The Impact of Disaster Relief on Economic Growth: Evidence from China

Xian Xu and Jiawei Mo
School of Economics, Fudan University, 600 Guoquan Road, Shanghai 200433, China.
E-mail: xianxu@fudan.edu.cn

In this paper we construct a simple two-period equilibrium model for analysing the impact of post-disaster transfer payments on economic growth. This model can be used to show that direct payment of disaster relief funds may aggravate rather than mitigate the negative impact of disasters on the economy. The substitution effect of direct transfer payment depresses post-disaster labour supply and hence economic growth. This conclusion from the theoretical model is tested using Chinese provincial panel data and applying generalised method of moments (GMM) system estimation. The empirical analysis largely confirms the theoretical predictions. In China, post-disaster transfer payments are indeed found to exacerbate the negative impact of disasters on economic growth. Therefore, we suggest that relief should be oriented to create work incentive in order to avoid its depressing effect on economic growth.
The Geneva Papers (2013) **38,** 495–520. doi:10.1057/gpp.2013.15

Introduction and literature review

Natural disasters are one of the most serious external threats to sustainable economic development. On the one hand, they have a high human cost in terms of casualties that affect demand, labour supply and social stability. On the other hand, these economic losses hurt capital stock and subsequent production. China is a country that has experienced some of the most serious natural disasters in recent years, the frequency of which has increased significantly. As a consequence, both the population affected and the economic losses incurred have greatly increased. According to the database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain in Belgium, China experienced the highest frequency of natural disasters during the last decade since 1900, when they were first recorded, accounting for 37 per cent of total occurrences since then.[1] In terms of population affected and economic loss, the share of the last decade is even as high as 50 per cent (see Table 1). Especially after the 2008 earthquake in China's Sichuan province and the 2011 tsunami

---

[1] In China, there are five frequently occurring types of natural disasters, including floods, drought, earthquakes, typhoons and landslides, as well as mudslides and other kinds of disasters.

Table 1 Natural disasters of the past decade in China relative to the period 1900–2012, in per cent

	Occurrences	*Deaths*	*Affected population*	*Direct economic losses*
Drought	25.0	0.0	31.2	28.4
Earthquake	34.1	10.4	76.0	92.2
Flooding	53.0	0.1	35.6	38.8
Landslide	41.8	54.0	96.3	48.5
Local storm	39.0	18.6	19.8	68.7
Tropical cyclone	32.5	1.3	55.8	56.3
Average	37.6	14.1	52.4	55.5

Data include data up to 31 January 2012, 'Past Decade' roughly refers to the period from 2003 to 2012.
Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be—Université catholique de Louvain, Brussels (Belgium). Calculations and categorisation performed by the author.

in Japan, there has been a renewed interest on the part of economists both in China and abroad in studying the impact of natural disasters on economic growth.

Most of the discussion has focused on disaster preparedness and prevention, while post-disaster macroeconomic development has received rather little attention.[2] An early exception is Hirshleifer,[3] who undertook research into post-disaster development in his analysis of Western Europe after the onslaught of the Black Death in the 14th century. Distinguishing between short-term and long-term effects, he noted that the short-term economic impact of the Black Death was in line with economic theory, namely a slowdown of production, changed distribution of income (workers' wages rose, while capitalists' returns fell), and even political disintegration. However, he did not believe the Black Death to be the primary reason for the observed drop in European economic output and was not willing to conclude that natural disasters inevitably lead to economic recession and its consequences for society. Changes in social networks are another important aspect of post-disaster development. Chang[4] argues that community cohesion may have been strengthened by flooding in China, without, however amounting to a full substitute of outside assistance for economic recovery.

Some of the early empirical work applying econometric techniques examined changes in macroeconomic data after the occurrence of a disaster, such as a country's GDP, rate of inflation, balance of payments and general financial situation.[5] More recently, advanced econometric methods have been applied to data of developed countries in an attempt to identify factors that magnify and mitigate, respectively, the effect of natural disasters on economic growth.[6] In fact, some of the authors have found natural disasters to be a source of "creative destruction" promoting economic growth.[7]

In economic theory, there does not yet exist a theoretical framework for modelling the links between natural disasters and economic growth. Attempts at building

[2] Noy (2009).
[3] Hirshleifer (1966).
[4] Chang (2010).
[5] Rasmussen (2004).
[6] Toya and Skidmore (2007) and Noy (2009).
[7] Skidmore and Toya (2002) and Noy and Vu (2010).

a partial model, mainly by Anbarci and Escaleras,[8] revolved around the collective nature of efforts designed to reduce losses due to earthquakes. Hallegatte *et al.*,[9] extending Solow's model,[10] specified a non-equilibrium dynamic model for analysing the macroeconomic impact of severe climate change. Wang[11] built a two-sector endogenous growth model subject to natural disasters, with long-term growth depending mainly on the loss of human rather than physical capital. McDermott[12] and Barry,[13] based on the Solow model once more, introduced credit constraints, pointing out that these reflect the level of development rather than the acceleration or deceleration in economic growth caused by natural disasters.

In sum, it is fair to say that research on the impact of natural disasters on economic growth is still in its infancy, with limited connection to the development literature.

This study seeks to establish this connection, with particular emphasis on disaster relief. It examines whether disaster relief enhances economic growth, thus contributing to a rise in the standard of living, or whether it actually serves to depress labour supply and magnify the negative impact of disasters on the economy. The country to be analysed is China, where post-disaster assistance provided by the central government and by communities in the guise of donations is increasingly becoming the subject of debate. These types of assistance are suspected of being open to corruption and misappropriation of funds due to a lack of governance. Therefore, government relief and community donations may not be the best way to deal with disasters. In keeping with the adage, "Teaching a man to fish, rather than giving him a fish", it might be preferable to create work incentives designed to foster post-disaster activities that contribute to GDP and employment.

The remainder of this paper is organised as follows. The second section contains a simple two-period equilibrium model that includes both post-disaster transfer payments and investments. The third section is devoted to testing the theory using the data from China, while the fourth section offers a summary and conclusions.

Theory

The theoretical model is inspired by the work of Barry[13] and McDermott.[12] In the first period, natural disaster causes a loss both in capital stock and labour supply (due to injuries or casualties). In the second period, consumers in disaster-hit areas receive a one-time transfer payment covering their cost of living during the post-disaster period.[14] The following subsection presents the basics of this model.

---

[8] Anbarci *et al.* (2005).
[9] Hallegatte *et al.* (2007).
[10] Solow (1956).
[11] Wang *et al.* (2008).
[12] McDermott *et al.* (2011).
[13] Barry (1999).
[14] Note that this kind of economic relief aims at consumption compensation. There is another kind of transfer payment, related to government investment, which transfers resources directly to the production sector (such as for infrastructure and to private firms). This so-called investment relief increases employment and compensates the capital loss in the production sector directly, but it also crowds out private

The basic model

Consumers are assumed to maximise a utility function given by

$$\max_{C_1,C_2,L_1,L_2,I} U = [\alpha \ln C_1 + (1-\alpha)\ln(H-L_1)] + B[\alpha \ln(C_2 + Tr) + (1-\alpha)\ln(H-L_2)].$$

The level of utility attained thus depends on consumption C_1 and C_2 in periods 1 and 2 and leisure $(H–L_1)$ and $(H–L_2)$, respectively, where H denotes the time available for work per period while L_1 and L_2 symbolise labour supply. The disaster causes a reduction in H and therefore labour supply, *ceteris paribus*. In the second period, consumers receive transfer payments amounting to Tr. It is important to note that Tr is used for consumption, serving as a perfect substitute for C_2, which is the decision variable of interest. $B < 1$ reflects the rate of time preference. The utility weight of consumption share α satisfies $0 < \alpha < 1$. The inter-temporal budget constraint is therefore:

$$C_1 + RC_2 = F(K_1, L_1) - I + RF(K_1 + I, L_2),$$

where $R < 1$ is the discounting factor.[15] The production function F has capital and labour as its arguments, with K_1 denoting the initial capital stock of the economy and I is the personal investment in the first period. Following Barry,[13] it is assumed that additional new capital must become available in the first period to be productive in the second period. However, depreciation is neglected for simplicity. Investment entails a sacrifice of consumption during the first period, which means saving can be fully transferred to investment. For simplicity once more, we assume that there is no government investment and therefore I can be taken to directly affect the rate of economic growth. Indeed, I will be interpreted as the growth rate, neglecting issues surrounding its (potentially changing) marginal efficiency. Accordingly, the impact of a disaster on economic growth is analysed through its effect on I.[16]

The first-order conditions of this maximisation problem are[17]

$$C_1 = (C_2 + Tr)R/B, \tag{1}$$

$$C_1 = F_{L_1}(H - L_1)\alpha/(1-\alpha), \tag{2}$$

---

investment. The total effect of government investment is uncertain, depending on the response of private investment to government investment. While investment relief constitutes an important aspect of disaster relief, unfortunately, no pertinent data are available, making empirical testing of its impact impossible. Accordingly, there is no government investment in our model. We thank our referees for pointing out the different kinds of disaster relief and the risk of government investment crowding out private investment.

