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Upgrading destruction?

How do climate-related and geophysical natural disasters impact sectoral FDI

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Abstract

Purpose – The authors investigate natural disasters' impact on manufacturing and services foreign direct investment (FDI), both, in contemporaneous and time-lag contexts. Manufacturing and services FDI account for different types of technology transfers, respectively, through tangible physical assets and intangible knowledge assets. This paper aims to hypothesize that natural disasters that have pronounced physical impact, have different effect on different sectoral FDI.

Design/methodology/approach – The authors merge a data set from emergency events database, which covers natural disasters occurrences with a sector-level data on FDI for 69 countries for the period 1980-2011, distinguishing between four different kinds of natural disasters such as meteorological, climate, hydrological and geophysical, as well as between different geographical regions.

Findings – Controlling for commonly accepted determinants of FDI, such as output growth, quality of institutions and natural resource abundance, the authors find that manufacturing FDI is negatively affected immediately after the disaster and positively in the longer run- a finding that is in unison with the "creative destruction" growth theory. Services FDI, on the other hand, do not show such pattern. Meteorological disasters have no effect on services FDI and climate and hydrological disasters have long-lasting negative effects. For both, manufacturing and services FDI, geophysical disasters have a positive impact on FDI in the long run.

Research limitations/implications – The study is limited to 69 countries for the period 1980-2011.

Practical implications – FDI bears tangible and intangible knowledge assets and provides means of financing, even in countries with under-developed banking systems and stock markets. FDI is impacted by climate change, manifested by intensifying and increase of frequency of natural disasters.

Social implications – Natural disasters destroy infrastructure and displace people. The rebuilding of infrastructure and intangible capital present an opportunity for upgrading.

JEL classification – Q54, F21

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Originality/value – This is the first study that analyzes the impact of natural disasters on sector-level FDI in a multicounty and regional context.

Keywords Natural disasters, Climate-related natural disasters, Geographical regions, Geophysical natural disasters, Manufacturing and services FDI, Sectoral FDI, FDI inflows

Paper type Research paper

1. Introduction

Foreign direct investment (FDI) is a main source of financing for developing countries. FDI bears tangible and intangible knowledge assets and provides means of financing, even in countries with under-developed banking systems and stock markets. Like most of the macroeconomy, FDI is impacted by climate change. One of the manifestations of climate change is the intensifying and increase of frequency of natural disasters. The research on the economic impact of natural disasters, however, in still in its infancy. Natural disasters destroy or damage infrastructure, displace people and diminish human capital resources. However, in spite of the hypothesized negative initial impact, the long-run effects of disasters need not be negative. The replacement and rebuilding of infrastructure and intangible capital present also an opportunity for upgrading. The current study aims at exploring these links.

The theoretical foundation for the economic analysis of natural disasters resides in part with growth theory. Some of the questions discussed by the natural disaster literature concern the short-run and the long-run impacts of disasters on GDP. The hypothesis raised by many studies is that although the immediate impact of a disaster could be negative, the process of re-building the economy could lead to a recovery beyond the pre-disaster GDP levels. This hypothesis is broadly based on the endogenous growth theory of "creative destruction." By analogy with the "creative destruction" growth hypothesis, here we test for an "upgrading destruction" by hypothesizing that a natural disaster can destroy old capital assets working with outdated technologies and lead to a rebuilding using advanced technologies and practices (Skidmore and Toya, 2002; Hallegatte and Dumas, 2009; Doytch and Klein, 2018; Noy and Vu, 2010).

However, not all studies find empirical support for this capital upgrading theory. Some studies argue about a recovery to the trend. They reason that there is post-disaster rise in marginal productivity of capital, which is because of less capital available for the same number of workers. This eventually leads to converging to pre-disaster levels (Smith *et al.*, 2006; Vigdor, 2008; Belasen and Polachek , 2008, 2009; Hornbeck, 2012; Strobl, 2011; Boustan *et al.*, 2012).

In addition, some studies find that the outcome of catastrophes' impact depends on the country level of development. Crespo Cuaresma *et al.* (2008) find that risk has a negative effect on the volume of knowledge spillovers between industrialized and developing countries and that only developed countries experience capital upgrading after a natural disaster. This, according to their study, happens through international trade.

As economic resources are limited and there are competing ends for their use, disaster-spurred replacement of capital is good for growth only if there is capital upgrading. The two ways of upgrading can occur through domestic innovation and through adoption of foreign technology. For developing countries, FDI is one of the important vehicles for adoption of new technology. Moreover, post-disaster domestic investment may be constrained in ways of financing, if the financial system experiences post-disaster stress. In addition, any post-disaster fall in the value of the domestic assets would make them seem attractive to foreign investors. Therefore, it is not unreasonable to expect that FDI plays an important role in capital upgrading in disaster-prone countries and especially developing disaster-prone countries.

Although the link between natural disasters and foreign investment appears to be important for post-disaster growth, it has not been well explored. The only published studies we could find are Escaleras and Register (2011) and Anuchitworawong and Thampanishvong (2015) , with the second one performed on Thailand. As we argue below, both of them have some limitations and none of them explores sectoral differences in FDI, which may be important for disaster risk management. We seek to fill in this gap.

In the current study, we ask the question: is there a pattern that shows FDI increasing as a result of natural disasters? When we control for other commonly accepted determinants of FDI, such as the growth rate of income, quality of institutions and natural resource abundance, do we see a change in post-disaster FDI and does the disaster reaction of FDI differ in the short and the long run? Further, is there a difference between the reaction of manufacturing sector FDI inflows and services sector FDI? Arguably, the two sectoral flows transfer different kinds of technology as follows: manufacturing sector FDI-technology embodied in tangible physical assets such as equipment upgraded for advanced production processes, and services FDI-technology embodied in intangible knowledge assets, such as information technology know-how, organizational skills, marketing and distribution strategies and so on. that does not get easily destroyed by natural disasters (UNCTAD, 2004; Doytch and Uctum, 2011). The tangible/intangible aspect of the damages are also the object of the newly developed typology of disasters that claims intangible losses could be qualified as “higher-order” long-run effects of disasters (López, 2009; Noy and Du Pont IV, 2016).

