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The impact of human development on natural disaster fatalities and damage: panel data evidence

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ABSTRACT

Countries with high levels of human development should be able to reduce the impact of natural disasters in terms of the total numbers of people killed and affected, and damage. In this study we investigate the impact of human development indicators such as income per capita and human capital (education level) on natural disaster fatalities (total deaths, total affected and total economic losses) in 79 selected countries. Using dynamic panel data analysis, we found that the level of economic development plays an important role in mitigating the impact of natural disasters such as droughts, earthquakes, extreme temperatures, floods, storms, volcanoes, landslides and wildfires. Other factors that are found to determine the number of natural disaster fatalities include population, population density, unemployment, investment, government consumption, openness, education and corruption. Using the dynamic panel data model, we found that education, investment, government consumption and openness display an inverse relationship, while population and population density have a direct positive relationship.

1. Introduction

For nations to sustain long-term growth of real gross domestic product (G.D.P.) it is crucial to maintain the standard of living in the long term. To raise living standards a country should increase its average output per person over time. It has been recognised that the factors determining economic growth are the growth rates of the stocks of physical and human capital, and also the rate of technological change. Therefore, investment in plant, equipment, technology, the accumulation of skills and education (human capital) are indeed crucial for a long-term economic growth strategy.

The economic importance of human capital-enhancing economic growth has been discussed by Barro (1991), Becker, Murphy and Tamura (1990), Lucas (1988) and

Nelson and Phelps (1966). On one hand, Nelson and Phelps (1966) demonstrated that the innovation of new ideas and products are the result of the accumulation of larger stocks of human capital and could positively affect the growth of the economy. Echoing this, Becker et al. (1990) and Lucas (1988) argue that increasing human capital could lead to a higher rate of human and physical capital investment and economic growth.

As human capital rises, it increases productivity in the economy, reduces fertility rates and drives economic growth. Barro (1991) shows that the rate of technological progress depends on the initial stocks of human capital, assuming that human capital acts as a primary input in research and development (R&D).

Nevertheless, numerous studies have shown that natural disasters could pose a great challenge to human development in particular to the developing countries. According to the Asian Disaster Reduction Center (A.D.R.C., 2007), the level of human development is a measure of the factors that express a country's level of development, including its literacy rates, gross school enrolment rate (human capital), per capita income and life expectancy. The United Nations Development Programme (U.N.D.P., 2004) estimates that countries with a low level of human development accounted for more than half of all reported casualties during the last two decades, even though they represented only one-tenth of those exposed to natural disasters. The study also estimates that nearly 85 percent of the people exposed to natural disasters live in medium and low human development countries. Rodriguez-Oreggia, de la Fuente and de la Torre (2008) studied the impact of natural disasters on human development and poverty at the municipal level in Mexico, and found that the impact of natural disasters is higher for municipalities with lower social indicators (lower human development index (H.D.I.) and poor communities). In the aftermath of a disaster, the poor could be losing access to some basic services, with reversals in the accumulation of physical and human capital and these could result in an increase in child labour and criminal activities.

Baez, de la Fuente and Santos (2010) argue that disasters affect human development by bringing about substantial damage, including death and destruction, to human and physical assets. They can dramatically reduce nutrition, education, health and many income-generating processes. Destruction to schools and other infrastructure, and teacher casualties, affect the supply of education in the aftermath of a disaster. On the other hand, children who lose a parent tend to have a lower investment in human capital as a result of losing their source of income for attaining their education level (Cuaresma, 2010). Furthermore, disasters can lead to a reduction in children's nutrient intake, leading to malnutrition and therefore resulting in a lower formation of biological human capital in early childhood (see Del Ninno & Lundberg, 2005; Hoddinott & Kinsey, 2001). In a recent study by Yamauchi, Yohannes and Quisumbing (2009) on the children of Bangladesh, Ethiopia and Malawi, they found that children with more biological human capital (health and nutritional status) are less affected by the adverse effects of flooding, and the rate of investment in intellectual human capital (schooling and cognitive skills) increases with the initial human capital stock after disasters, achieving a faster recovery.

The purpose of the present study is to investigate the impact of human development indicators such as income per capita and human capital (education level) on

natural disaster fatalities in 79 selected countries from 1985 to 2010. The Asian Disaster Reduction Center (A.D.R.C.) (2009) has reported in various accounts that, for countries with a higher human development level, disaster mitigation, preparedness planning, disaster reduction and management strategies, and follow-up activities are made easier in post-disaster periods. Furthermore, improving the level of human development, such as improving a country's literacy rate, life expectancy, education level and income per capita, could contribute immensely to reducing the impact of natural disasters. It is therefore to be expected that a higher education level and income per capita will lead to a reduction in fatalities due to natural disasters.

The paper is organised as follows. The next section discusses the related literature on the topic. Models, methods of analysis and sources of data are presented in Section 3. A discussion and an interpretation of the empirical results are given in Section 4. The final section contains our conclusions, and the limitations of the study.

2. Literature review

Empirical evidence suggests that natural disasters produce a devastating impact on macroeconomic conditions in the short term, resulting a sudden collapse in domestic production and a pronounced slowdown in national income (Okon, 2018; Padli, Habibullah & Baharom, 2010, 2013). Worse, in line with the collateral damage they cause, such irreversible losses of human capital affect not merely the standard of living, but also increase the poverty rate, resulting in more chronic economic decay. In line with the increasing frequency of natural disasters in recent years, the social, economic and physical impacts have heightened public awareness and brought the issue to the forefront of public attention worldwide.