[15] Unlike Barry (1999) and McDermott *et al.* (2011), who also considered the case of an open economy, a closed economy is assumed here because China limits international factor movements. Still, China ties its interest rate to the international capital market, making R an exogenous parameter. Domestically, free movement of factors is assumed.

[16] Generally, economic growth is measured by the growth rate of real output. Solow (1956) shows that capital accumulation is the primary engine for economic growth. In line with Solow, we use investment as an indicator of economic growth, a simplification that is problematic in a world with government investment (which is assumed away in our model). Thanks to an anonymous referee for pointing this out.

[17] For details, see the mathematical appendix B1.

$$C_2 + Tr = F_{L_2}(H - L_2)\alpha/(1 - \alpha), \tag{3}$$

$$RF_{K2} = 1. \tag{4}$$

Equations (1) and (4) represent the inter-temporal efficiency conditions for the consumption and investment decisions, respectively.[18] Eqs. (2) and (3) are the inter-temporal efficiency conditions relating to the relationship between leisure and consumption. F_{Li} and F_{Ki} represent the marginal product of labour and of capital, respectively. Capital stock of each period satisfied $K_2 = K_1 + I$ (Investment).

The market-clearing conditions read,[19]

$$C_1 + I = F(K_1, L_1), \tag{5}$$

$$C_2 = F(K_1 + I, L_2). \tag{6}$$

The impact of disaster relief on post-disaster investment

A natural disaster hitting the economy in the first period has two effects. First, the capital stock is destroyed, that is, $dK_1 < 0$. Second, the potential supply of labour is impaired, due to injuries and casualties or due to the disruption of production processes because workers cannot reach their workplaces or lack important intermediate goods, that is, $dH < 0$. In order to obtain definite results, the production function is assumed to be of the Cobb–Douglas form $(0 < \beta < 1)$ with constant returns to scale and no technological change,[20]

$$F(K, L) = K^\beta L^{1-\beta}. \tag{7}$$

After substitution into (1)–(6), this results in the following expression for optimal second-period labour supply and investment, respectively[21]:

$$L_2 = (\beta R)^{-1/(1-\beta)}(A_1 H - A_2 Tr), \tag{8}$$

$$I = -K_1 + A_1 H - A_2 Tr, \tag{9}$$

where $A_1 = \alpha(1-\beta)(\beta R)^{1/(1-\beta)}/(1-\alpha\beta)$, $A_2 = (1-\alpha)\beta R/(1-\alpha\beta)$.

---

[18] In keeping with Solow, as pointed out by the anonymous referee.

[19] The market-clearing conditions implicitly assume that consumers cannot borrow against second-period production or save for second-period consumption except through investment.

[20] Neglecting technological change is justified in the present context because focus is on the short-term impact of disasters on the economy and its recovery. In the short term, new investment cannot significantly improve technology, while the quality of the workforce does not change.

[21] For details, see the mathematical appendix B2.

Proposition 1: All else equal,

(1) A decline in the initial capital stock is fully compensated by investment, that is, $\partial I/(-\partial K_1)=1$;
(2) A decline in the potential supply of labour depresses investment, that is $\partial I/\partial H=A_1>0$ since $A_1>0$ (note that $0<\alpha\beta<1$);
(3) An increase in transfers depresses investment, that is $\partial I/\partial Tr=-A_2<0$ since $A_2>0$ $(0<\alpha\beta<1)$.

These results are intuitive. Everything else being equal, when (1) the capital stock (K_1) declines while the market interest rate ($1/R$) remains unchanged, the marginal return on investment exceeds the rate of interest. In order to achieve equality again, the loss in K_1 must be fully compensated by extra investment.[22] This is exactly how "creative destruction" works. The occurrence of disaster leads to extra investment, boosting the economy with a higher growth rate. By way of contrast, when (2) there is a drop in labour endowment (H), translating into a drop in actual labour supply (L_2), the marginal productivity of capital falls as well. Equality with the interest rate can only be achieved by reducing investment. Finally, when (3) transfer payments are stepped up, the substitution effect of disaster relief crowds out second-period consumption and discourages work incentive, which by Eq. (8) shows a further reduction in actual labour supply (L_2), making the marginal return of investment go lower and optimal investment go down. Therefore, direct disaster relief has a negative effect on investment.

Up to now, the size of the transfer payment has been independent of disasters. A more realistic assumption is that the amount of transfer payment is positively related to the disaster area's capital loss or labour endowment loss. Linking transfer payment to ΔK_1 (<0) or ΔH (<0) reduces post-disaster investment, as shown by Proposition 2.

Proposition 2: Transfer payments that are designed as a share of loss in capital stock or labour endowment (i.e. $\Delta Tr=-\delta\Delta K_1$ or $\Delta Tr=-\delta\Delta H$, with δ denoting the share of the loss compensated) drive down post-disaster investment (for proof, see Appendix A1).

Disaster relief of this type depresses investment due to its negative effect on work incentives, amounting to "giving a man a fish". However, transfer payments could also be geared to second-period labour supply, encouraging a man to "fish" rather than "receive a fish", as stated in Proposition 3.

Proposition 3: Transfer payments that are designed as a share of second-period labour supply (i.e. $Tr=\delta L_2$) can alleviate the negative effect of disaster relief on investment (for proof, see Appendix A2).

Propositions 2 and 3 can be interpreted as follows. When the economy has been hit by a natural disaster, the way disaster relief is implemented makes a difference. If relief reflects the loss in capital or labour, it runs the risk of depressing post-disaster

---

[22] McDermott *et al.* (2011) consider a closed economy where the decline in K leads to a decline in R, that is, a rise in the market interest rate. This causes post-disaster re-investment to fall somewhat short of the capital loss.

investment. This is because relief payments crowd out private consumption, causing a fall in second-period labour supply that translates into reduced investment. However, if relief is designed to encourage work, it in fact serves to stabilise labour supply to some extent, thus alleviating its negative impact on post-disaster investment.

An empirical test

This section contains an empirical test especially of Proposition 2 in the section "Theory",[23] stating that disaster relief related to the loss of capital and labour depresses investment and impedes post-disaster economic growth. The panel data refer to China, a choice that can be justified on at least two grounds. First, China has been hit by major natural disasters in the recent past (see the first section again). Second, Chinese disaster relief is indeed related to the losses in capital stock or labour. Therefore, the country constitutes an interesting case for testing Proposition 2.

Data

This paper uses panel data of 31 provinces, municipalities and autonomous regions (*PMAs*) in China over the period 2004–2010. Table 2 reports summary statistics for variables used in this study. There are two core variables to be constructed: disaster damages (*DM*) and disaster relief (*Tr*). Control variables are also included.

Indicators of disaster damages
Three reported damage measures of disasters are often used in the related literatures: (1) The number of people affected (*AFF*)[24]; (2) the amount of direct economic loss (*LOSS*)[25]; (3) the number of people killed (*KIL*).[26] Tables 3 and 4 report natural disaster damages in China in terms of year and region, respectively. As can be seen from Table 3, *AFF, LOSS* and *KIL* are relatively stable except for the year 2008, when the earthquake occurred in Sichuan Province. In China, natural disasters such as floods and storms happen almost every year (see Table 5), with the western and central regions suffering most (see Table 4).