The contributions of this study are multi-fold. Mainly, first, to our knowledge, this is the first study that merges the widely-used emergency events database (EM-DAT) data set on natural disasters with detailed sector-level data for FDI for 69 countries for 1980-2011[1] and applies a system generated method of moments (GMM) to deal with the endogeneity between FDI and income. This is an improvement over the methodology used in Escaleras and Register (2011) . Second, we distinguish between four kinds of catastrophic disasters as follows: meteorological, climate, hydrological and geophysical disasters while estimating both, short-run (contemporaneous) and long-run (five-year lagged) effects of natural disasters on FDI. We are also able to explore the effects of disasters within several geographical regions as follows: West Europe (a developed region); Eastern Europe and Central Asia (a region of transitional economies); South and East Asia and the Pacific (developing countries regions); and Latin America and the Caribbean (developing countries regions)[2]. Third, to disentangle the tangible/intangible aspect of capital upgrading, we consider the effects of two kinds of FDI flows manufacturing and services FDI. This is a unique feature of this study. The sectoral and industry-level differences in FDI are often ignored in the FDI determinants literature, too.

Our findings are intriguing. We find some nuances in the effects of natural disasters on manufacturing and services FDI. Manufacturing FDI shows a pattern of being negatively affected immediately after the disaster and an opportunity for post-disaster capital rebuilding in a longer term, such as five years. Services FDI does not show such pattern. Some disasters, such as meteorological, have no effect; and some, such as climate and floods, have long-lasting negative effects. For both types of FDI flows-manufacturing and services, there is one common theme: the most destructive disasters – geophysical disasters have a positive impact on FDI in the long run. This appears to be the case with manufacturing FDI to Western Europe, East Europe and Central Asia, and

Latin America and the Caribbean and the case with services FDI to West Europe and South and East Asia and the Pacific.

The rest of the paper is organized as follows. Section 1 examines a literature review on natural disaster economic impacts. Section 2 discussed some stylized facts about natural disasters and FDI inflows. Section 3 introduces the model, the data, and the methodology; Section 4 discussed the empirical findings and Section 5 concludes.

2. Literature review

As previously mentioned, the impact of natural disasters on FDI has not been well explored. Most of the existing studies investigate the effects of disasters on productivity and in that discussion, there are two streams of arguments as follows: about factors mitigating disaster preparedness and about direct disaster impact. One of the seminal papers exploring the mitigating factors is the study by Noy (2009) on macroeconomic consequences of natural disasters. Noy (2009) , whose model focuses on disaster damage and disaster deaths, rather than disaster occurrences, finds that institutions and policies play a role in the magnitude of the macroeconomic consequences of natural disasters. The author identifies that: "Countries with higher literacy rates, better institutions, higher per capita incomes, larger governments and higher degree of openness to trade appear to be better able to withstand the initial disaster shock and prevent its effects spilling deeper into the macro-economy". He also finds that less openness of the capital account, more foreign exchange reserves and higher levels of domestic credit reduce disaster vulnerability. In addition, he finds that developing countries suffer larger shocks from similar disaster magnitudes than developed countries and small economies are more vulnerable than large ones. The effects on investment and trade flows, however, are inconclusive.

One of the widely cited macro-level papers on the direct economic effects of disasters is the study by Albala-Bertrand (1993) , who finds an increase in GDP, in capital formation, and in the twin deficits, especially the trade deficit. At the same time, the author finds no change in inflation and exchange rates. Rasmussen (2004) and Tol and Leek (1999) have similar findings, all in the scope of univariate analysis. In the meantime, Skidmore and Toya (2002) is one of first studies to examine the long-run impact of disasters on growth with cross-sectional country-level data set, where they account for frequency of disasters normalized by land size. They find that climatic disasters are correlated with both, accelerated human capital accumulation and increases in total factor productivity.

Exploring further the long-run effect of disasters, Noy and Du Pont IV (2016) summarize that these depend on the severity of disasters, on the income level of the economy, as well as on the size of the geographical area impacted. Meanwhile, Cavallo *et al.* (2013) clarify that only very large disasters have a negative impact on output. However, when controlling for political change, Cavallo *et al.* (2013) find that rather than having an output effect, disasters have an impact on the political systems of impacted countries and lead to radical political changes.

The above findings lead to a recent discussion about the direct and secondary effects of natural disasters. Vu and Noy (2015) describe, the secondary effects may occur because the capital replacement pulls resources from other sectors and leads to economic restructuring. With the restructuring, the economy can reach a new steady state equilibrium. However, the issue of what constitutes long-run in this case remains open. Therefore, some of the conclusions about the impact depend on the time horizon of the analysis. Disregarding the long-run economic effects may lead to incorrect conclusions[3].

Another aspect of the effects of disasters, highlighted by Noy and Vu (2010) , is that the nature of the disaster matters for the economic impact, as the nature is related to disaster predictability. For example, some countries have high exposure to storms. In this case, storms are predictable events that call for disaster preparedness. Unlike storms, geophysical disasters, such as earthquakes, are oftentimes unpredictable and catastrophic. Vulnerability to geophysical disasters is, therefore, higher and because of that the economic impact of geophysical disasters is stronger. This is the reason why in this study, we differentiate between four different kinds of disasters as follows: meteorological, climate, hydrological and geophysical disasters.

Some recent interdisciplinary research on natural disasters uses meteorological storm models, which are embedded in stochastic economic models evaluating the impact of disasters. Hsiang and Jina (2014) evaluate the long-run economic growth impact of 6,700 cyclones during 1950-2008. The meteorological data allows for reconstruction of the wind speed characteristics of the storm and allows for precise accounting of severity of each cyclone. The authors refute the "upgrading destruction" hypothesis and find that cyclone disasters do not stimulate growth and there is no evidence that short-run losses disappear in the long-run. The authors find support of declining national incomes relative to pre-disaster trend and no recovery within 20 years. This finding does not depend on the country income level.