Loayza, Olaberria, Rigolini and Christiaensen (2012) recently stressed that natural disasters cause significant economic and physical losses, whose effects could spread beyond the immediate locality. The impact on economic growth is not always negative, and the developing countries are more vulnerable as more sectors are affected. The World Bank and The United Nations (2010) suggest that the economies of underdeveloped regions rarely grow after the occurrence of natural disasters, and the negative effects depends on the structure of the economy. Moreover, regions with low social capital may also have weak economic structures, thus experiencing difficulties in securing adequate resources due to the damage from natural disasters.

According to Freitas, Carvalho, Ximenes, Arraes and Gomes (2012) and the International Federation of Red Cross and Red Crescent Societies (I.F.R.C.) (I.F.R.C., 2003, 2010), natural disasters have a comparatively greater affect upon the poorest countries, which leads to them having to deal with more serious consequences. Most less-developed nations experience degradation of health (Datar, Liu, Linnemayr, & Stecher, 2013) due to diseases related to poor sanitary conditions (Takahashi, Goto, Yoshida, Sumino, & Matsui, 2012).

In the developed nations with social capital (e.g., Japan, U.S.A.) there are comparatively significantly fewer fatalities (Guha-Sapir, Vos, Below, & Ponserre, 2012; Kahn, 2005). Nations with a higher G.D.P., with a more educated population, and more social and political freedom coupled with a more comprehensive financial system,

will suffer fewer losses during extreme natural disasters (Oxley, 2013; Skidmore & Toya, 2007). In a comprehensive analysis on natural disasters and economic growth, Jaramillo (2007) concluded that both the short- and long-term effects of a natural disaster are determined by a country's income level and population, and the type of disaster.

Noy's (2009) study on the potential factors that can influence the impact of disasters, looking into the differences in population size, the size of the economy and the timing of incidences, found that the macroeconomic costs are much higher in developing nations than in developed nations. He also concluded that higher levels of literacy, better institutional qualities, higher per capita incomes, higher levels of government spending and more open economies, along with better financial conditions, are likely to contribute to countries' macroeconomic performance after natural disasters.

According to Wildavsky (1988), safety is a natural product of a growing market economy. Since the demand for safety rises with income, a nation's per capita income is a good first approximation of the degree of safety it enjoys. Furthermore, a rise in income will not only provide general safety: with a high enough level of income, protection could be directed to mitigate the impact of natural disaster fatalities and damage (Horwich, 2000). Kahn (2005), Eisensee and Strömberg (2007) and Skidmore and Toya (2007) collectively found that rich countries report fewer deaths, and lower levels of economic and human losses; even if they do, they would experience fewer or weaker impacts from natural disasters. The reason is that they can afford better housing, warning systems, medical care and better evacuation plans (Eisensee and Strömberg, 2007). Most urban areas have better physical infrastructure and administrative support systems such as emergency plans (I.F.R.C., 2010).

Albala-Bertrand (1993) argues that the higher the level of economic development, the smaller the numbers of deaths, injuries and relative material losses, in a study that employed data from 1960 to 1979 in low- and middle-income countries. The level of economic development includes income per capita and income distribution, economic diversification and social inclusion, institutionalisation and participation, education and health, choice and protection.

Burton (1993) and Tol and Leek (1999) show that there is an inverse relationship between deaths due to natural disaster and level of income for twenty countries for the period 1973-1986. Tol and Leek (1999) argue that the positive effect of G.D.P. can be readily explained since natural disasters destroy the capital stock, while the G.D.P. measure focuses on the flow of new production. They emphasise the incentives for saving and investing in mitigating and recovery efforts. Furthermore, the loss of capital in the longer term may have a positive impact, provided that sufficient re-investment from designated reserves takes place.

Economic development allows a country to better manage and mitigate the risk from disasters (Anbarci, Escaleras, & Register, 2005; Kahn, 2005; Toya & Skidmore, 2007). Macro-level policy prescriptions to manage the human and economic risk from natural disasters will allow countries to develop, and the risk from the damage from natural disasters should fall. Hoke (2005) and Okonski (2004) have argued that the best way to avoid large levels of damage from disasters is for poor countries to develop more quickly.

Kellenberg and Mobarak (2008) suggest that poor countries may have to be more proactive in enacting policies that can change the behavioural choices of their peoples that can potentially impact upon their country's exposure to the risk of natural disasters.

Haque (2003) investigated the impact of socio-economic and demographic factors on natural disaster fatalities. Empirical evidence shows that socio-economic and demographic factors have a very significant relationship to deaths from disasters and economic losses for the East, South Asia and Pacific islands. He also argues that emergency preparedness and fast action in handling dangerous situations in such disaster events would lessen the severity of the negative impact of each event. He also pointed out the importance of having special training programmes such as disaster management programmes for teachers, volunteers, and public and social workers, and local emergency agencies such as the police and fire department in order to minimise the risk of a natural disaster event.

