimulus. Suppose the indicator is GRP, indirect losses are the reduction in aggregate production, compared with the no-disaster development baseline trajectory (i.e., a scenario of what would have occurred without disasters) in the recovery period. Indirect gains are the cumulative production increase exceeding the no-disaster development trend. In this analysis, the economic development level of the normalized economic indicators prior to the disaster (time T-1) is considered as the baseline scenario for calculating the disaster-induced losses or gains:

$$Indirect\ Economic\ Effects = \sum_{i=T}^{t^*} [(X_i - X_{T-1}) \times Y_i^{China}] \tag{1}$$

Here, X_i is the normalized economic indicator (e.g., GRP) of the study area, X_{T-1} is the economic indicator level just prior to the disaster (e.g., the GRP level in 2007 for the Wenchuan earthquake), Y_i^{China} is the real economic indicator value at comparable prices for all of China (e.g., GDP of China in 2008 at constant 2005 prices) at time *i*. The cumulative indirect economic effects, when $X_i < X_{T-1}$, are the indirect losses, while the cumulative indirect economic effects, when $X_i > X_{T-1}$, are the indirect gains in the recovery process.

Depending on the geographic scale on which the economic assessment is performed, indirect losses and indirect gains may be different. For the disaster-affected region, damages in critical intermediate sectors may result in negative 'ripple effects' in the economy. For example, the interruption of electricity, gas and transportation has immediate consequences on the entire local economic system, even outside the immediate area of the disaster.

The recovery measurement frameworks are used to identify the recovery process and recovery periods of Sichuan region and the rest of Sichuan (shown in Figure 1). Aggregate economic losses and gains are calculated to analyze the economic consequences of this quake.

3 Results

The GRP level (as a percentage of Chinese GDP) of the worst-hit area of Sichuan decreased by 35.4% in 2008 compared to the 2007 level. After three years of reconstruction, the region had still not returned to its pre-earthquake GRP level, but the GRP level of the rest of Sichuan experienced a boom in those three years because of the reconstruction demand stimulus. The GRP per capita level of Sichuan (as ratio to Chinese GDP per capita) in 2010 increased by 10.0% compared with the 2007 pre-earthquake level. The GRP of the worst-hit region of Sichuan needed more than three years to surpass its pre-earthquake level.

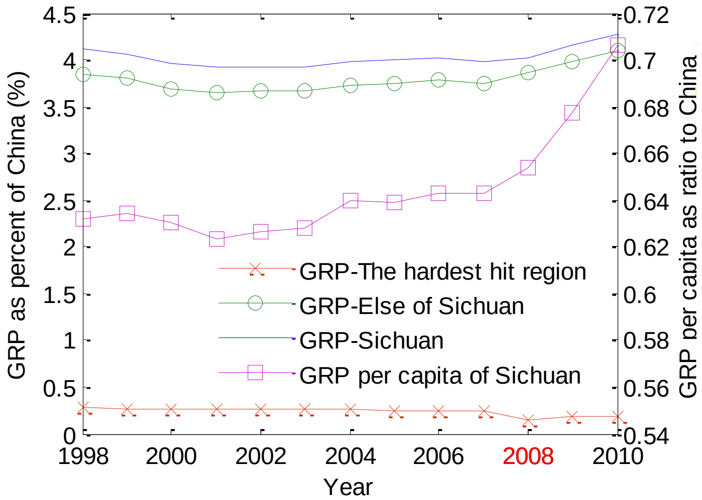

Figure 2. Economic recovery of the worst-hit region in Sichuan after the 2008 Wenchuan earthquake. The hardest hit region in Sichuan includes the ten serious-damaged counties in Sichuan as shown in right side. Source: Author, based on data from Sichuan Provincial Bureau of Statistics *Sichuan Statistical Yearbook 2011* and National Bureau of Statistics of *China Statistical Yearbook 2011.*

In understanding the difference in recovery curves or economic consequences, the spatial scale of the analysis is the main explanation (Figure 2). By restricting the analysis to the worst-hit area, the direct damages from the disaster can reduce the production capacity and result in supply and demand shortages. A small amount of direct damage may have an enormous amount of economic disruption because of bottleneck effects within in the economic system (also known as “ripple effects”) (Hallegatte 2008). The severity of bottlenecks can vary over the recovery period, and the time needed for recovery plays an important role in determining the overall indirect losses. At the same time, with reconstruction demand expansion and outside assistance, the reconstruction stimulus and preferential policies implemented by the central government can have positive effects on the local economy. However, when the cost of reconstruction spending is shifted to the region’s victims (e.g., when the economic conditions are back to ‘normal’ with no preferential policies and outside aid), the gains from rebuilding are offset by reduced household spending (Cochrane 1997). The worst-hit region can also have a chance to re-optimize its economic structure in the recovery process and potentially embark upon a sustainable growth trajectory.