With respect to FDI, which is the topic of the current investigation, there are very few studies that venture into analyzing the question of natural disaster impact. In general, in the post-disaster period domestic firms could see falling value of their assets, which makes them relatively cheap and more attractive for acquisition by foreign investors. This is often considered an income effect of FDI (Levy-Yeyati *et al.*, 2007; Doytch, 2019). As a result of the income effect, FDI inflows are to increase. At the same time, disasters could impact relative rates of return to capital because of an adverse effect on the marginal productivity of capital. This could be qualified as a substitution or arbitrage effect (Levy-Yeyati *et al.*, 2007). As a result of the arbitrage effect, FDI inflows are supposed to decrease. The standard FDI determinants models account also for output growth, as a proxy for the size of the market, for natural resource endowments; for quality, human capital and for quality of institutions (Doytch and Eren, 2012).

In that light, a recent study on Thailand asks about the impact on natural disasters on FDI (Anuchitworawong and Thampanishvong, 2015). The authors hypothesize that investor perception of disaster risk is a main determinant of FDI in Thailand. Although they do not find a connection between frequency of disasters and FDI, the authors find that severity of disasters, tends to lower FDI. Escaleras and Register (2011) end up with a similar conclusion based on a panel of 94 countries for 1984-2004. They also find a negative and significant effect of disasters on inward FDI. One shortcoming of the study could be the methodology of fixed effects, which does allow for control of endogeneity of some of the right-hand-side variables. Similar are the shortcomings of the study by Kukulka (2014) about the impact of catastrophic events on FDI inflow in five developing countries with high catastrophic risk of South-Eastern Asia region, i.e. Indonesia, Malaysia, Philippines, Thailand and Vietnam with an ordinary least squares methodology. The results point out to a negative correlation between FDI disaster occurrence for Thailand and Malaysia, but not for Indonesia and the Philippines.

3. Stylized facts

Table I summarizes statistics on frequency, value damaged and population affected by different types of disasters, averaged by geographical region and by year.

On average, meteorological disasters occur most often up to 27 times a year throughout the entire sample of 67 countries. Next are climate and hydrological disasters, with

Table I. Summary statistics, disaster occurrences, damages and population affected

Occurrences	Obs	Mean	Std. dev	Min	Max	Damages (thousands of US$)	Obs	Mean	Std. dev	Min	Max
All countries											
Meteorological	5,600	0.5030357	1.569486	0	27	Meteorological	5,600	167,942.5	2,740,529	0	1.58E + 08
Climate	5,528	0.290521	1.156273	0	25	Climate	5,528	42,722.27	545,557.6	0	2.13E + 07
Hydrological	5,949	0.7100353	1.511045	0	21	Hydrological	5,948	109,387.9	1,095,939	0	4.03E + 07
Geophysical	3,710	0.2773585	0.8050123	0	11	Geophysical	3,710	191,013.4	4,216,516	0	2.10E + 08
WE											
Meteorological	630	0.495238	0.963141	0	8	Meteorological	630	146,847.4	719,086.6	0	1.20E + 07
Climate	524	0.305344	0.650261	0	4	Climate	524	79,848.94	437,270.9	0	4,500,000
Hydrological	595	0.415126	0.827214	0	6	Hydrological	595	162,534.6	1,004,051	0	1.29E + 07
Geophysical	385	0.161039	0.46215	0	3	Geophysical	385	136,360.8	1,341,718	0	2.00E + 07
EECA											
Meteorological	910	0.125275	0.416543	0	3	Meteorological	910	2,880.916	24,295.52	0	392,000
Climate	1,014	0.227811	0.648771	0	8	Climate	1,014	14,455.06	150,296	0	3,600,000
Hydrological	979	0.383044	0.876505	0	10	Hydrological	979	28,093.58	201,534.5	0	3,500,000
Geophysical	664	0.152108	0.517619	0	6	Geophysical	664	38,879.54	818,641.5	0	2.10E + 07
SEAP											
Meteorological	1,260	0.969048	1.973975	0	15	Meteorological	1,260	158,980.8	874,561.9	0	1.51E + 07
Climate	980	0.629592	2.398191	0	25	Climate	980	77,171.66	894,613.6	0	2.13E + 07
Hydrological	1,120	1.5	2.612611	0	21	Hydrological	1,119	337,693.7	2,152,985	0	4.03E + 07
Geophysical	875	0.557714	1.26556	0	11	Geophysical	875	581,540.5	8,461,533	0	2.10E + 08
LAC											
Meteorological	1,015	0.386207	0.779804	0	5	Meteorological	1,015	64,215.74	437,899.1	0	7,910,000
Climate	980	0.209184	0.486925	0	4	Climate	980	15,940.4	168,638.6	0	4,300,000
Hydrological	1,085	0.725346	1.147013	0	8	Hydrological	1,085	62,303.6	863,932	0	2.76E + 07
Geophysical	770	0.267533	0.623435	0	5	Geophysical	770	72,906.65	1,136,784	0	3.00E + 07

(*continued*)

Table I.