---

[23] A full test of Proposition 3 would require an international comparison. However, comparable data from other countries are not available.

[24] They require basics for survival such as food, water, shelter, sanitation and immediate medical assistance. The affected population as defined here refers to the population suffering any type of loss due to natural disasters in the administrative area (including non-residents).

[25] Direct economic losses refer to the product of the share of the population affected times damages suffered relative to provincial GDP. Indirect losses are not considered here. The definition of natural disasters underlying *LOSS* is quite comprehensive. It includes drought, flood, hail, typhoons, earthquakes, extreme freezing and extreme heat, landslides and flows of debris, ground sinks and fissures, pests, disaster-caused diseases, and other natural disasters. For specific statistical methods and explanations, see the 2008 report by the Ministry of Civil Affairs entitled "Natural Disasters in Statistics".

[26] Estimated number of deaths as a direct result of natural disasters (including non-residents).

Table 2   Summary statistics of 31 provinces, regions and autonomous areas (PMAs), 2004–2010

Variables	Description	Source	Obs.	Mean	SD	Min	Max
y^a	Real GDP growth	CSY^h	248	0.128	0.021	0.054	0.238
$AFFP^b$	Per capita times disaster-affected	$CESY^i$	217	0.326	0.222	0.000	1.080
$LOSSP^c$	Economic loss as a share of GDP	$CESY^i$	217	0.021	0.052	0.000	0.689
Tr_Rural^d	Growth of transfer payments to rural residents	CSY^h	216	0.264	0.369	−0.438	3.750
Tr_Urban	Growth of transfer payments to urban residents	CSY^h	217	0.123	0.399	−0.356	5.826
Tr_All^d	Growth of transfer payments to all residents	CSY^h	216	0.126	0.303	−0.240	4.399
$Openness^a$	Total volume of export and import as a share of GDP	CSY^h	248	0.352	0.454	0.037	1.843
$Capital^a$	Gross capital formation as a share of GDP	CSY^h	248	0.551	0.128	0.314	1.114
FDI^a	Foreign direct investment as a share of GDP	CSY^h	248	0.003	0.003	0.000	0.012
$West^e$	Dummy, PMAs in western region	—	217	0.355	0.479	0.000	1.000
$Central^f$	Dummy, PMAs in central region	—	217	0.290	0.455	0.000	1.000
$East^g$	Dummy, PMAs in eastern region	—	217	0.355	0.479	0.000	1.000

[a]Data include the year 2003 for the lagged term in the regression.
[b]The number of affected population divided by total population in the preceding year (which excludes migrant workers who stay less than one year).
[c]The real economic loss due to disasters relative to the GDP in the preceding year.
[d]Data of Xizang autonomous in year 2004 are missing.
[e]Shanxi, Neimenggu, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan (9).
[f]Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang (11).
[g]Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan (11).
[h]China Environmental Statistics Yearbooks 2005–2011, issued by the Ministry of Civil Affairs.
[i]Statistics Yearbook published by 31 provinces, municipalities and autonomous regions (PMAs) in China of various years.

Table 3   Total natural disaster damage in China, 2004–2010

Year	2004	2005	2006	2007	2008	2009	2010	Total
AFF^a (mn persons)	338.6	406.0	434.0	397.3	478.0	479.0	425.2	2958.0
$LOSS^a$ ($bn, RMB)	159.4	203.4	251.8	234.9	1175.2	251.4	530.4	2806.6
KIL^a (person)	2,250	2,473	3,186	2,323	88,928	1,528	6,539	107,227
$AFFP^b$	0.266	0.319	0.321	0.310	0.382	0.351	0.335	0.326
$LOSSP^b$	0.014	0.016	0.016	0.013	0.046	0.011	0.027	0.021
$KILP^b$	0.018	0.021	0.025	0.022	0.367	0.015	0.196	0.095

[a]Total amount.
[b]Simple arithmetic average value.
Source: China Environmental Statistics Yearbooks 2005–2011, issued by the Ministry of Civil Affairs.

In this paper, we use *AFF* and *LOSS* as the measures of damage and construct the indicator as follows.[27] Let *AFFP* be the number of affected population of the province divided by its population in the preceding year, indicating the per capita times affected

---

[27] The number of deaths is not used here because the values are small and frequently zero, causing this indicator to be imprecise. In fact, the number of deaths may be largely underestimated due to the local government's concern for its reputation. In spite of this underestimation, few records of deaths do not mean small losses in labour supply since there are many people who are affected, injured or unable to work.

Table 4 Total natural disaster damage in three regions, 2004–2010

Region	AFF^a (mn persons)	$LOSS^a$ (bn, yuan)	KIL^a (persons)	$AFFP^b$	$LOSSP^b$	$KILP^b$
East[c]	722.2	598.6	3,434	0.200	0.009	0.010
Central[c]	1088.8	770.0	4,269	0.350	0.018	0.014
West[c]	1147.0	1437.9	99,524	0.433	0.034	0.247
Total	2958.0	2806.6	107,227	0.326	0.021	0.095

[a]Total amount.
[b]Simple arithmetic average.
[c]See Table 2 for PMAs in three regions.
Source: China Environmental Statistics Yearbooks 2005–2011, issued by the Ministry of Civil Affairs.

Table 5 Occurrences of major natural disasters in China, 2004–2010

Disasters	2004	2005	2006	2007	2008	2009	2010	Total	LOSS (bn $US)
Earthquake	5	2	6	1	7	2	5	28	86.79
Flood	9	11	20	12	7	7	5	71	35.29
Storm	7	14	8	6	9	10	6	60	26.37
Drought	0	2	1	0	1	2	0	6	6.74
Extreme temperature	1	1	0	0	2	0	0	4	21.10

Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be—Université catholique de Louvain, Brussels (Belgium). Calculations and categorisation performed by the author.

every year.[28] Likewise, let *LOSSP* be the direct economic loss in billions of yuan relative to the GDP of the province in the preceding year, both in real terms. Then, the economic importance of a natural disaster can be measured either by *AFFP* or *LOSSP*.

Indicators of disaster relief
Data on disaster relief paid to victims is currently unavailable. We use the change of transferred income of residents as a proxy. It is constructed as follows.

(1) Transfers to urban residents are excluded. Their main component (60–70 per cent) consists of pensions[29], which have nothing to do with disaster relief. By way of contrast, transfers to rural residents are to a great extent triggered by natural

---

[28] Note that *AFFP* may be greater than one because the population may be suffering from several disasters during the same year. Also, the affected population is divided by population of the preceding rather than the current year to avoid the impact of disaster on the population during the current year. *LOSSP* is constructed similarly. See also Noy (2009).

[29] Transfers to urban residents include retirement pensions, price subsidies, income maintenance, donations, support received from family and friends, income from the sale of property, and other sources such as public welfare. However, pensions have been constituting the major component of over the past few years (Statistical Yearbook of China, 2012, p. 346).
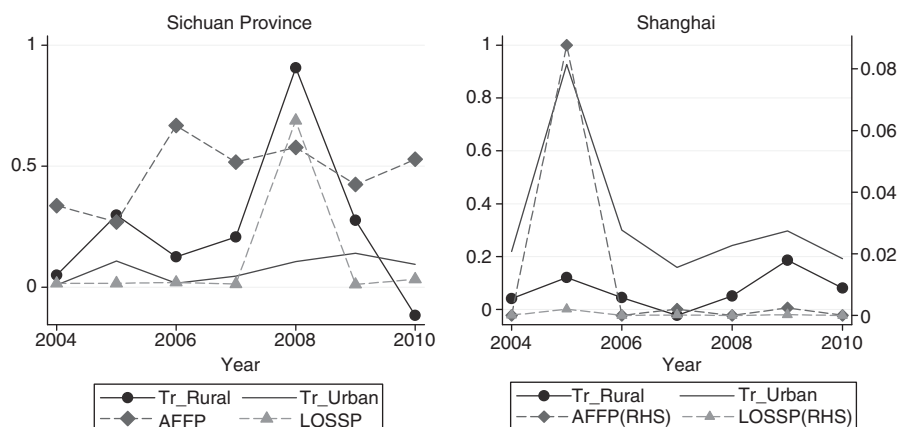
Figure 1. Disaster damage and changes in transfers, Sichuan province and Shanghai.

disasters, and they account for most of rural transferred income and their fluctuations.