For the surrounding areas, if the worst-hit region produces the critical materials and substitutes, which are not available, then the indirect losses from the worst-hit area can spill over to the surrounding area; however, these negative effects seem limited in the rest of Sichuan. The supply shortage and reconstruction demand from the worst-hit region can be satisfied by speeding up production (increase work hours or production equipment) in the surrounding areas. This increased production is driven by profits because some commodity prices often increase due to the excess demand caused by disaster damage. This result can be interpreted as evidence that “disasters provide opportunities to update the capital stock and adopt new technologies” (Skidmore and Toya 2002). The concept of Schumpeterian “creative destruction", embedded in a theory of endogenous growth (Aghion and Howitt 1998), can explain the positive productivity shock of disasters on the whole economy (Okuyama et al. 2004, Cuaresma et al. 2008).

Above all, indirect losses and indirect gains can be experienced by both the worst-hit area and by the surrounding area; the relative magnitudes depend on several constraints, including presence of outside assistance, preexisting economic development circumstances, the insurance and disaster relief system, and even previous disaster experience. For the Wenchuan earthquake, the socio-economic boom occurring in China at the time could have been a major factor in the successful economic recovery of Sichuan.

After the Wenchuan earthquake, the government also implemented positive reconstruction policies to the disaster area. Along with the reconstruction funds provided by the government, 18 assistance provinces (or cities) offered assistance with no less than 1% of their last ordinary budget revenues to their 18 counterpart counties (or districts) in Sichuan[1]. Thus, the government aid to the disaster areas ensured the rapid economic recovery.

The destruction effects can benefit the surrounding region, at least in the short run, as shown in the cases of the Wenchuan earthquake. However, for the worst-hit area, it is difficult to tell whether the disaster is beneficial or harmful to the local economy. While Guimaraes et al. (1993) propose that disaster areas will "*potentially benefit from recovery efforts if there is a transfer of funds from outside the area that more than compensate for the losses*", further investigation is necessary to determine how these constraints drive the economic recovery across different spatial and temporal scales.

4 Conclusions and Discussion

The present study provides an empirical analysis of the interregional economic impact analysis of the Wenchuan earthquake. It is specifically aimed at measuring the impact of catastrophic events inside and immediately outside of the disaster-hit region. The results showed that the worst-hit area need more than three years to recovery. The area surrounding the worst-hit region benefited from the disaster, both in terms of GRP level and per capita GRP level.

This empirical disaster recovery study can provide valuable knowledge for indirect economic loss assessment models or to design disaster recovery simulation models. It can also provide valuable insights or experience (or inspiration) for disaster recovery planners in preparation for the next unexpected disasters.

The apparent change in the per capita GRP, compared to other economic variables in Sichuan just after the earthquake deserves further discussion and explanation. Firstly, the external recovery assistance post-disaster ensured a rapid recovery in the GRP of the disaster area in the short term. Additionally, the population bonus for survivors, such as the increased per capita land resources resulting from the population decrease post-disaster, was an important factor which contributed to the improved per capita GRP in Sichuan in the short term. Simultaneously, as happened after the Wenchuan earthquake, labor shortages can occur after

[1] In September 2008, 4 months after the earthquake, National Development and Reform Committee of China completed "*The state overall planning for the post-Wenchuan earthquake restoration and reconstruction*" to facilitate the reconstruction (Ge et al. 2010).

earthquakes, and the wage rise resulting from a labor supply shortage may also contribute an increase in per capita GRP. Furthermore, the growth rate of the local population during the earthquake recovery process in Sichuan was lower than the increase in GRP, leading to an apparent long-term improvement in the per capita GRP. Further studies are needed to analyze the per capita GRP change post-disaster over the long term.

References

Aghion, P., and Howitt, P.,1998. *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

Albala-Bertrand, J. M., 1993. *The Political Economy of Large Natural Disasters: With Special Reference to Developing Countries*. Oxford: Clarendon Press.

Albala-Bertrand, J. M., 2007. Globalization and Localization: An Economic Approach, in: *Handbook of Disaster Research* (eds.), H., Rodriguez, E. L., Quarantelli, and R. R., Dynes, New York: Springer, pp. 147-167.

Brookshire, D., Chang, S. E., Cochrane, H., Olson, R., Rose, A., and Steenson, J., 1997. Direct and indirect economic losses from earthquake damage, *Earthquake Spectra* **13**(4), 683-701.

Burton, C., Mitchell, J. T., and Cutter, S. L., 2011. Evaluating post-Katrina recovery in Mississippi using repeat photography, *Disasters* **35**(3), 488−509.

Chang, S. E., 2010. Urban disaster recovery: a measurement framework and its application to the 1995 Kobe earthquake, *Disasters* **34**(2), 303−327.

Cochrane, H. C., 1975. *Natural Hazards and Their Distributive Effects*, Natural Hazards Research Applications Information Center, Boulder, CO.

Cochrane, H. C., 1997. Economic Impacts of a Midwestern Earthquake, *The Quarterly Publication of NCEER*, **11**(1), 1-5.