Affected population	Obs	Mean	Std. dev	Min	Max
All countries					
Meteorological	5,600	157,734.8	2,066,278	0	1.07E + 08
Climate	5,528	335,728.4	6,406,348	0	3.00E + 08
Hydrological	5,949	585,283.8	7,571,946	0	2.43E + 08
Geophysical	3,710	43,564.12	878,573.9	0	4.74E + 07
WE					
Meteorological	5,960	148,208.7	2,003,244	0	1.07E + 08
Climate	5,828	318,446.6	6,239,696	0	3.00E + 08
Hydrological	6,289	554,068	7,365,583	0	2.43E + 08
Geophysical	3,930	41,380.52	853,732.4	0	4.74E + 07
EECA					
Meteorological	6,120	144,334.5	1,977,021	0	1.07E + 08
Climate	6,108	303,848.5	6,095,340	0	3.00E + 08
Hydrological	6,509	535,161.5	7,240,699	0	2.43E + 08
Geophysical	4,090	39,854.1	836,884.3	0	4.74E + 07
SEAP					
Meteorological	6,320	151,522.3	1,969,002	0	1.07E + 08
Climate	6,088	359,285.9	6,744,101	0	3.00E + 08
Hydrological	6,589	562,963.4	7,247,591	0	2.43E + 08
Geophysical	4,210	38,822.64	824,898.3	0	4.74E + 07
LAC					
Meteorological	6,180	143,566.8	1,967,538	0	1.07E + 08
Climate	6,088	30,7791.1	6,106,869	0	3.00E + 08
Hydrological	6,569	532,491	7,208,058	0	2.43E + 08
Geophysical	4,150	42,709.49	837,535.2	0	4.74E + 07

respective maximum frequencies of 25 and 21 time a year on average for the entire sample (Table I , left panel). The least common are the geophysical disasters, occurring on up to 11 times year in all 67 countries studies.

The frequency, however, does not capture well the destruction of assets. The most damaging ones appear to be the geophysical disasters with a mean value loss of $191,013,400 or approximately US$200m per country per year for our sample of countries (Table I , middle panel)[4]. The second most destructive appear to me meteorological disasters (Table I , middle panel). However, the type of disasters that affect the most people are the hydrological disasters on average close to 600,000 people per country per year vs geological disasters that effect on average about 50,000 people per country per year (Table I , right panel). Of course, the average numbers are hard to interpret in a sample with heterogeneous climatic and geophysical conditions. For that reason, we look at geographical regions.

The region with the greatest frequency of disasters is SEAP: up to 15 meteorological, 25 climate, 21 floods and 11 geophysical disasters in a given country and year (Table I , left panel). The capital value destroyed by disasters in this region is also staggering: on average close to US$600m lost in geophysical disasters per country per year: more than US$300m lost in flood disasters per country per year; approximately US$150m value lost in storm disasters per country/year, and another US$80m lost in climate disasters per country/year (Table I , middle panel). There are large populations affected in disaster zones in Asia with floods heading the statistics close to 600,000 people annually per country in this region (Table I , right panel).

For comparison, in the Latin America and the Caribbean (LAC) region, the annual value lost in disasters is follows: US$73m geophysical disasters; US$62m lost in hydrological disasters per country/year; about the same amount US$64m lost in meteorological disasters and about US$16m in climate disasters (Table I , middle panel). The populations affected are also smaller than the populations in South and East Asia, with hydrological disasters affecting the most close to 600,000 people per country annually (Table I , middle panel).

The reason why we have decided to focus on the frequency rather than the value lost and the population affected in this study is that the frequency is the only exogenous variable among the three. Both the value lost and the population affected are partially an outcome of disaster preparedness, which is a function of both income levels and the investment levels in the country.

4. Empirical model, data and methodology

To determine the impact of natural disasters on FDI we run two models as follows: a contemporaneous model and a model with "lagged" natural disasters, where the disaster variable is lagged five time periods relative to the period of FDI. Following a methodology by Blonigen (2005), we construct the following empirical equations (1) and (2):

$$\log\left(FDI_{it}^{j}\right) = \beta_0 + \beta_1 \log\left(FDI_{it-1}^{j}\right) + \beta_2 GDP_{it} + \beta_3 Demo_{it} + \beta_4 Nat\mathrm{Re}\,nt_{it} + \beta_5 Disaster_{it}^{\mathrm{k}} + \mu_i + \eta_t + \varepsilon_{it} \quad (1)$$

$$\log\left(FDI_{it}^{j}\right) = \beta_0 + \beta_1 \log\left(FDI_{it-1}^{j}\right) + \beta_2 GDP_{it} + \beta_3 Demo_{it} + \beta_4 Nat\mathrm{Re}\,nt_{it} + \beta_5 Disaster_{i,t-5}^{k} + \mu_i + \eta_t + \varepsilon_{it} \quad (2)$$

$$\mu_i \sim i.i.d\left(0, \sigma_{\mu_i}\right), \varepsilon_{it} \sim \text{i.i.d.}(0,\sigma_{\varepsilon}), E[\mu_i \varepsilon_{it}] = 0.$$

The definitions and sources of the variables are as follows:

- FDI^j_{it} – this refers to the net *inflows of FDI* as a share of GDP in natural logarithm form; the "*j*" superscript is an index, indicting the sector, *j* = 1, 2, corresponding to manufacturing and services sectors, respectively[5]. The statistical properties of the sectoral FDI by regions are presented in Table II.
- GDP_{it} *– growth rate of GDP per capita* in 2005 US$, purchasing power parity is a proxy for host country market size. This variable is instrumented with a GMM-style matrix to avoid potential endogeneity and reverse causality. The variable is sourced from world development indicators.
- $Demo_{it}$ *– democratic accountability* is a variable associated with the quality of institutions. Democratic accountability is evidence for the presence of checks and balances in the government, specifically in the executive, legislative and judicial branches, as well as of for protection of personal liberties. It is compiled in the International Country Risk Guide (ICRG)[6].
- $\text{NatRent}_{\text{it}}$ – *natural resources rents share of the GDP*. Rents are generated by coal, forest, mineral, natural gas and oil resources. These are estimates based on sources and methods described in "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium" (World Bank, 2011). We hypothesize that the natural resources endowments impact differently FDI inflows to different sectors.
- *Disasters – natural disasters occurrences* variables are the key explanatory variable, sourced from International Disaster Database EM-DAT[7]. The superscript *"k"* is an index of type of natural disaster, with k=1 to 4 for the four types of disasters. *Meteorological disasters* include extreme temperatures and storms. *Climate disasters* include wild fires and droughts. *Hydrological disasters* include disturbances, caused by movement of surface and subsurface fresh and saltwater. *Geophysical disasters*