(2) Rather than levels, relative changes in transfers are used. In the rural population as well, levels would be dominated by pensions. However, pension income is relatively stable over years. As can be seen from Figure 1, percentage changes are much more likely to reflect the on-off nature of disaster relief.

(3) Relief payments were not recorded separately at the central government level before 2010. Therefore, one is forced to rely on the times series for total transfers paid to residents.[30]

Figure 1 is based on data from Sichuan Province and Shanghai city. The impact of the 2008 earthquake in Sichuan is clearly shown by the line labelled *LOSSP* on the left-hand side of Figure 1. Note that transfers to the urban population do not increase much in the wake of the earthquake, whereas transfers to the rural population exhibit a marked spike. This is consistent with the fact that farmers suffered more than urban citizens in such an agriculture-dominated province. By way of contrast, Shanghai is a city with few farmers and agricultural products. Transfers to urban residents in Shanghai are more sensitive to the impact of the powerful typhoon *Matsa* in 2005 as Figure 1 (RHS) shows. At the national level, however, rural residents are still the main victims of natural disasters to and income transferred to them is much less than urban citizens and more volatile (see Figure 2). This suggests that the relative change in total transfers paid to the rural population could be a more reliable proxy for the unobserved development of payments for disaster relief.

Two additional factors may affect the relative change in transfer payments: regional difference and the growth in agricultural subsidies. Table 6 reports the income transfers to three regions. While payments to eastern residents are almost two times as

---

[30] One could also use the (change in) provincial government expenditure as a proxy of disaster relief. However, this variable proved insignificant.
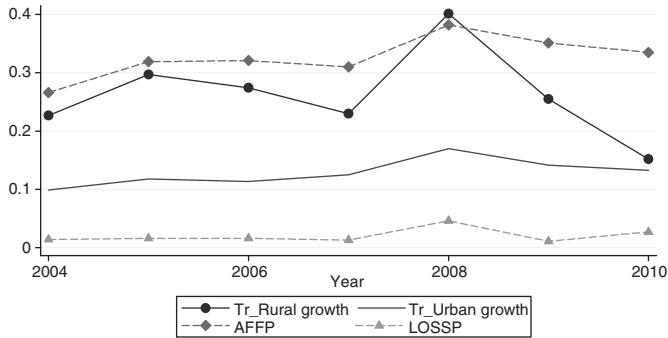
Figure 2. Disaster damage and average (change in) transfers to residents, whole China.

Table 6 Transfer payments to residents of three regions during 2004–2010 (in RMB per capita)

Region	Tr_Rural[a]	Tr_Urban[a]	Tr_Rural growth[a]	Tr_Urban growth[a]
East[b]	441	4,242	0.24	0.12
Central[b]	231	2,870	0.35	0.15
West[b]	213	2,563	0.26	0.13
Total	299	3,248	0.28	0.13

[a]Simple arithmetic average.
[b]See Table 2 for PMAs in three regions.
Source: Statistics Yearbook of various years published by 31 PMAs in China.

large as that of western and central ones, their rate of growth is the highest in the central part, with the western region ranking second.[31] This calls for including regional dummy variables controlling for the increasingly preferential treatment of the central and western regions. Besides, Figure 2 indicates that the average growth rate of payments to rural residents is higher than that of payments to urban citizens, which likely reflects the agricultural subsidy policy started in early 2004. However, the growth in subsidies is relatively stable and can be controlled by adding a time trend in the empirical specification.

Other control variables
Other control variables include *openness*: total volume of exports and imports as a share of GDP; *capital*: gross capital formation as a share of GDP; and *fdi*: foreign direct investment as a share of GDP. These variables are frequently used in the literature on economic growth.[32] The lagged terms of these variables are used in order to avoid simultaneity bias, since disasters may well affect their current values.

[31] This is largely consistent with the disaster damage distribution shown in Table 4.
[32] Hana *et al.* (2010); Noy (2009).

Empirical specification

The empirical model follows Noy[2] by relating real per capita GDP growth to both the damage suffered from natural disasters and the amount of transfers paid for relief,

$$y_{i,t} = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 DM_{i,t} + \beta_3 DM_{i,t} * Tr_{i,t} + \beta_4 Tr_{i,t} + \theta_i + t + \varepsilon_{i,t}. \quad (10)$$

Here, $y(i,t)$ denotes real GDP growth in region i in time t, with provincial GDP measured at constant prices, using the GDP deflator. This dependent variable is regressed on its lagged value $y(i,t-1)$. In this way, region-specific influences that fail to be reflected in the fixed effect $\theta(i)$ are controlled for.[33] Also, recent research into the determinants of short- to medium-term growth suggests that the number of lags does not need to be extended beyond one year in annual data.[34] *DM* (*disaster measure*) is the relative importance of the damage caused by natural disasters as mentioned in the data section. The variable *Tr* is designed to reflect post-disaster transfers, calculated as the relative change in per capita transfers received by rural and urban households, divided by GDP deflator. The meaning of these two core variables is described in the data section above.

The interaction term $DM \times Tr$ is crucial for testing Proposition 2 because according to it, a given damage *DM* can have a different effect on economic growth depending on the extent to which transfers are paid (which are reflecting the loss in capital stock or loss in labour supply in the case of China). Here, the specification again follows Noy[2] and McDermott.[12]

Finally, $\theta(i)$ represents the fixed effect pertaining to province i. Of course, there is no guarantee that unmeasured factors influencing $\theta(i)$ do not influence $\varepsilon(it)$, the random error, as well. However, this risk is reduced by the inclusion of the lagged dependent variable, which picks up those unmeasured factors that are time-varying. t is the time trend as mentioned in data description section, controlling the time trend effect.

The coefficient β_2 pertaining to *AFFP* is expected to have a negative sign since natural disasters hurt labour supply, but it might also have a positive sign, being positively related to *LOSSP* to the extent that post-disaster investment might fully make up for the loss in capital. However, according to Proposition 2, the sign of β_3 should always be negative since transfers designed according to the loss in capital or labour are predicted to hamper economic growth more strongly when they increase in step with the size of the damage.

Estimation methodology

In view of the endogeneity introduced by the lagged dependent variable, Blundell-Bonds GMM estimation is applied. Blundell and Bond[35] combine Arellano and Bond's[36] difference GMM estimator with Arellano and Bover's[37] level GMM estimator. This

---

[33] Islam (1995).
[34] See, for example, Raddatz (2007).
[35] Blundell and Bond (1998).
[36] Arellano and Bond (1991).
[37] Arellano and Bover (1995).

Table 7 Economic growth and share of population affected, system GMM estimator

Regressors	(1)	(2)	(3)	(4)
	No Tr	Rural	Urban	All
Dependent variable (y): Real GDP growth				
y(t−1)	0.3955***	0.4443***	0.3996***	0.4057***
	(5.1)	(5.5)	(5.1)	(5.2)
AFFP	−0.0343***	−0.0124	−0.0318***	−0.0292***
	(−6.4)	(−1.3)	(−6.1)	(−5.0)
AFFP_Tr_Rural		−0.0685***		
		(−3.4)		
Tr_Rural		0.0063		
		(1.2)		
AFFP_Tr_Urban			−0.0371*	
			(−1.8)	
Tr_Urban			0.0019*	
			(1.9)	
AFFP_Tr_All				−0.0644**
				(−2.6)
Tr_All				0.0023***
				(3.1)
Time Trend	−0.0006	−0.0006	−0.0004	−0.0004
	(−0.8)	(−0.8)	(−0.6)	(−0.5)
Constant	0.0925***	0.0832***	0.0917***	0.0908***
	(11.4)	(9.2)	(11.2)	(10.9)
Observations	217	216	217	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5 and 10 per cent level in the system GMM regression, respectively.

approach significantly improves the efficiency of the two previous ones; however, it requires the lagged dependent variables after differentiation $\{\Delta y_i, t-1, \Delta y_i, t-2, \dots\}$ to be uncorrelated with the random error term u_i[38](pp. 179−181). However, Herzer *et al.*[39] point out that the GMM approach needs strong assumptions for consistent estimates and the weak instruments may bias coefficient estimates. Therefore, fixed effects regression is also employed as a check of robustness.[40] Robust standard errors are given in all the following regression reports in order to account for heteroscedasticity. The software used is STATA 10.0.