Kahn (2005) tested several hypotheses concerning natural disaster fatality mitigation. He employed annual data for deaths from natural disasters in 73 nations from 1980 to 2002. Empirical results proves the hypothesis that richer nations experience fewer shocks or are lucky enough to experience weaker natural disaster shocks than those experienced by poorer nations. In the face of an equal quantity and quality of shocks compared to those for poorer nations, the richer nations suffer fewer deaths from natural disasters. He also found that the geography and institutions also play roles in shielding a nation from a higher number of deaths.

Research by Skidmore and Toya (2007) focuses on the degree to which the human and economic losses from natural disasters are reduced as economies develop. Their sample uses annual data for every recorded natural disaster from 151 countries over the period 1960–2003. Empirical evidence shows that with a higher income, higher educational attainment, greater openness, more complete financial systems and smaller government, there are lower levels of losses.

Raschky (2008) investigated the relationship between economic development and vulnerability against natural disasters. His sample consists of 2792 events where the numbers of natural disaster victims are available and 1103 events with figures for economic losses. Empirical results show that countries with a higher quality of institutions experienced fewer fatalities and lower economic losses from natural disasters, and there is a nonlinear relationship between economic development and economic disaster losses. Raschky further concluded that an institutional framework is a key socio-economic determinant of a nation's vulnerability against natural disasters.

Padli and Habibullah (2009) investigated the relationship between natural disaster fatalities and the level of economic development, years of schooling, land area and population for a panel of 15 Asian countries from 1970 to 2005. They found that the relationship between natural disaster losses and the level of economic development is nonlinear in nature, suggesting that, at a lower income level, a country is more natural disaster-resilient; but at a higher income level, an economy becomes less natural disaster resistant. Other natural disaster determinants of interest are the level of education, which suggests that educational attainment reduces human fatalities as a result of natural disaster; a larger population will increase the death toll; and a larger land area will reduce natural disaster fatalities.

Padli et al. (2010) investigated the relationship between the impact of a natural disaster such as number of deaths per capita, total affected and total damage/G.D.P., and macroeconomic variables namely G.D.P. per capita (as a proxy for the level of economic development), G.D.P. per capita squared to identify the linearity or non-linearity of the relationship, government consumption, ratio of the M2 money supply classification over G.D.P. as a proxy for financial deepening, years of schooling attainment, land area and population as a dependent variable by using cross-sectional analysis. Three different points of time were regressed, namely 1985, 1995 and 2005, covering 73 countries. They found that wealthy nations and their citizens are better prepared for natural disasters and that they could lessen the economic aftermath of the impacts of natural disasters. The size of the government is also found to be significant and inversely related, which strengthened the understanding of government intervention and consumption on minimising the impacts of natural disasters.

3. Methodology

Based on the previous literature, we propose the following equation in a log-log regression

$$
\begin{aligned}
\ln ND_{jit} = \beta_0 &+ \beta_1 \ln RGDPC_{it} + \beta_2 \ln POP_{it} + \beta_3 \ln POPDEN_{it} \\
&+ \beta_4 \ln UNEMP_{it} + \beta_5 \ln RINV_{it} + \beta_6 \ln RGCON_{it} \\
&+ \beta_7 \ln OPEN_{it} + \beta_8 \ln EDU_{it} + \beta_9 \ln COR_{it} + \varepsilon_{jit}
\end{aligned}
\tag{1}
$$

where i denotes country 1, 2, 3, ... n, j denotes the types of natural disasters and ε_{jit} is the error term. ND is the measurement for the natural disaster fatalities proxy for the total number of deaths (TD), total affected (TA) and total economic losses (TEL) caused by eight types of natural disasters, i.e., droughts, earthquakes, extreme temperatures, floods, storms, volcanoes, wildfires and landslides. As for the regressors, $RGDPC_{it}$ is the real G.D.P. per capita; POP_{it} is the total population, $POPDEN_{it}$ is the population density, $UNEMP_{it}$ is the unemployment rate, $RINV_{it}$ is the ratio of real investment to G.D.P., $RGCON_{it}$ is the real government consumption as a percentage of G.D.P., $OPEN_{it}$ is openness, EDU_{it} is the education level (number of students enrolled in higher education, and primary and secondary schools) as a proxy for human capital, and COR_{it} is corruption. Finally, ln denotes the natural logarithm of the variables used in the study. Thus, $RGDPC$ and EDU in Equation (1) represent the human development indicators in this study and are our variables of interest.

From Equation (1), for the two variables of interest, $RGDPC_{it}$ and EDU_{it}, we expect that both these variables would show a negative relationship with ND. Economists have found that safety is generally a normal or luxury good: as people become wealthier and secure the necessities of life, they look to reduce the risk of premature death (Kem, 2010). Based on the literature (Barro, 1991; Cuaresma, 2010; Freitas et al. 2012), the relationship between G.D.P. per capita and ND is, however, ambiguous. On the other hand, an educated population is well prepared in the event of natural disasters and would be able to reduce fatalities as well as damage. As people became more educated and knowledgeable, they are more aware, alert and better

Table 1. Lists of countries included in the study.