Variable	obs	Mean	Std. dev	Min	Max
All countries					
Man. FDI	1,933	2,535.154	9,060.977	−37,967.4	143,274
Ser. FDI	1,732	5,902.806	21,071.99	−52,944.7	415,035
WE					
Man. FDI	482	2,718.082	6,390.076	−37,967.4	52,131.3
Ser. FDI	373	13,681.74	35,794.84	−52,944.7	415,035
EECA					
Man. FDI	299	955.4091	2,638.583	−13,521.5	31,948
Ser. FDI	285	2,639.155	6,152.292	−952.42	67,350
SEAP					
Man. FDI	408	2,778.984	7,916.663	−3,268.86	52,100.5
Ser. FDI	359	4,944.624	12,013.67	−7,328.75	92,406.9
LAC					
Man. FDI	527	988.6761	2,965.329	−2,959	31,664
Ser. FDI	509	1,208.069	3,294.806	−979	30,454

Table II. Sectoral FDI inflows (million US$), summary statistics by regions include landmass movements, earthquakes and volcanic activity. We account for the number of disaster occurrences.

- The variables μ_i and η_t are country and time-specific effects, respectively[8]. The country-specific effects are fixed (within-group) effects. The alternative random effects assume an independent distribution of the explanatory variables from the individual effects. This assumption is violated between $FDI^j_{i,t-1}$ and μ_i.

The method we choose for this study is a dynamic Blundell–Bond "system" GMM estimator. The Blundell–Bond system GMM uses lagged-level observations as instruments for differenced variables and lagged differenced observations as instruments for level variables using a matrix of "internal" instruments. It has one set of instruments to deal with the endogeneity of some regressors and another set to deal with the correlation between the lagged dependent variable and the induced MA(1) error term. A necessary condition for the "system GMM" is that the error term should not be serially correlated of the second-order; otherwise, the standard errors of the instrument estimates grow without bound[9]. Second-order autocorrelation in the error term: $E\left[FDI^j_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})\right] = 0$; $E\left[GDP_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})\right] = 0$; $E[x_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})] = 0$; $E\left[Disaster^k_{i,t-s}(\varepsilon_{it} - \varepsilon_{i,t-1})\right] = 0$ for $s \geq 2$ and $t = 3, \ldots, T$.

The "system GMM" estimator requires one additional condition: even if the unobserved country-specific effect is correlated with the levels of the regressors, it should not be correlated with their differences. The second set of conditions are: $E\left[\left(FDI^j_{i,t-1} - FDI^j_{i,t-2}\right)(\mu_i + \varepsilon_{it})\right] = 0$; $E[(GDP_{i,t-1} - GDP_{i,t-2})(\mu_i + \varepsilon_{it})] = 0$; $E[(x_{i,t-1} - x_{i,t-2})(\mu_i + \varepsilon_{it})] = 0$; $E\left[\left(Disaster_{i,t-1} - Disaster^k_{i,t-2}\right)(\mu_i + \varepsilon_{it})\right] = 0$ [10].

The condition also means that the deviations of the initial values of the independent variables from their long-run values should not be systematically related to the country-specific effects[11].

5. Empirical results

A summary of the key regression coefficients is provided in Table III[12]. The table contains the regression estimates of natural disaster coefficients for all categories of disasters by region. The estimated contemporaneous and lagged effects of disasters are presented in sequential rows, with odd-numbered rows showing contemporaneous and even-numbered rows showing lagged effects coefficients. The pair of contemporaneous-lagged coefficients is being referred to as a "block."

Panels 1 and 2 present results regarding manufacturing and services FDI, respectively. Along the rows, coefficients of four types of disasters as follows: metrological; climate, hydrological and geophysical disasters are presented, paired with the coefficients of the lagged disasters. The geographical regions covered correspond to the Column 1-all countries; Column 2-West Europe; Column 3-Eastern Europe and Central Asia; Column 4-South and East Asia and the Pacific; and Column 5-Latin America and the Caribbean. The full regression results for "All countries" are displayed in Tables IV and V.

As predicted by theory, the contemporaneous effects of natural disasters on FDI are negative. The first row of each block of regression coefficients in Table III presents estimates of contemporaneous disasters, respectively, for manufacturing and for services FDI. An overview of manufacturing FDI regressions shows a pattern of contemporaneous disasters having a negative impact in some geographical regions while lagged disasters, disasters occurring five

Table III. Summary of regression coefficients for contemporaneous and lagged natural disasters