Regression results

Tables 7 and 8 relate real per capita income growth to the population affected and to direct economic losses incurred, respectively. Starting with Table 7, it may be noted that the coefficients of the lagged dependent variable have (highly significant) values

[38] Chen (2010).
[39] Herzer *et al.* (2012).
[40] Thanks to the anonymous referee for pointing this out.

Table 8 Economic growth and losses as a share of GDP, system GMM estimator

Regressors	(1)	(2)	(3)	(4)
	No Tr	*Rural*	*Urban*	*All*
Dependent variable (y): Real GDP growth				
$y(t-1)$	0.3091***	0.3163***	0.3260***	0.3320***
	(4.0)	(4.4)	(4.3)	(4.5)
LOSSP	−0.0755***	0.1669*	−0.0040	0.0614
	(−3.6)	(1.8)	(−0.1)	(0.6)
LOSSP_Tr_Rural		−0.2923***		
		(−2.7)		
Tr_Rural		−0.0023		
		(−0.5)		
LOSSP_Tr_Urban			−0.7314	
			(−1.4)	
Tr_Urban			0.0051*	
			(1.9)	
LOSSP_Tr_All				−0.9688
				(−1.4)
Tr_All				0.0060*
				(1.7)
Time Trend	−0.0009	−0.0013	−0.0008	−0.0009
	(−1.2)	(−1.5)	(−1.1)	(−1.1)
Constant	0.0953***	0.0936***	0.0921***	0.0908***
	(11.9)	(11.8)	(11.4)	(11.4)
Observations	217	216	217	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5 and 10 per cent level in the system GMM regression, respectively.

between 0.39 and 0.44. After a shock, it therefore takes only between 1.64 and 1.79 years on average for a province to return to its long-term growth rate.

The four columns of Table 7 refer to different specifications. Column (1) abstracts from transfer incomes. The coefficient for *AFFP* says that a high share of population affected by natural disasters is strongly associated with a slower growth of real per capita GDP. An average disaster event (*AFFP*=0.33) would reduce growth contemporaneously by approximately 1.12 (=3.4 × 0.33) percentage points.

Column (2) introduces the two variables related to transfer, *Tr_Rural* and *AFFP*Tr_Rural*. While the (change in) transfers to rural households per se does not seem to have an impact on economic growth, the fact that it is geared to *AFFP*, the population affected, is seen to depress economic growth significantly, to the tune of some 6.85 percentage points per percentage point (change in) transfers, holding *AFFP* constant. This implies that at the mean values of about 0.33 for *AFFP* and 0.26 for *Tr_Rural* (see Table 2), disaster transfers to rural households are responsible for roughly 0.59 (=6.85 × 0.33 × 0.26) percentage points of growth loss. This does not seem much compared with the average growth rate of 12.8 per cent p.a.; however, there must be at least one instance where *AFFP* has reached its maximum value of 1.08 and *Tr_Rural*, its maximum value of 3.75 (both values reflecting the fact that a

province can be hit by more than one disaster during a given year), while minimum average growth was as low as 5.4 per cent p.a. While this combination of values presumably does not apply to a single province, it does indicate that the effect of transfers on growth may be substantial in some cases.

In column (3) of Table 7, a test is performed by applying the specification of column (2) to the urban population. Since transfers paid to urban households are less sensitive to natural disasters (see the section "Data" above), the expectation is that they do not affect provincial economic growth significantly. This expectation is borne out in that *AFFP* is negatively related to growth as before, but the interaction variable $AFFP \times Tr\_Urban$ is only significant at the 10 per cent level.

Finally, another specification test is performed in column (4) by using the (change in) total transfers as an explanatory variable. It is reassuring to see that while the other coefficients (among them, also the one pertaining to *AFFP*) are little affected, both *Tr_All* and *AFFP*Tr_All* are significant. In a less detailed analysis, one might have been tempted to conclude from the positive and significant coefficient of *Tr_All* that transfers possibly affect economic growth favourably. This shows the importance of distinguishing between relief payments going to rural and urban households when trying to discern their effects on economic growth. In sum, Table 7 provides clear empirical support for Proposition 2.

In Table 8, the same four specifications are displayed, but with *AFFP* replaced by the economic losses relative to *GDP*, *LOSSP*. It is gratifying to note that the coefficient of the lagged dependent variable implies an average adjustment period of 1.5 years, much the same as the values of Table 7.

Starting with specification (1), one recognises a (highly significant) negative effect of *LOSSP* on economic growth, amounting to an estimated 7.55 percentage points. To illustrate, let a province be hit by a disaster whose economic loss is the average of 2 per cent of its GDP (see Table 2). *Ceteris paribus*, one would predict its growth rate to drop by almost 0.15 ($=7.55 \times 0.02$) percentage points. However, this estimate likely is on the high side because it is not replicated by the other specifications, where *LOSSP* never comes close to statistical significance.

Specification (2) again introduces an interaction term in the guise of $LOSSP \times Tr\_Rural$. Similar to the *AFFP* regression, the interaction term is negative and highly significant. More interestingly, the impact of *LOSSP* on growth turns out to be positive, though not quite significant. This might be consistent with the prediction of Proposition 1 that investment would increase after a disaster to compensate the loss of capital, boosting the economic growth. For an interpretation, let the growth of transferred income of rural household be the mean value of 0.26. A province with economic loss of 2 per cent of its GDP would tend to exhibit an increase in economic growth of 0.18 ($=16.7 \times 0.02 - 29.2 \times 0.02 \times 0.26$) percentage points. However, the change in transfer payments still has a negative effect on growth by reducing the compensating investment.

Specification (3) in Table 8 again relates economic growth to the (change in) transfers paid to the urban population. As one would expect in view of the nature of these transfers (mainly pensions), these transfers do not contribute to economic growth, and there is no indication either of the interaction term $LOSSP \times Tr\_Urban$ playing a role.

Column (4) of Table 8 contains a final specification check by again introducing the (change in) total transfers. The fact that $LOSSP \times Tr\_All$ falls far short of statistical significance provides indirect corroborating evidence for the discussion in the section "Data", which puts exclusive emphasis on the transfers paid to rural households.

The results displayed in Tables 7 and 8 may be summed up in two statements. First, the greater the share of the population affected by (and not necessarily the greater the economic loss suffered from) a natural disaster, the more important is the drop in the growth rates of Chinese provinces, *ceteris paribus*. Second, the faster the transfer payments increase as a signal of receiving disaster relief, the more they tend to stifle economic growth, likely through their depressing effect on the supply of labour and hence post-disaster investment.

Robustness checks

In this section, we present a range of robustness checks on the findings relating to the depressing effect of (the change in) transfer payments to rural residents.[41] The findings suggest that the results reported in the previous section are quite robust to various changes in specification.

The disturbance of the year 2008

One concern with our results might be the potential disturbance of the year 2008, with its coincidence of the subprime mortgage crisis as well as the earthquake in Sichuan province. For this effect, we repeat the analysis by including a dummy for the year 2008 in Table 9 and excluding observations of this year in Table 10. The 2008 dummy variable in Table 9 is highly significant, suggesting that the subprime mortgage crisis led to a reduction by almost two percentage points in the growth rates of Chinese provinces. The coefficients of the interaction terms in the two tables are negative and significant in most cases. While the coefficients in Table 9 differ somewhat from the basic regressions, the estimation without the observations pertaining to the year 2008 is still consistent with the benchmark specification.

Including control variables

In Table 11 we present regression results including three growth-related factors as mentioned above. In addition, in order to control for the regional policy effects of transfer payments as discussed in the section "Data", the variable *Tr_Rural* is interacted with the dummy for the western and central regions. As can be seen from Table 11, the coefficients of *DM* and $DM \times Tr\_Rural$ are still consistent with the basic results. Note that the coefficients of *openness*, the share of total amount of imports plus exports in GDP, are negative and significant, which is quite counter-intuitive at first sight. However, a possible explanation is that in a first-order dynamic regression, reversion in a time series cannot be modelled directly. The variable *openness* might

---

[41] Regressions including Tr_Urban and DM × Tr_Urban have also been tried. Both variables remained insignificant in all of the following robustness checks.