Algeria	Ghana	Malawi	Slovenia
Australia	Greece	Malaysia	South Africa
Austria	Guatemala	Mexico	Spain
Bangladesh	Haiti	Mozambique	Sri Lanka
Belgium	Honduras	Netherlands	Sudan
Bolivia	Hong Kong	New Zealand	Sweden
Brazil	Hungary	Nicaragua	Switzerland
Bulgaria	Iceland	Pakistan	Tanzania
Cameroon	India	Panama	Thailand
Canada	Indonesia	Papua New Guinea	Trinidad & Tobago
Chile	Ireland	Paraguay	Turkey
Colombia	Islam Republic of Iran	People's Republic of China	Uganda
Costa Rica	Israel	Peru	United Kingdom
Czech Republic	Italy	Philippines	United States of America
Dominican Republic	Jamaica	Poland	Uruguay
Ecuador	Japan	Portugal	Venezuela
Egypt	Kenya	Romania	Vietnam
El Salvador	Korea Republic	Russia	Yemen
France	Luxembourg	Senegal	Zimbabwe
Germany	Madagascar	Slovakia	

prepared for any natural disaster event. As for population and population density, we expect the result to have a positive impact on natural disaster fatalities due to urbanisation. More and more people in a crowded area will lead to more deaths and fatalities if a natural disaster happens in that area. The unemployment rate is also expected to give mixed results: a positive impact on total deaths and a negative impact on the total affected and economic losses due to limited or no income and wealth (resources) available. As for the coefficient sign for real investment and openness, we would expect a negative relationship with the impacts of a disaster. As there is more investment, there are more research and development activities, more avenues to absorb new ideas in natural hazard preparedness, ultimately reducing the impact of natural disaster fatalities. Similarly, for government consumption, we would expect a negative relationship on human fatalities and a positive impact on economic losses. Last but not least, corruption as an institutional measurement factor is expected to show a positive impact on disaster damage and fatalities, whereby natural disasters are the direct outcome of deviant political and economic decisions and actions by institutional participants.

3.1. Descriptions and sources of data

The data set consists of a observation panel for 79 countries encompassing developed and developing countries for the period 1981–2010. The data used in the analysis were five-year averages: 1981–1985, 1986–1990, 1991–1995, 1996–2000, 2001–2005 and 2006–2010. A list of countries is provided in Table 1. The impact of natural disasters such as the number of deaths, the number affected per capita and the data for the cost of damage were taken from the Office of Foreign Disaster Assistance (O.F.D.A.)/Centre for Research on the Epidemiology of Disaster (C.R.E.D.). Since 1988, C.R.E.D. has maintained the Emergency Events Database (C.R.E.D., 2000). Other regressors were obtained from various sources, which are summarised in Table 2. All variables were transformed into natural logarithms before estimation.

Table 2. Description of variables and sources of data used in the study.

Variable name	Brief description	Source of data
Number of deaths (*TD*)	Persons confirmed as dead and persons missing and presumed dead	Emergency events database (Centre for Research on the Epidemiology of Disaster (C.R.E.D.) (2000))
Number of total affected per capita (*TA*)	Sum of injured, homeless and affected	C.R.E.D. (2000)/Heston, Summers, and Aten (2009)
Total damage cost (*TEL*)	Estimates include both direct costs (such as damage to property, infrastructure, and crops) and the indirect losses due to reductions in economic activity	C.R.E.D. (2000)
Income per capita (*RGDPC*)	Real gross domestic product (G.D.P.) per capita	World Development Indicator (W.D.I.) (2008)
Population (*POP*)	Total population	Heston et al. (2009)
Population density (*POPDEN*)	Total population divide by land area (km^2)	Heston et al. (2009)/W.D.I. (2008)
Unemployment (*UNEMP*)	The rate of unemployment	W.D.I. (2008)
Investment (*RINV*)	Investment percentage of G.D.P.	W.D.I. (2008)
Openness (*OPEN*)	Export plus import divided by G.D.P.	Heston et al. (2009)
Government consumption (*RGCON*)	Government expenditure percentage of G.D.P.	W.D.I. (2008)/International Monetary Fund (I.M.F.) (2008)
Education (*EDU*)	Number of schooling attainment	Barro and Lee (1996)
Corruption (*COR*)	The extent to which public power is exercised for private gain, including petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests	International Country Risk Guide (I.C.R.G.) (2006)

4. Empirical results

To add a dynamic to the panel data analysis, we have included one lagged period for the dependent variable in Equation (1). If lagged dependent variables also appear as explanatory variables, strict exogeneity of the regressors no longer holds. The general method of moment (G.M.M.) estimators are known to be consistent, asymptotically normal and efficient in the class of all estimators that do not use any extra information aside from that contained in the moment conditions. The general way to deal with dynamic panel data is to apply a first-differenced G.M.M. estimator using the levels of the series-lagged two periods or more as instrumental variables.

When the number of time series observations is small, however, the first-differenced G.M.M. may behave quite poorly because lagged levels of the variables are only weak instruments for subsequent first-differences (Bond, Hoeffler & Temple, 2001). On top of that, there might arise situations whereby the difference G.M.M. model might not be able to perform as a good estimator. When model errors are heteroskedastic, we need two-step G.M.M. estimators that are robust under heteroskedasticity, but then again their standard errors are downwardly biased. Solutions are, however, provided by Windmeijer (2005), who proposed a correction for two-step G.M.M. estimators. Blundell and Bond (1998) proposed an alternative method. In addition to differentiating the model equation and using lagged levels of $Y_{i,t-1}$ as instruments of $\Delta Y_{i,t-1}$, they worked with the 'original' model and used the difference $\Delta Y_{i,t-1}$ as instruments of $Y_{i,t-1}$. The estimators obtained in this way are called system G.M.M. estimators.