Disaster type	(1) All countries	(2) West Europe	(3) Eastern Europe and Central Asia	(4) South and East Asia and the Pacific	(5) Latin America and the Caribbean
Manuf. FDI (Panel 1)					
(1) Meteorological disasters	*−0.126** (0.0644)*	−0.183 (0.349)	*−1.401*** (0.304)*	−0.114 (0.0878)	−0.0199 (0.141)
(2) Lagged meteorological disasters	−0.0746 (0.0606)	−0.213 (0.399)	*−1.680*** (0.213)*	0.0559 (0.102)	−0.0763 (0.113)
(3) Climate disasters	*−0.253** (0.126)*	0.453 (0.320)	−0.0835 (0.246)	−0.0564 (0.0527)	−0.407 (0.500)
(4) Lagged climate disasters	−0.118 (0.152)	*0.901*** (0.234)*	0.0191 (0.277)	−0.0478 (0.0661)	0.239 (0.249)
(5) Hydrological disasters	−0.0344 (0.102)	0.130 (0.230)	−0.157 (0.194)	0.0716 (0.0550)	−0.0169 (0.0805)
(6) Lagged hydrological disasters	0.0238 (0.0829)	*0.466* (0.264)*	0.161 (0.235)	−0.0693 (0.0651)	−0.138 (0.101)
(7) Geophysical disasters	0.0428 (0.174)	*−0.290*** (0.000)*	*−0.789*** (0.213)*	0.0905 (0.188)	−0.267 (0.389)
(8) Lagged geophysical disasters	0.0348 (0.111)	*1.363*** (0.322)*	*0.500** (0.252)*	0.118 (0.229)	*0.835* (0.440)*
Services FDI (Panel 2)					
(1) Meteorological disasters	−0.0700 (0.0504)	−0.0391 (0.190)	0.0655 (0.670)	−0.0641 (0.121)	0.102 (0.104)
(2) Lagged meteorological disasters	−0.0380 (0.0536)	0.356 (0.254)	−1.099 (0.786)	−0.0153 (0.101)	0.00718 (0.193)
(3) Climate disasters	*−0.177** (0.0855)*	−0.0174 (0.348)	0.334 (0.418)	*−0.180** (0.0753)*	−0.327 (0.292)
(4) Lagged climate disasters	−0.106 (0.0852)	−0.192 (0.321)	−0.374 (0.452)	−0.0813 (0.0704)	*−0.371** (0.170)*
(5) Hydrological disasters	−0.0878 (0.0847)	0.102 (0.117)	−0.236 (0.233)	0.00544 (0.129)	*−0.252*** (0.0939)*
(6) Lagged hydrological disasters	−0.174 (0.116)	*−0.740*** (0.248)*	−0.0388 (0.272)	0.00561 (0.139)	*−0.192** (0.0949)*
(7) Geophysical disasters	−0.0656 (0.0756)	*0.316*** (0.000)*	*−13.06*** (1.96e − 10)*	0.0437 (0.0551)	−0.00727 (0.247)
(8) Lagged geophysical disasters	−0.102 (0.110)	*0.152*** (1.25e−10)*	−1.255 (1.419)	*0.0615* (0.0342)*	−0.163 (0.172)

Notes: Robust standard errors in parentheses; ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table IV. Manufacturing FDI and disasters, sample of "all countries"

Variables	(1) Contemp. metrological disasters	(2) Lagged metrological disasters	(3) Contemp. climate disasters	(4) Lagged climate disasters	(5) Contemp. hydrological disasters	(6) Lagged hydrological disasters	(7) Contemp. geophysical disasters	(8) Lagged geophysical disasters
Lag, ln (FDI Manuf	0.594***	0.493***	0.503***	0.460***	0.315**	0.206	0.214*	0.642***
Share of GDP)	(0.116)	(0.127)	(0.183)	(0.141)	(0.154)	(0.183)	(0.121)	(0.0703)
Growth rate, GDP per cap, 2005 USD$, purchasing power	−1.151	−0.274	−3.850	−0.567	3.658	−1.733	2.181	−2.587
parity	(3.410)	(2.354)	(4.183)	(2.814)	(2.498)	(4.236)	(5.288)	(4.583)
Natural Resources	0.0113	0.00225	0.0155*	0.00531	0.00640	0.00997	0.0167	0.00190
Rent, share of GDP	(0.00968)	(0.00927)	(0.00932)	(0.00643)	(0.00720)	(0.00801)	(0.0126)	(0.00758)
Democratic	−0.0157	−0.0466	−0.0237	−0.0392	0.00491	−0.0352	−0.0724	−0.00752
Accountability	(0.0422)	(0.0535)	(0.0693)	(0.0550)	(0.0592)	(0.0798)	(0.109)	(0.0754)
Ln (disaster	*−0.126***	−0.0746	*−0.253***	−0.118	−0.0344	0.0238	0.0428	0.0348
occurrence)	*(0.0644)*	(0.0606)	*(0.126)*	(0.152)	(0.102)	(0.0829)	(0.174)	(0.111)
Constant	−1.992***	−2.622***	−2.353**	−3.274***	−3.996***	−4.267***	−3.782***	−1.991***
	(0.757)	(0.747)	(1.086)	(0.904)	(0.902)	(1.078)	(0.865)	(0.612)
Observations	483	464	388	355	655	591	222	229
Number of countries	67	69	68	67	74	73	42	43
AR(2)	0.591	0.075	0.035	0.224	0.044	0.190	0.348	0.209
Sargan χ^2	88.93***	184.75***	113.81***	107.37***	164.36***	188.94***	165.09***	143.21***

Notes: Robust standard errors in parentheses; ***$p < 0.01$; **$p < 0.05$; * $p < 0.1$

Table V.
Services FDI and disasters, sample of "all countries"

Variables	(1) Contemp. metrological disasters	(2) Lagged metrological disasters	(3) Contemp. climate disasters	(4) Lagged climate disasters	(5) Contemp. hydrological disasters	(6) Lagged hydrological disasters	(7) Contemp. geophysical disasters	(8) Lagged geophysical disasters
Lag, ln(FDI Services	0.776***	0.720***	0.660***	0.734***	0.746***	0.648***	0.396***	0.523***
Share of GDP)	(0.0783)	(0.116)	(0.110)	(0.0850)	(0.100)	(0.181)	(0.117)	(0.139)
Growth rate, GDP per cap, 2005 US$, purchasing power	−2.147	−2.360	−6.773*	−2.975	−0.247	1.501	−2.011	−0.236
parity	(3.046)	(3.597)	(3.834)	(3.308)	(2.322)	(1.822)	(3.555)	(3.118)
Natural Resources	0.00642	−0.00816	0.0272**	0.00642	0.00328	−0.00235	0.0171	−0.00580
Rent, share of GDP	(0.0112)	(0.00994)	(0.0109)	(0.00837)	(0.00696)	(0.00841)	(0.0118)	(0.0102)
Democratic	−0.00103	−0.0417	0.0644	−0.0136	0.0280	0.00878	−0.0610	−0.0366
Accountability	(0.0321)	(0.0326)	(0.0573)	(0.0483)	(0.0383)	(0.0324)	(0.0441)	(0.0438)
Ln (disaster	−0.0700	−0.0380	*−0.177***	−0.106	−0.0878	−0.174	−0.0656	−0.102
occurrence)	(0.0504)	(0.0536)	*(0.0855)*	(0.0852)	(0.0847)	(0.116)	(0.0756)	(0.110)
Constant	−0.818	−0.533	−2.856***	−2.128	−1.641***	−1.677*	−1.764***	−1.050
	(0.689)	(0.805)	(0.776)	(1.629)	(0.528)	(0.924)	(0.488)	(0.675)
Observations	385	368	299	282	521	492	181	192
Number of countries	67	65	60	62	65	66	33	38
AR(2)	0.909	0.346	0.441	0.204	0.214	0.214	0.620	0.663
Sargan χ^2	155.06***	91.92***	118.85***	133.43***	68.55***	136.78 ***	116.59***	148.22***