Table 9 Economic growth and disaster relief, including dummy for the year 2008

Regressors	AFFP			LOSSP		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable (y): Real GDP growth						
$y(t-1)$	0.6180***	0.6230***	0.6996***	0.5616***	0.5541***	0.6030***
	(7.1)	(7.4)	(9.8)	(7.1)	(8.0)	(12.1)
DM	−0.0277***	−0.0173**	−0.0224***	−0.0455*	0.1465	0.1783*
	(−4.7)	(−2.0)	(−2.7)	(−1.9)	(1.1)	(1.8)
Dummy 2008	−0.0197***	−0.0178***	−0.0192***	−0.0192***	−0.0198***	−0.0199***
	(−4.2)	(−4.1)	(−4.9)	(−4.5)	(−4.4)	(−4.9)
DM × Tr_Rural		−0.0313*	−0.0256		−0.2343	−0.2697**
		(−1.9)	(−1.4)		(−1.5)	(−2.5)
Tr_Rural		0.0010	0.0027		0.0036	0.0026
		(0.2)	(0.6)		(0.9)	(0.7)
Trend			0.0004			−0.0002
			(0.8)			(−0.3)
Constant	0.0626***	0.0607***	0.0503***	0.0616***	0.0598***	0.0539***
	(5.7)	(5.9)	(5.5)	(6.2)	(6.8)	(8.7)
Observations	217	216	216	217	216	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5and 10 per cent level in the system GMM regression, respectively.

Table 10 Economic growth and disaster relief, with the year 2008 excluded

Regressors	AFFP			LOSSP		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable (y): Real GDP growth						
$y(t-1)$	0.3642***	0.4734***	0.5029***	0.3193***	0.4029***	0.4207***
	(3.5)	(5.3)	(5.8)	(3.2)	(5.3)	(7.0)
DM	−0.0250***	−0.0304***	−0.0083	−0.0714**	−0.0820**	0.2213*
	(−4.3)	(−5.9)	(−1.0)	(−2.0)	(−2.4)	(2.0)
Time trend		0.0024***	0.0019**		0.0020**	0.0014
		(2.8)	(2.0)		(2.3)	(1.4)
DM × Tr_Rural			−0.0716***			−0.3716***
			(−3.6)			(−2.6)
Tr_Rural			0.0096			0.0032
			(1.2)			(0.7)
Constant	0.0935***	0.0727***	0.0666***	0.0923***	0.0742***	0.0702***
	(7.7)	(6.4)	(6.0)	(7.8)	(8.6)	(9.3)
Observations	186	186	185	186	186	185

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5 and 10 per cent level in the system GMM regression, respectively.

pick up this effect, since imports and exports typically decrease in the wake of a natural disaster which boosts transportation costs. This might be reasonable since we are running the regression in a dynamic structure and on the lagged term of *openness*,

Table 11 Economic growth and disaster relief including control variables, system GMM estimator

Regressors	AFFP		LOSSP	
	(1)	*(2)*	*(3)*	*(4)*
Dependent variable (y): Real GDP growth				
$y(t-1)$	0.3076***	0.3577***	0.2196***	0.2243***
	(4.0)	(4.3)	(3.1)	(3.2)
DM	−0.0339***	−0.0106	−0.0777***	0.1439*
	(−6.8)	(−1.2)	(−4.3)	(1.7)
DM × Tr_Rural		−0.0711***		−0.2651***
		(−3.7)		(−2.7)
Tr_Rural		−0.0048		−0.0146
		(−0.7)		(−1.6)
Tr_Rural × West		0.0136*		0.0149
		(2.0)		(1.5)
Tr_Rural × Central		0.0186**		0.0165
		(2.4)		(1.6)
Openness $(t-1)$	−0.0235**	−0.0197**	−0.0257**	−0.0246**
	(−2.2)	(−2.0)	(−2.4)	(−2.4)
Capital $(t-1)$	0.0637*	0.0604*	0.0695*	0.0582
	(1.8)	(1.7)	(1.9)	(1.6)
FDI $(t-1)$	−2.5638	−1.6298	−1.7418	0.3558
	(−1.6)	(−1.1)	(−1.6)	(0.3)
Time trend	−0.0013	−0.0013	−0.0019	−0.0023*
	(−1.0)	(−1.0)	(−1.5)	(−1.9)
Constant	0.0887***	0.0761***	0.0879***	0.0863***
	(6.5)	(5.0)	(6.0)	(5.8)
Observations	217	216	217	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5 and 10 per cent level in the system GMM regression, respectively.

the negative sign might indicate the reversion behaviour in the time series. For the regional effect, the coefficients of *Tr_Rural × West* and *Tr_Rural × Central* imply that transfer payments to rural residents in the central and western regions are relatively higher than those going to the eastern part.

Fixed effects regression

One might argue that the GMM approach could bias the estimation, since the instruments used might be weak while the assumptions for consistency are strong. In an attempt at avoiding these potential weaknesses of GMM estimation, we also present regression results using fixed effects regression (see Table 12). The lagged dependent variable is excluded to avoid an endogeneity problem. As can be seen from Table 12, the coefficients of the interaction term *DM × Tr_Rural* remain negative and significant. Most of the estimates are consistent with Table 11. Note that the effect of *Tr_Rural* on growth now becomes negative and significant, supporting the prediction of Proposition 1 that direct disaster relief has a negative impact on economic growth. However, the fixed effect model might fail to control for the time-variant

Table 12 Economic growth and disaster relief, fixed effects estimator

Regressors	AFFP			LOSSP		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable (y): Real GDP growth						
DM	−0.0148**	−0.0067	−0.0050	−0.0397*	0.1248*	0.1691***
	(−2.0)	(−0.8)	(−0.6)	(−1.8)	(1.8)	(2.9)
DM × Tr_Rural		−0.0317**	−0.0318*		−0.2167***	−0.2616***
		(−2.0)	(−2.0)		(−−2.8)	(−4.0)
Tr_Rural		−0.0150*	−0.0148*		−0.0187**	−0.0193**
		(−1.7)	(−1.8)		(−2.0)	(−2.4)
Tr_Rural × West		0.0203**	0.0202**		0.0253**	0.0264***
		(2.0)	(2.2)		(2.4)	(2.9)
Tr_Rural × Central		0.0195**	0.0210**		0.0209**	0.0239***
		(2.0)	(2.5)		(2.1)	(2.8)
Capital ($t-1$)	0.0512***		0.0471**	0.0500***		0.0415**
	(3.0)		(2.5)	(2.8)		(2.1)
Openness ($t-1$)	−0.0125		−0.0066	−0.0145		−0.0096
	(−1.3)		(−0.6)	(−1.6)		(−0.9)
FDI ($t-1$)	1.1049		1.6148	1.1478		2.6080**
	(1.0)		(1.4)	(1.0)		(2.1)
Time trend	−0.0013*	−0.0002	−0.0013*	−0.0014**	−0.0004	−0.0017***
	(−1.9)	(−0.3)	(−1.9)	(−2.1)	(−0.8)	(−2.7)
Constant	0.1126***	0.1348***	0.1104***	0.1102***	0.1306***	0.1076***
	(13.6)	(39.5)	(11.6)	(13.4)	(48.4)	(11.4)
Observations	217	216	216	217	216	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5and 10 per cent level in the fixed effect regression, respectively.

region-specific influences as mentioned previously, and it might not be the appropriate methodology for empirical analysis in a dynamic structure.[33]

Binary measure of disaster relief
In Table 13 we present the regression results using a binary measure of disaster relief (=1 if *Tr_Rural* > 0.264, the mean value).[42] As can be seen from Table 13, the major results reported previously are still robust. In columns (1) and (2) , the negative and significant coefficients of interaction term suggest that, for those provinces with *Tr_Rural* above mean value, the change in transfer payments aggravate the negative impact of *AFFP* by 1.36 percentage points. More interestingly, results in columns (3) and (4) indicate that *LOSSP* has a positive effect on economic growth only when provinces have a slower growth in *Tr_Rural*. For those provinces with *Tr_Rural* above average, *LOSSP* seems to hurt the economy by 9.41(=21.54–12.13) percentage points per one unit increase of *LOSSP*.