Table 3. Factors affecting natural disaster fatalities (total deaths, *TD*) by type of disaster.

Variable	Drought	Earthquake	Extreme temperature	Flood	Storm	Volcano	Wildfire	Landslide
ln TD_{t-1}	−0.165**	−0.111**	0.201**	−0.023	0.246**	0.129**	0.232**	0.174**
	(−2.57)	(−18.45)	(0.054)	(−0.65)	(5.10)	(40.54)	(29.42)	(13.52)
ln $RGDPC_t$	−0.477**	−0.997**	0.004	−1.243**	−0.040	−0.017	−0.109**	−0.496**
	(−7.14)	(−9.05)	(0.03)	(−12.10)	(−0.27)	(−1.12)	(−3.69)	(−5.41)
ln POP_t	−	−	−	−	−	−	−	−
ln $POPDEN_t$	−0.065**	−0.018	0.085	0.041	0.295***	0.013	−0.074**	0.077
	(−2.03)	(−0.28)	(0.64)	(0.55)	(4.12)	(0.82)	(−2.24)	(1.36)
ln $UNEMP_t$	−0.129**	0.083**	0.113**	−0.044	0.206**	0.041**	−	−0.028
	(−2.87)	(2.74)	(2.17)	(−0.74)	(3.51)	(4.25)		(−0.38)
ln $RINV_t$	0.038	−	−0.029	0.101	0.142**	−	−	0.148**
	(1.67)		(−0.34)	(1.89)	(3.91)			(6.48)
ln $RINVPC_t$	−	0.138**	−	−	−	−	−	−
		(8.28)						
ln $RGCON_t$	0.340**	0.442**	0.365**	0.623	0.012	−	0.148**	0.248**
	(5.64)	(7.15)	(2.68)	(7.03)	(0.082)		(7.21)	(3.89)
ln $RGCONPC_t$	−	−	−	−	−	−	−	−
ln $OPEN_t$	0.478**	0.513**	0.233	0.112	−0.418**	−0.083**	0.078	−0.075
	(4.46)	(3.76)	(0.84)	(0.47)	(−2.43)	(−2.48)	(1.44)	(−0.65)
ln EDU_t	−0.320	−1.915**	−0.835	0.011	−0.504	−0.234**	0.002	−1.453**
	(−1.62)	(−5.78)	(−1.89)	(0.02)	(−1.39)	(−3.26)	(0.03)	(−7.34)
ln COR_t	−0.058	0.293**	−0.168	0.359**	0.164**	0.071**	0.033	0.202**
	(−1.40)	(6.22)	(−0.97)	(6.50)	(2.01)	(6.90)	(1.36)	(4.72)
Constant	−6.421**	−2.702**	−8.640**	−6.858**	−1.911	0.878**	−3.061**	−2.890**
	(−6.55)	(−2.14)	(−3.53)	(−3.37)	(−1.26)	(5.67)	(−8.95)	(−2.68)
Observation	245	245	245	245	245	324	435	245
No. of countries	62	62	62	62	62	62	76	62
Dummy year	No	No	No	No	No	No	No	No
AR(1) *p*-value	0.083	0.030**	0.001**	0.024**	0.001**	0.064	0.000**	0.007**
AR(2) *p*-value	0.457	0.923	0.871	0.219	0.107	0.429	0.478	0.297
Hansen test *p*-value	0.731	0.370	0.864	0.432	0.657	0.389	0.373	0.405

Notes: Figures in parentheses are *t*-statistics. ** denotes statistically significant at 5% level. *RINVPC* = ratio of real investment to G.D.P.; *RGCONPC* = ratio of real government consumption to G.D.P. All other variables are defined in Table 2.

Once difference or system G.M.M. estimators are obtained, the validity of the model must be checked. To establish the validity of the instrumental variables used in the analysis, specification tests are conducted using the Hansen test. The null hypothesis is that there is no correlation between instruments and errors, and failure to reject the null can be viewed as evidence in favour of using valid instruments. The next test is the test for the errors that are not serially correlated in the first-differenced equation. By construction, the differenced error term may be first-order serially correlated even if the original error term is not (Carkovic & Levine, 2002). Thus, if the null hypothesis no serial correlation of the AR(2) model it cannot be rejected: it can be viewed as evidence supporting the validity of the instruments used.

Tables 3 to 5 show the results of the two-step system G.M.M. showing the estimated coefficients, the sign and significance of several economic factors affecting natural disaster fatalities (*TD*, *TA*) and damage (*TEL*). The Hansen test indicates that valid instrumental variables were used in the analysis. The AR(2) test results suggest that there is no serial correlation in the first-difference equations. The lagged dependent variable is significant in the cases of total affected (Table 4) and total economic losses (Table 5). In Table 4, the previous number of people affected has a reducing effect on the current number of people affected in the event of droughts, earthquakes

Table 4. Factors affecting natural disaster fatalities (total affected, *TA*) by type of disaster.