Notes: Robust standard errors in parentheses; ***$p < 0.01$; **$p < 0.05$; * $p < 0.1$

years prior, stimulate FDI. Meteorological disasters (Panel 1, Block 1) have negative effects on manufacturing FDI in the regions Eastern Europe and Central Asia and "all countries" (Panel 1, Block 1, Row 1, Columns 1 and 3). The negative effect in Eastern Europe and Central Asia countries does not disappear in the long run. Five years past the disaster, the effect is still present (Panel 1, Block 1, Row 2, Column 3).

There is a negative contemporaneous effect of climate disasters when "all countries" are considered together (Panel 1, Block 2, Row 3, Column 1). Five years past the climate and hydrology disasters, however, industrialized countries of Western Europe recover and increase their manufacturing FDI inflows. The lagged effect of these disasters on manufacturing FDI in Western Europe is positive (Panel 1, Blocks 2 and 3, Rows 4 and 6, Column 2). This is evidence that developed economies have the potential to overturn droughts and floods and rebuild their FDI capacity.
Likewise, geophysical disasters (earthquakes, landslides and volcano eruptions) have immediate negative effects on FDI in the manufacturing sectors in West Europe and in the Eastern Europe and Central Asia countries (Panel 1, Block 4, Row 7, Columns 2 and 3). However, the lagged effects, i.e. the effects five years after the disaster are positive in these countries (Panel 1, Block 4, Row 8, Columns 2 and 3). Therefore, geophysical disasters present some opportunity for rebuilding FDI capacity when other internal conditions are right. In addition, lagged geophysical disasters present a positive opportunity for attracting FDI flows in the process of rebuilding in Latin America and the Caribbean, too (Panel 1, Block 4, Row 8, Column 5).

Overall, manufacturing FDI, which consists of a bigger share of tangible capital assets, appears to suffer from an initial negative impact of natural disasters and recover over time to turn disaster destruction into opportunity for more investment. While climate and hydrology disasters opportunities appear to be used primarily by the countries of West Europe, which are both, economically developed, and geographically less exposed to droughts and floods than some other world regions, the opportunities created by the geophysical disasters arguably the most detrimental kind, appear to be captured by foreign investors in Eastern Europe and Central Asia and Latin America and the Caribbean.

The broad FDI inflow that we analyze is services FDI (Table III , Panel 2). Services FDI can be characterized with a large intangible investment component that we hypothesize, could be less sensitive to disasters. The reaction of services FDI to natural disasters appears to be different from that of manufacturing FDI inflows. First, meteorological disasters appear not to have an impact on services FDI in either contemporaneous or longer term (Panel 2, Block 1, Rows 1 and 2). Unlike the case of manufacturing FDI inflows, climate and hydrology disasters do not a positive effect on services FDI in the long run in any of the geographical regions. Climate disasters appear to produce a negative immediate effect on services FDI in the South and East Asia and the Pacific region that is also seen when all countries are considered together (Panel 2, Block 2, Row 3, Columns 1 and 4). At the same time, climate disasters have a negative lagged effect on services FDI in Latin America and the Caribbean region (Panel 2, Block 2, Row 4, Column 5).

Meanwhile, there is evidence about the detrimental effects of hydrological disasters on services FDI in the Latin America and the Caribbean region, both contemporaneous and lagged coefficients are negative and significant in this region (Panel 2, Block 3, Rows 5 and 6, Column 5). This points to a lack of investment recovery from flood disasters even in the long run. Similar is the situation with West Europe where the long run impact of flood disasters on services FDI is also negative (Panel 2, Block 3, Row 6, Column 2). For West

European countries services FDI are a big share of aggregate FDI inflows and the services sector, in general, plays a bigger role in their economies.

Finally, we analyze the arguably most catastrophic natural disaster group – the geophysical disasters (Panel 2, Block 4). With this group of disasters, which notably included earthquakes and landslides, similarly to manufacturing FDI, we do see some positive impact on services FDI in the long run. First, the imminent impact appears to be mixed- it presents some opportunities for FDI growth in West Europe, but it is negative for services FDI in Eastern Europe and Central Asia (Panel 2, Block 4, Row 7, Columns 2 and 3). The lagged effect of geophysical disasters, however, appears to present an opportunity for more FDI in the tertiary sector for the countries of two regions, such as West Europe and South and East Asia and the Pacific (Panel 2, Block 4, Row 8, Columns 2 and 4).

In summary, the effects of natural disasters on manufacturing and services FDI appear to have some nuances. Manufacturing FDI shows a pattern of being negatively affected immediately after the disaster and use the disaster as an opportunity of rebuilding in a longer term, such as five years. Services FDI do not show such pattern. Some disasters, such as meteorological, have no effect and some, such as climate and floods, have long-lasting negative effects on tertiary sector FDI. For both types of FDI flows manufacturing and services, there is one common theme – the most destructive disasters, the geophysical disasters, have a positive impact on FDI in the long run. This appears to be the case with manufacturing FDI to West Europe, East Europe and Central Asia, and Latin America and the Caribbean and the case with services FDI to West Europe and South and East Asia and the Pacific.