---

[42] Among those provinces with Tr_Rural > 0.264, there are 7 in 2004, 14 in 2005 and 2006, 8 in 2007, 20 in 2008, 14 in 2009 and 2 in 2010. The total number is 79 out of 217.

Table 13 Binary measure of disaster relief, system GMM estimator

Regressors	AFFP		LOSSP	
	(1)	*(2)*	*(3)*	*(4)*
Dependent variable (y): Real GDP growth				
$y(t-1)$	0.4420***	0.3525***	0.3414***	0.2576***
	(5.3)	(4.0)	(4.2)	(3.3)
DM	−0.0256***	−0.0263***	0.1560*	0.1213
	(−3.6)	(−4.1)	(1.8)	(1.5)
DM × Tr_Rural_Dummy	−0.0170***	−0.0136**	−0.2558***	−0.2154***
	(−2.6)	(−2.6)	(−2.9)	(−2.6)
Tr_Rural	−0.0164*	−0.0087	−0.0200*	−0.0146
	(−1.7)	(−1.1)	(−1.7)	(−1.6)
Tr_Rural × West	0.0099	0.0038	0.0209*	0.0161*
	(0.9)	(0.4)	(1.8)	(1.7)
Tr_Rural × Central	0.0174*	0.0085	0.0192*	0.0127
	(1.8)	(1.0)	(1.7)	(1.3)
Time trend	−0.0005	−0.0013	−0.0011	−0.0022*
	(−0.6)	(−1.0)	(−1.4)	(−1.9)
Openness $(t-1)$		−0.0233**		−0.0260**
		(−2.3)		(−2.5)
Capital $(t-1)$		0.0544		0.0533
		(1.6)		(1.5)
FDI $(t-1)$		−1.5129		0.6362
		(−1.0)		(0.5)
Constant	0.0871***	0.0848***	0.0910***	0.0846***
	(8.9)	(6.0)	(9.6)	(5.8)
Observations	216	216	216	216

Figures in parentheses are *t*-values based on robust standard errors.
***, **,* indicate significance at 1, 5 and 10 per cent level in the system GMM regression, respectively.

Conclusion

The objective of this paper is to assess the impact of public relief on economic growth. A simple two-period model predicts that the substitution effect of disaster relief depresses labour supply, hampering post-disaster investment and hence economic growth. This prediction, formulated as Proposition 2, is tested using observations covering the 31 provinces and independent municipalities of China during 2004–2010. China provides an interesting test case because disaster relief is indeed paid according to the amount of disaster damage; moreover, it is reflected much more in the change in rural incomes than urban households, where pensions constitute the main component of public transfers.

The econometric inference combines level and change GMM estimation to deal with both endogeneity and heteroscedasticity. It produces a good deal of support for Proposition 2. First, disaster relief aggravates the negative impact of disaster damage measured by the population affected. Second, disaster relief impedes the possibly positive effect of disaster damage measured by direct economic losses.

These findings lend support to the policy advice based on Proposition 3 of Section "The Impact of Disaster Relief on Post-Disaster Investment". It predicts that if

transfers are conditioned on post-disaster labour supply rather than the loss of capital or labour endowment, the substitution effect of transfers can be alleviated by strengthening work incentives. One could cite the Chinese proverb, "If you give a man a fish, he will not go hungry for one day; if you teach him to fish, he will never go hungry again". It appeals to the same logic as "food for work" in public welfare programmes. Public relief for disaster-stricken areas might take the form of investment in infrastructure and projects designed to prevent future disasters, both creating local employment. However, it could also take the form of assistance for finding employment in other areas of the country, not least by improving labour productivity through additional schooling and vocational training. In all, encouraging post-disaster labour supply is an important concern since it avoids the depressing effect of direct transfer payments.

Of course, this advice is based on an analysis that has its limitations. For one, the theoretical model may be too simplistic by neglecting problems of governance in the allocation of transfer relief. The fact that direct government assistance is often subject to corruption and the misappropriation of funds is an important aspect of the negative impact of transfer relief, which is not included in our model.[43] Second, the empirical evidence refers to China and may apply to other countries only with major modifications. Third, empirical testing has been hampered by data availability, the fact that the time series are fairly short, and disaster transfers were not measured directly. However, this work may still provide some preliminary insights into the adverse side effects of disaster relief and help redirect government intervention towards enhancing post-disaster labour supply.

Acknowledgements

References

Anbarci, N., Escaleras, M. and Register, C.A. (2005) 'Earthquake fatalities: The interaction of nature and political economy', *Journal of Public Economics* 89(9–10): 1907–1933.

Arellano, M. and Bond, S. (1991) 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations', *The Review of Economic Studies* 58(2): 277–297.

Arellano, M. and Bover, O. (1995) 'Another look at the instrumental variable estimation of error-components models', *Journal of Econometrics* 68(1): 29–51.

Barry, F. (1999) 'Government consumption and private investment in closed and open economies', *Journal of Macroeconomics* 21(1): 93–106.

Blundell, R. and Bond, S. (1998) 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics* 87(1): 115–143.

---

[43] Thanks to the referee for pointing this out.

Chang, K. (2010) 'Community cohesion after a natural disaster: Insights from a Carlisle flood', *Disasters* 34(2): 289–302.

Chen, Q. (2010) *Advanced Econometrics and the application of STATA*, Beijing: Higher Education Press, pp. 179–181.

Hallegatte, S., Hourcade, J-C. and Dumas, P. (2007) 'Why economic dynamics matter in assessing climate change damages: Illustration on extreme events', *Ecological Economics* 62(2): 330–340.

Han, L., Li, D., Moshirian, F. and Tian, Y. (2010) 'Insurance development and economic growth', *The Geneva Papers on Risk and Insurance—Issues and Practice* 35(2): 183–199.

Herzer, D., Strulik, H. and Vollmer, S. (2012) 'The long-run determinants of fertility: One century of demographic change 1900–1999', *Journal of Economic Growth* 17(4): 357–385.

Hirshleifer, J. (1966) 'Disaster and recovery: The Black Death in Western Europe', RAND Corporation Memorandum RM-4700-TAB, pp. 1–31.

Islam, N. (1995) 'Growth empirics: A panel data approach', *The Quarterly Journal of Economics* 110(4): 1127–1170.

McDermott, T., Barry, F. and Tol, R. (2011) *Disasters and development: Natural disasters, credit constraints and economic growth*, ESRI Working Paper No 411.

National Bureau of Statistics of China (2012) *China Statistical Yearbook 2012*, Beijing: China Statistics Press.

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

Noy, I. and Vu, T.B. (2010) 'The economics of natural disasters in a developing country: The case of Vietnam', *Journal of Asian Economics* 21(4): 345–354.

Raddatz, C. (2007) 'Are external shocks responsible for the instability of output in low-income countries?' *Journal of Development Economics* 84(1): 155–187.

Rasmussen, T. (2004) *Macroeconomic implications of natural disasters in the Caribbean*, IMF Working Paper No. 04/224.

Skidmore, M. and Toya, H. (2002) 'Do natural disasters promote long-run growth?' *Economic Inquiry* 40(4): 664–687.

Solow, R.M. (1956) 'A contribution to the theory of economic growth', *The Quarterly Journal of Economics* 70(1): 65–94.

Toya, H. and Skidmore, M. (2007) 'Economic development and the impacts of natural disasters', *Economics Letters* 94(1): 20–25.

Wang, Y., Chen, M. and Wang, X. (2008) 'The impact of natural disasters on long-term economic growth', *Economics and Management* 30(19): 144–150.