Variable	Drought	Earthquake	Extreme temperature	Flood	Storm	Volcano	Wildfire	Landslide
ln TA_{t-1}	−0.053**	−0.173**	0.321**	0.115**	0.364**	0.690**	0.057	0.222**
	(−9.05)	(−3.33)	(12.03)	(4.16)	(5.20)	(33.55)	(1.95)	(7.80)
ln $RGDPC_t$	−2.453**	−1.818**	−0.305**	−2.607**	−1.043**	0.025	0.027	−0.354**
	(−12.03)	(−4.46)	(−2.50)	(−17.13)	(−3.80)	(0.55)	(0.15)	(−2.85)
ln POP_t	–	–	–	–	–	–	–	–
ln $POPDEN_t$	−0.472**	−0.278	−0.148	0.132	0.370**	–	−0.639**	0.045
	(−2.73)	(−1.05)	(−1.83)	(0.73)	(2.10)		(−6.58)	(0.46)
ln $UNEMP_t$	−0.419**	–	–		0.423**	–	0.182	–
	(−3.99)				(3.46)		(1.79)	
ln $RINV_t$	−0.019	0.441**	–	0.307**	–	−0.158**	0.227**	0.193**
	(−0.16)	(3.25)		(2.99)		(−4.82)	(2.06)	(2.11)
ln $RINVPC_t$								
ln $RGCON_t$	1.354**	0.788**	0.254**	1.185**	–	0.057	–	0.263**
	(5.36)	(2.54)	(3.33)	(9.18)		(1.38)		(2.49)
ln $RGCONPC_t$								
ln $OPEN_t$	0.536	−1.805**	−0.123	1.387**	−0.989**	−0.067	0.418	–
	(1.65)	(−3.80)	(−0.56)	(3.57)	(−2.06)	(−0.59)	(0.92)	
ln EDU_t	−1.320**	1.365	−0.689**	–	1.928	–	–	−1.004**
	(−2.36)	(1.48)	(−2.22)		(1.61)			(−2.83)
ln COR_t	−1.398**	0.068	−0.080	–	–	−0.012	0.018	0.288**
	(−12.33)	(0.24)	(−0.78)			(−0.14)	(0.07)	(2.35)
Constant	−7.031	−9.214	−4.194**	−19.03**	8.341**	2.764**	−5.176	−7.203**
	(−1.72)	(−1.72)	(2.23)	(−7.09)	(3.51)	(2.78)	(−1.50)	(−4.86)
Observation	245	327	435	451	337	339	252	327
No. of countries	62	76	76	79	63	78	64	76
Dummy year	No	No	No	No	No	No	No	No
AR(1) *p*-value	0.031**	0.013**	0.004**	0.001**	0.000**	0.046*	0.004**	0.000**
AR(2) *p*-value	0.346	0.145	0.132	0.515	0.755	0.768	0.516	0.120
Hansen test *p*-value	0.856	0.811	0.503	0.680	0.292	0.872	0.477	0.316

Notes: Figures in parentheses are *t*-statistics. ** denotes statistically significant at 5% level. *RINVPC* = ratio of real investment to G.D.P.; *RGCONPC* = ratio of real government consumption to G.D.P. All other variables are defined in Table 2.

and landslides, but not extreme temperatures. On the other hand, as shown in Table 5, the previous amount of total economic losses has a mitigating effect on the current amount of total economic losses in the event of earthquakes and volcanic eruptions. Thus, previous experience of 'hardships' is valuable for states in handling future events in the occurrence of natural disasters. The results are indirectly indicating that previous losses, total economic losses and the total affected has, to a certain extent, some mitigating impact, either for the cause of concern or through lessons learnt.

We next focus on our variables of interest, the human development indicators – per capita income and human capital measured by the level of education. The results presented in Table 3 for total deaths (*TA*), Table 4 for total affected (*TA*) and Table 5 for total economic losses (*TEL*) suggest that the level of economic development proxy by income per capita (*RGDP*) exhibits a negative relationship with total deaths due to droughts, earthquakes, extreme temperatures, volcanoes and landslides; total affected due to droughts, earthquakes, extreme temperatures, floods, storms, volcanoes and wildfires; total economic losses due to droughts, floods, storms, volcanoes and landslides. All of these variables are statistically significant at a 5 percent level. As pointed out by Wildavsky (1988), a nation's per capita income is a good first approximation of the degree of safety it enjoys. A nation's per capita income could

Table 5. Factors affecting natural disaster fatalities (total economic losses, *TEL*) by type of disaster.