6. Conclusion

In the current study, we investigate the question about the pattern of FDI in a post-natural disaster period, considering a time span of one year and five years. We differentiate between the reaction of manufacturing sector FDI inflows and services sector FDI inflows, which account, respectively, for tangible physical assets and intangible knowledge assets technology transfer. This is the first study that merges the widely-used EM-DAT data set on natural disasters with sector-level data for FDI for 69 countries for 1980-2011 and analyze the response of FDI with a dynamic panel methodology. It is also the first study that both, distinguishes between different kinds of natural disasters as follows: meteorological, climate, hydrological and geophysical, and between different geographical regions such as West Europe, Eastern Europe and Central Asia, South and East Asia and the Pacific, and Latin America and the Caribbean.

Controlling for commonly accepted determinants of FDI, such as output growth, quality of institutions and natural resource abundance, we find that manufacturing FDI shows a pattern of being negatively affected immediately after the disaster and positively in the longer run – a finding that is in unison with the "upgrading destruction" hypothesis we are testing. Services FDI, on the other hand, does not show such pattern. Meteorological disasters have no effect on services FDI and climate and hydrological disasters have long-lasting negative effects. For both types of FDI flows, manufacturing and services, geophysical disasters have a positive impact on FDI in the long run. This appears to be the case with manufacturing FDI to West Europe, East Europe and Central Asia, and Latin America and the Caribbean and the case with services FDI to West Europe and South and East Asia and the Pacific.

The evidence for "upgrading destruction" by natural disasters means replacement of old capital assets and outdated technologies with more advanced one. This means increased productivity in the long run. A capital upgrading also means an increase of wealth for households in the long run. However, all of this is conditioned on proper disaster risk management and disaster preparedness. Countries that are on the path of predictable and repetitive natural disasters are like to suffer from them on a continuous basis. Therefore, all possible capital improvements that follow a disaster should be "locked in" by preventing a severe impact by the next one. Foreign capital, and FDI in particular, help not only by supplying a means of financing but also by building new facilities and infrastructure that are better equipped to withstand the blows of nature.

FDI is one of the main sources of financing for developing countries. FDI is impacted by climate change. The intensifying and increase of frequency of natural disasters not only presents a challenge but also an opportunity for attacking FDI. The destruction of infrastructure and displacement of people result in a negative initial impact and a positive long-run impact of some disasters. Governments need to take advantage of the opportunities created by the need for the replacement and rebuilding of infrastructure and intangible capital. With proper incentives and industry-specific targeted policies, rebuilding can result in upgrading. FDI can be attracted in a targeted way to bring in the necessary external capital and advanced technological knowledge to make upgrading possible.

Notes

1. The list of countries is available in the Appendix.
2. Unavailability of sectoral FDI data for both, the Middle East and North Africa and the Sub Saharan Africa regions, prevents us from including these regions in the study.
3. For example, the conclusion of Horwich (2000) that the economic devastation of the 1995 Kobe earthquake in Japan is not very large in magnitude is based a limited number of post-disaster years.
4. Because of lack of sectoral FDI data, we have excluded the African region from the study.
5. Manufacturing refers to industries belonging to the International Standard Industrial Classification (ISIC), revision 3, divisions 15-37. Services correspond to ISIC divisions 50-99. Services include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services, such as education, health care and real estate services. Also, included are imputed bank service charges, import duties and any statistical discrepancies noted by national compilers, as well as discrepancies arising from rescaling. The source for these data are a proprietary data set, complied by United Nations Conference on Trade and Development (UNCTAD) and Division of Investment and Enterprise.
6. The working definition of democracy that ICRG uses includes, for example, the following features: a government/executive that has not served more than two successive terms; free and fair elections for the legislature and executive as determined by constitution or statute; active presence of more than one political party and a viable opposition; evidence of checks and balances among the three elements of government, namely, executive, legislative and judicial; evidence of an independent judiciary; and evidence of the protection of personal liberties through constitutional or other legal guarantees, reflects how responsive government is to its people, on the basis that the less responsive it is, the more likely it is that the government will fall, peacefully in a democratic society, but possibly violently in a non-democratic one (ICRG).
7. EM-DAT database D. Guha-Sapir, R. Below, Ph. Hoyois – EM-DAT: The CRED/OFDA International Disaster Database – www.emdat.be – Université Catholique de Louvain – Brussels – Belgium.
8. The year-dummy are not reported because of space constraints.
9. By construction, the differenced error term is first-order serially correlated even if the original error term is not.

10. x is a vector of the control variables: $Demo_{it}$ and N at $Rent_{it}$.
11. The regressions are run on Stata 14, using the command "xtabond2" and creating instruments with the "ggmstyle" option with two-lag instruments. This is a procedure for reducing the number of instruments suggested by Roodman (2009).
12. The full regression results for the sample of "all countries" are presented in Tables IV and V.

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Appendix

All countries: Albania, Argentina, Australia, Austria, Bangladesh, Belgium, Belize, Bolivia, Brazil, Brunei Darussalam, Bulgaria, Canada, Chile, China, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, El Salvador, Estonia, Finland, France, Germany, Greece, Guyana, Honduras, Hungary, Iceland, India, Indonesia, Italy, Jamaica, Japan, Kazakhstan, Korea

Rep., Latvia, Lithuania, Macedonia FYR, Malaysia, Mexico, Netherlands, Nicaragua, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Thailand, Trinidad and Tobago, Turkey, Ukraine, UK, USA, Uruguay, Venezuela and Vietnam.

Western Europe: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Netherlands, Norway, Portugal, Spain, Sweden and UK.

Eastern Europe and Central Asia: Albania, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, FYR, Poland, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia and Ukraine.

South and East Asia and the Pacific: Australia, Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Japan, Korea, Dem. Rep., Lao PDR, Malaysia, Pakistan, Philippines, Singapore, Thailand and Vietnam.

Latin America And the Caribbean: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Dominican Republic, Ecuador, El Salvador, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Peru, Trinidad and Tobago and Uruguay.

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