Appendix A

A1. Proof of Proposition 2

Proof: Given $\Delta Tr = -\delta \Delta K_1$, Eq. (9) shows that $\Delta I = -(1-\delta A_2)\,\Delta K_1 + A_1 \Delta H$. Then we have $\partial I/(-\partial K_1) = 1 - \delta A_2 < 1$. Post-disaster investment now does not fully compensate the loss in capital anymore. Similarly, when $\Delta Tr = -\delta \Delta H$, the change of investment is now $\Delta I = -\Delta K_1 + (A_1 + \delta A_2)\Delta H$. Then $\partial I/\partial H = (A_1 + \delta A_2) > A_1$. Investment is now decreasing further. The reason is that one who suffers more is expected to receive larger transfer payments, and has less incentive to work in the second period. When labour supply declines, investment declines as well. In this case, direct disaster relief hinders post-disaster capital replacement and exaggerates the negative effect of labour loss. □

A2. Proof of Proposition 3

Proof: Since L_2 is an endogenous variable determined by the consumer, the first-order condition will be changed given that $Tr=\delta L_2$. The trade-off between second-period consumption and leisure is given by:

$$C_2 + Tr = (\delta + F_{L_2})(H - L_2)\alpha/(1 - \alpha).$$

Using the Cobb-Douglas production function in Eq. (7), we can solve for the optimal investment in this case:

$$I = -K_1 + \frac{A_1 + [\alpha\delta\beta R/1 - \alpha\beta]}{1 + [\delta A_1/(R\beta(1 - \beta))]} H - \frac{A_2}{1 + [\delta A_1/(R\beta(1 - \beta))]} Tr. \qquad \text{(A1)}$$

Then the marginal effect of Tr on investment can be easily obtained as follows[44]:

$$\frac{\partial I}{(-\partial Tr)} = \frac{A_2}{1 + [\delta A_1/(R\beta(1 - \beta))]} < A_2. \qquad \text{(A2)}$$

Equation (A.2) shows that, given $Tr=\delta L_2$, the depressing effect of transfer payments on investment is now smaller. This is intuitive because the return of working now becomes higher with an extra income of transfer payments. $\square$

Appendix B

B1. The solution to Eqs. (1)–(4)

First, solve the following maximisation problem:

$$\max_{C_1,C_2,L_1,L_2,I} U = [\alpha \ln C_1 + (1 - \alpha) \ln(H - L_1)] + B[\alpha \ln(C_2 + Tr) + (1 - \alpha) \ln(H - L_2)]$$

s.t.

$$C_1 + RC_2 = F(K_1, L_1) - I + RF(K_1 + I, L_2).$$

Create a LaGrange function:

$$L = [\alpha \ln C_1 + (1 - \alpha) \ln(H - L_1)] + B[\alpha \ln(C_2 + Tr) + (1 - \alpha) \ln(H - L_2)]$$
$$+ \lambda[F(K_1, L_1) - I + RF(K_1 + I, L_2) - C_1 - RC_2]$$

---

[44] For details, please refer to Appendix B3.

F.O.C

$$\frac{\partial L}{\partial C_1} = \frac{\alpha}{C_1} - \lambda = 0,$$

$$\frac{\partial L}{\partial C_2} = \frac{\alpha B}{C_2 + Tr} - \lambda R = 0,$$

$$\frac{\partial L}{\partial L_1} = -\frac{1 - \alpha}{H - L_1} + \lambda F_{L1} = 0,$$

$$\frac{\partial L}{\partial L_2} = -\frac{(1 - \alpha)B}{H - L_2} + \lambda R F_{L2} = 0,$$

$$\frac{\partial L}{\partial I} = -1 + R F_{K2} = 0.$$

By solving the above-mentioned five first-order conditions the four equations (1)–(4) can be made available.

B2. Derivation of Eq. (9)

Eq. (6) substituted into Eq. (3) eliminates C2, and once that is substituted into the C–D production function (7) we get:

$$(K_1 + I)^{\beta} L_2^{1-\beta} + Tr = \frac{\alpha}{1 - \alpha}(1 - \beta)\left(\frac{K_1 + I}{L_2}\right)^{\beta}(H - L_2).$$

C–D function (7) substituted into Eq. (4) makes:

$$\beta R\left(\frac{L_2}{K_1 + I}\right)^{1-\beta} = 1.$$

Simultaneously the above two equations create:

$$L_2 = \frac{\alpha(1 - \beta)}{1 - \alpha\beta}H - \frac{1 - \alpha}{(1 - \alpha\beta)(\beta R)^{\beta/(1-\beta)}}Tr.$$

Substituting into the investment conditions (4) gives:

$$I = -K_1 + \frac{\alpha(1 - \beta)(\beta R)^{1/(1-\beta)}}{1 - \alpha\beta}H - \frac{(1 - \alpha)\beta R}{1 - \alpha\beta}Tr.$$

B3. The solution to Eqs. (11)–(12)

First, solve the following maximisation problem:

$$\max_{C_1,C_2,L_1,L_2,I} U =[\alpha \ln C_1 + (1 - \alpha) \ln(H - L_1)]+B[\alpha \ln(C_2 + Tr(L_2)) + (1 - \alpha) \ln(H - L_2)]$$

s.t.

$$C_1 + RC_2 = F(K_1, L_1) - I + RF(K_1 + I, L_2)$$

$$Tr(L_2) = \delta L_2.$$

Create a LaGrange function:

$$L =[\alpha \ln C_1 + (1 - \alpha) \ln(H - L_1)]+B[\alpha \ln(C_2 + Tr(L_2)) + (1 - \alpha) \ln(H - L_2)]$$
$$+\lambda[F(K_1, L_1) - I + RF(K_1 + I, L_2) - C_1 - RC_2]$$

F.O.C

$$\frac{\partial L}{\partial C_1} = \frac{\alpha}{C_1} - \lambda = 0,$$

$$\frac{\partial L}{\partial C_2} = \frac{\alpha B}{C_2 + Tr} - \lambda R = 0,$$

$$\frac{\partial L}{\partial L_1} = -\frac{1 - \alpha}{H - L_1} + \lambda F_{L1} = 0,$$

$$\frac{\partial L}{\partial L_2} = \frac{\alpha B\delta}{C_2 + Tr} - \frac{(1 - \alpha)B}{H - L_2} + \lambda RF_{L2} = 0,$$

$$\frac{\partial L}{\partial I} = -1 + RF_{K2} = 0.$$

C-D function (7) substituted into above equations makes:

$$(K_1 + I)^\beta L_2^{1-\beta} + Tr = \left[\delta + (1 - \beta)\left(\frac{K_1 + I}{L_2}\right)^\beta\right](H - L_2)\frac{\alpha}{1 - \alpha}.$$

Combining with

$$\beta R\left(\frac{L_2}{K_1 + I}\right)^{1-\beta} = 1.$$

We have

$$L_2 = \frac{\delta + (1-\beta)(\beta R)^{\frac{\beta}{1-\beta}}}{\delta + \left(\frac{1}{\alpha} - \beta\right)(\beta R)^{\frac{\beta}{1-\beta}}} H - \frac{1-\alpha}{\alpha\delta + (1-\alpha\beta)(\beta R)^{\frac{\beta}{1-\beta}}} Tr,$$

$$I = -K_1 + \frac{\delta\beta R + (1-\beta)(\beta R)^{\frac{1}{1-\beta}}}{\delta(\beta R)^{\frac{\beta}{1-\beta}} + \left(\frac{1-\alpha\beta}{\alpha}\right)} H - \frac{(1-\alpha)(\beta R)}{\alpha\delta(\beta R)^{\frac{\beta}{1-\beta}} + (1-\alpha\beta)} Tr.$$

Since $A_1 = \alpha(1-\beta)(\beta R)^{1/(1-\beta)}/(1-\alpha\beta)$, $A_2 = (1-\alpha)\beta R/(1-\alpha\beta)$
Substituting A1 and A2 into the above equation and we have

$$I = -K_1 + \frac{A_1 + [\alpha\delta\beta R/1 - \alpha\beta]}{1 + [\delta A_1/(\beta R(1-\beta))]} H - \frac{A_2}{1 + [\delta A_1/(\beta R(1-\beta))]} Tr.$$

About the Authors

Xian Xu is an assistant professor at the School of Economics and deputy director of the Insurance Research Institute at Fudan University. In 2010, he received his doctoral degree of Economics from Karlsruhe Institute of Technology (KIT) in Germany, after obtaining a Master of Economics from the University of Göttingen and a Master of Law from the University of Osnabrück in Germany.

Jiawei Mo is the postgraduate student of World Economy at Fudan University. He holds a B.A. of Finance from Sun Yat Sen University (2011).