Variable	Drought	Earthquake	Extreme temperature	Flood	Storm	Volcano	Wildfire	Landslide
ln TEL_{t-1}	0.160**	−0.029**	−0.092**	0.136**	0.209**	0.046**	0.057	−0.330**
	(41.32)	(−2.29)	(−4.34)	(2.31)	(6.33)	(2.04)	(1.05)	(−4.96)
ln $RGDPC_t$	−0.346**	−0.937**	0.067	−1.097**	0.425	−0.026	0.256	−0.643
	(−2.64)	(−2.44)	(0.91)	(−3.58)	(1.43)	(−0.35)	(1.10)	(−1.92)
ln POP_t	–	–	–	–	–	–	–	–
ln $POPDEN_t$	−0.404**	−0.330	–	−0.404**	0.735**	–	−0.395**	0.060
	(−3.44)	(−1.08)		(−2.28)	(3.04)		(−2.33)	(0.32)
ln $UNEMP_t$	–	0.318*	–	0.653**	0.368**	0.026	0.141	−0.069
		(1.85)		(4.21)	(2.39)	(0.80)	(1.33)	(−0.43)
ln $RINV_t$	−0.174**	0.115**	0.083**	–	–	–	0.318**	0.041
	(−4.72)	(2.96)	(2.12)				(2.38)	(0.23)
ln $RINVPC_t$								
ln $RGCON_t$	0.673**	0.749**	0.219**	1.290**	0.950**	−0.046	−0.049	0.597**
	(4.89)	(3.82)	(2.32)	(5.88)	(3.39)	(−1.02)	(−0.26)	(2.26)
ln $RGCONPC_t$	–	–	–	–	–	–	–	–
ln $OPEN_t$	−0.285	−0.245	–	0.757	−0.825	−0.270**	−0.312	0.166
	(−1.27)	(−0.54)		(1.80)	(−1.62)	(−3.85)	(−0.79)	(0.30)
ln EDU_t	–	−2.237**	−0.320	–	0.583	0.304	–	–
		(−2.12)	(−1.17)		(0.50)	(0.98)		
ln COR_t	0.027	0.407	–	−0.402	−0.044	–	0.030	−0.121
	(0.33)	(1.50)		(−1.29)	(−0.20)		(0.11)	(−0.34)
Constant	−6.877**	−8.756**	−7.584**	−24.747**	28.69**	2.068**	−6.269	−11.54**
	(−2.49)	(−3.16)	(−4.10)	(−5.25)	(−5.62)	(2.40)	(−1.97)	(−2.49)
Observation	337	245	441	330	322	338	251	251
No. of countries	78	62	77	64	62	63	64	64
Dummy year	No	No	No	No	No	No	No	No
AR(1) *p*-value	0.020**	0.004**	0.027**	0.000**	0.000**	0.024**	0.005**	0.008**
AR(2) *p*-value	0.568	0.149	0.309	0.881	0.172	0.104	0.173	0.544
Hansen test *p*-value	0.499	0.655	0.909	0.143	0.547	0.515	0.918	0.619

Notes: Figures in parentheses are *t*-statistics. ** denotes statistically significant at 5% level. *RINVPC* = ratio of real investment to G.D.P.; *RGCONPC* = ratio of real government consumption to G.D.P. All other variables are defined in Table 2.

also be an indicator of improved and increased availability of sources of funding for precautionary measures.

On the other hand, our results for the human capital variable, which is a proxy for the level of education, indicate that ln*EDU* is significant at a 5 percent level and shows a negative sign for earthquakes in terms of total economic losses – implying that the population's level of education can reduce the severity of total economic losses due to earthquakes. But, at the 10 percent level of significance, the results suggest that an increase in human capital (education level) can mitigate the impact of landslides on the number of total deaths, and the impact of floods on total economic losses. Through education, people can learn to reduce disaster risk and prepare to manage the impact of natural disasters.

Other variables that seem to have impacted upon natural disasters (total deaths, total affected and total economic losses in Tables 3–5, respectively) include population, population density, unemployment rate, investment, government consumption, openness and corruption. Our results indicate that populated areas are associated with a higher number of people affected in the event of flooding. Total economic losses are also high, with a higher population, when earthquakes, extreme temperatures and floods occur. On the other hand, in a densely populated area, more deaths,

a greater number of people affected and higher total economic losses were experienced in the event of extreme temperatures, volcanic eruptions and stormy weather.

A positive relationship between real investments, as well as government consumption, with total deaths implies that older equipment is more exposed to damage when a disaster hits the capital stock, and thus the replacement of these facilities would constitute a positive productivity shock, which may have permanent consequences in the growth rate of the whole economy. For urbanisation to take place, huge investment in building infrastructures and services is needed. As a result of urbanisation, population growth and migration, these human-induced demand factors will increase pressure on the environment, and these trends will impact upon the vulnerability of urban centres to natural disasters (Brauch, 2001, 2002). Since urban areas have higher-income populations and higher investment in infrastructure than rural areas, in the event of natural disasters it is expected that a higher number of fatalities and amount of damage will be the result.

Openness (OPEN) also contributed to a reduction in the number of total deaths, the total affected and total economic losses. Openness as a proxy for the transfer of technological knowledge from abroad can reduce natural disaster fatalities. A nation with a financial sector in a steady state may have a reduced disaster resilience because a more efficient financial system is less likely to finance projects in essentially risky locations (Skidmore & Toya, 2002). The extent of the catastrophic risk attached to climatic disasters is a significant determinant of both medium- and long-term patterns of technological transfer, and is positively related to the size of the spillover; the results for geological disasters are only significant and very sizeable in the medium term for recovery following the occurrence of a disaster. Gassebner, Keck and Teh (2010) also found a negative relationship between the occurrence of natural disasters and a nation's volume of trade.

Lastly, corruption leads to a higher total number affected and total economic losses. A higher level of corruption increase the number of people affected in the event of earthquakes and wildfires; and a corrupted state is also associated with an increased amount of total economic losses as a result of droughts, earthquakes and wildfires.