Cuaresma, J. C., Hlouskova, J., and Obersteiner, M., 2008. Natural disasters as creative destruction? evidence from developing countries, *Economic Inquiry* **46** (2), 214-226.

Dacy, D. C., and Kunreuther, H. C., 1969. *The Economics of Natural Disasters*. New York: Free Press.

Ellson, R. W., Milliman, J.W., and Blaine Roberts, R., 1984. Measuring the regional economic effects of earthquakes and earthquake predictions, *Journal of Regional Science* **24**(4), 559-579.

Ewing, B. T., Kruse, J. B., and Thompson, M. A., 2005. Empirical examination of the Corpus Christi unemployment rate and Hurricane Bret, *Natural Hazards Review* **6**(4), 191-196.

Grossi, P., del Re, D., and Wang, Z., 2006. *The 1976 Great Tangshan Earthquake: 30-year retrospective*. Risk Management Solutions, Inc. Newark, CA, pp. 1-14.

Guimaraes, P., Helfner, F. L., and Woodward, D. P., 1993. Wealth and income effects of natural disasters: an economic analysis of Hurricane Hugo, *Review of Regional Studies*, **23**(2), 97-114.

Haas, J. E., Kates, R. W., and and Bowden, M. J. (eds.), 1977. *Reconstruction Following Disaster*, MIT Press, Cambridge, MA.

Hallegate, S., and Pruzyluski, V., 2010. The Economics of Natural Disasters, *CESifo Forum* **11**(2), 14-24.

Hallegatte, S., 2008. An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina, *Risk Analysis* **28**(3), 779-799.

Hallegatte, S., Ranger, N., Mestre, O., Dumas, P., Corfee-Morlot, J., Herweijer, C., and Muir-Wood, R., 2011. Assessing climate change impacts, sea level rise and storm surge risk in port cities: a case study on Copenhagen, *Climatic Change* **104** (1), 113-137.

Kates, R. W., Colten, C. E., Laska, S., and Leatherman, S. P., 2006. Reconstruction of New Orleans after Hurricane Katrina: a research perspective, *Proceedings of the National Academy of Sciences* **103** (40), 14653–14660.

McComb, R., Moh, Y. –K., Schiller, A. R., 2011. Measuring long-run economic effects of natural hazard, *Natural Hazards* **58**(1), 559-566.

NCDR (National Commission for Disaster Reduction), and MOST (Ministry of Science and Technology of China), 2008. *Wenchuan earthquake disaster—a comprehensive analysis and evaluation*. Science Press, Beijing.

Noy, I., 2009. The macroeconomic consequences of disasters, *Journal of Development Economics* **88** (2), 221-231.

Okuyama, Y., and Chang, S. E., 2004. *Modeling Spatial and Economic Impacts of Disasters*. Springer, New York.

Okuyama, Y., G. Hewings, J. D., and Sonis, M., 2004. Measuring Economic Impacts of Disasters: Interregional Input-Output Analysis using Sequential Interindustry Model, in: *Modeling the Spatial and Economic Effects of Disasters* (eds.), Y., Okuyama, and S. E., Chang, Springer, New York, pp. 77-101.

Porter, K. A., Kiremidjian, A. S., and LeGrue, J. S., 2001. Assembly-based vulnerability of buildings and its use in performance evaluation, *Earthquake Spectra* **17**(2), 291–312.

Rose, A., and Liao, S. -Y., 2005. Modeling regional economic resilience to disasters: A computable general equilibrium analysis of water service disruptions, *Journal of Regional Science* **45** (1), 75-112.

Rose, A., Benavides, J., Chang, S., Szczesniak, P., and Lim, D., 1997. The regional economic impact of an earthquake: Direct and indirect effects of electricity lifeline disruptions, *Journal of Regional Science* **37** (3), 437-458.

Santos, J. R., and Haimes, Y. Y., 2004. Modeling the demand reduction input–output (I–O) inoperability due to terrorism of interconnected infrastructures, *Risk Analysis* **24** (6), 1437-1451.

Skidmore, M., and Toya, H., 2002. Do Natural Disasters Promote Long-Run Growth?, *Economic Inquiry* **40**(4), 664-687.

Steenge, A. E., and Bočkarjova, M., 2007. Thinking about rigidities and imbalances in post-catastrophe economies; an input–output based proposition, *Economic Systems Research* **19** (2), 205-223.

Strobl, E., 2012. The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions, *Journal of Development Economics* **97**(1), 130-141.

Tatano, H., Tsuchiya, S., 2008. A framework for economic loss estimation due to seismic transportation network disruption: a spatial computable general equilibrium approach, *Natural Hazards* **44** (2), 253-265.

Wu, J., Li, N., Hallegatte, S., Shi, P., Hu, A., and Liu, X., 2012. Regional indirect economic impact evaluation of the 2008 Wenchuan Earthquake, *Environmental Earth Sciences* **65**(1), 161-172.

Xiao, Y., 2011. Local economic impacts of natural disasters, *Journal of Regional Science* **51**(4): 804-820.