4.1. Similar findings of previous studies

The findings of this study on the negative impact of income per capita on fatalities is quite consistent with many previous studies. It makes perfect sense that a higher income per capita, which translates into a higher development level or standard of living, indeed mitigates the impact of natural disasters. This finding is consistent with the findings of Anbarci et al. (2005), Kahn (2005), Kellenberg and Mobarak (2008), Narayan (2003), Noy (2009), Padli and Habibullah (2009), Padli et al. (2010), Price (2008), Raschky (2008), Skidmore and Toya (2007) and Yamamura (2008). In all of these studies it was found that the income per capita (proxy for economic development) is inversely related with natural disaster fatalities.

The finding of an inverse relationship between human capital and fatalities of natural disaster as found in our study is also consistent with and similar to Barro

(1991), Cuaresma, Hlouskova and Obersteiner (2008), Nelson and Phelps (1966) and Romer (1990). Nelson and Phelps (1966) point out that nations with larger stocks of human capital may absorb new ideas and products that have been developed abroad more easily, which could generate a feedback effect between growth and human capital. According to Barro (1991) and Romer (1990), human capital is considered to be a primary input, where the approach of technological progress depends on the stock of human capital. Cuaresma et al. (2008) argue that overall catastrophic risk tends to increase knowledge spillovers, the effect of geological disasters tends to be observable only in the medium term, while a climatic disaster risk systematically increases the size of the R&D spillovers in the long term.

Similar findings for investment and openness were also obtained by Okuyama (2003). Skidmore and Toya (2002) concluded that updates in technology and/or factor composition will positively influence long-term growth. Cuaresma et al. (2008) argued that natural catastrophic risk is positively related to the extent of technological transfer taking place between developed and developing countries.

5. Conclusions

Natural disasters are not uncommon events, though they are very much unpredictable. Droughts, earthquakes, extreme temperatures, floods, cyclones, volcanic eruptions, wildfires and landslides are natural phenomena that occur from time to time. For example, the A.D.R.C. (A.D.R.C., 2009) reported that 399 natural disasters occurred worldwide in 2009, killing almost 16,000 people and affecting over 220 million people. The estimated amount of economic damage came close to US$50 billion. By geographical region, Asia is the highest in all four accounts: 35.8 percent of the occurrence of disasters; 52.1 percent of the total number of people killed; 78.3 percent of the total number of people affected; and 44.9 percent of the amount of economic damage.

Within the Southeast Asian region, in 2009, Indonesia was impacted by earthquakes (five occurrences), floods (five occurrences) and landslides (two occurrences). Earthquakes caused 1330 deaths and affected more than 2.8 million people. The estimated cost of the damage reached about US$2.8 billion. Floods killed 126 people and affected more than 26,000 people; while landslides killed 29 people over two occasions. On the other hand, the Philippines account for five types of natural disasters – earthquakes, floods, landslides, storms and volcanic eruptions. Storms or cyclones account for most damage. In 2009, cyclones wreaked havoc in the Philippines 14 times, killing 1242 people, affecting more than 12 million people and causing damage costing more than US$900 million. Floods (eight occurrences) caused 55 deaths, affecting more than 1 million people and causing damage worth US$29 million. Volcanic eruptions in 2009 affected more than 47,000 people. Malaysia, however, experienced two floods in 2009. On these two occasions, more than 10,000 people were affected by the floods.

The purpose of the present study is to investigate the responsiveness for total deaths caused by natural disasters for two important human development indicators, that is, income per capita and education attainment, using a panel of data from

79 countries. We have identified several other economic variables that may affect natural disaster fatalities. These variables include population density, investment, government consumption, education and openness.

Generally, our study suggests that, among others, enhanced economic development can help in reducing the impact of natural disasters on human fatalities. Countries with a higher income will be able to be more prepared to face future devastation due to natural disasters. Spending on natural disaster relief centres, preparedness programmes for natural disasters, early warning systems, enforcement of building regulations in natural disaster prone areas, will lessen the impact of natural disasters on the public. Furthermore, coupled with higher investment and educating the public at large, human fatalities can be reduced. As well-informed citizens, people would be more willing to prepare themselves against any ill-effect as a result of natural disasters, for example by buying or building homes less prone to natural disasters or making extra precautions for facing future disasters.

While it is a known factor that natural disasters are indeed almost unpredictable phenomena, we could still mitigate or reduce the aftermath of these events. One important policy implication is that programmes and policies centring around the aim of increasing the income level of the people should be given priority because it could indirectly work positively in the long term in mitigating and reducing damage and losses as well as the fatalities due to natural disasters. Government expenditure and consumption would also need to be carefully planned and cautiously executed, as this study has also proved that government consumption is an important tool that, if used wisely and carefully, could mitigate losses and could reduce the negative impact of natural disasters. Governments also need to allocate a large proportion of their budgets to mitigation factors and facilities such as retainable walls or ensuring adequate forest reserves to act as cushions to prevent or lessen damage.

5.1. Limitations of the study

Due to the unavailability of valid, reliable and consistent data on other variables that might have a direct or indirect relationship with fatalities of natural disasters, not much manoeuvring could be done. With the availability of new, consistent data, it might be beneficial to revisit this study.

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