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Natural Disaster Mitigation in Developing Countries:

The Role of Trade Openness

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Abstract

Employing fixed effects estimations in a panel of 137 countries over 37 years, this study empirically investigates the relationship between trade openness and natural disaster fatality rates in developing countries. The findings suggest that trade openness reduces fatality rates from natural disasters in general in the developing world, and in particular losses resulting from earthquakes, storms and extreme temperature disasters. Specifically, our estimates suggest that for developing countries, increasing the trade ratio by 10% is significantly associated with a 2-3% reduction in subsequent natural disaster fatality rates. Building upon the initial findings, the analysis further suggests that the mitigating effect of trade openness on natural disaster losses arises from knowledge- and technology transfers, international collaboration, and improvements of infrastructure and investment climate. The established reduction in fatalities from trade openness is robust to various specifications; however, the extent to which trade openness mitigates losses depends on disaster type and country-specific features such as development level, degree of democracy and the efficiency of the public sector. The central policy implication of our findings is that trade policy may be a potential tool for developing countries to mitigate natural disaster risk without compromising economic development.

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1. Introduction

Over the course of the last century, natural disasters are estimated to have killed as many people as the two World Wars combined (Cohen & Werker, 2008). Over the period 1980-2016, about 10,500 reported natural disasters have resulted in about 2.4 million deaths and have caused around $2.9 trillion worth of direct economic damage (EM-DAT).[1] In 2017 alone, about 350 natural disasters claimed the lives of close to 10,000 people and caused economic losses of about $317 billion dollars (EM-DAT). Notably, recent empirical evidence suggests that those most affected by natural disasters are the world's poorest individuals (Sawada & Takasaki, 2017). In fact, 93% of all natural disaster deaths since 1980 happened in developing countries (EM-DAT), despite the geographical distribution of both frequency and intensity of hazards not being concentrated to these (Kahn, 2005; Strömberg, 2007; Sawada & Takasaki, 2017).

Fortunately, natural disaster risk reduction has become an important priority for policy-makers all over the world. Despite extreme weather events becoming more frequent and intense over time (Raschky, 2008; Cavallo & Noy, 2010; Field, Barros, Stocker & Dahe, 2012), reported deaths from such events have decreased globally, indicating generally improved natural disaster mitigation. Crucially, however, this downward trend in fatalities is mostly driven by high-income countries, whilst low- and middle-income countries fall behind.[2] Mitigation of natural disasters in developing countries is thus among the priorities on the global development agenda, with both local governments and multilateral efforts dedicated to the cause.

Since natural disasters can be studied econometrically as random shocks, there is an extensive literature on the impact and consequences of natural disasters on a plethora of variables like economic growth (Noy, 2009; Felbermayr & Gröschl, 2014), employment and wages (Belasen & Polachek, 2008) and even fertility rates (Nandi, Mazumdar & Behrman, 2018). However, and despite the immense harm caused by hazardous events, there is only a small body of literature investigating what factors determine the gravity of the impact of

[1] EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium. The majority of the existing literature uses this database.

[2] As defined by the World Bank's classification of development levels. (World Bank, 2018)

natural disasters. In other words, relatively few studies ask which economic or institutional factors determine the severity of losses and damages accrued from natural disasters.

The majority of the existing studies around this question concentrate on examining the relationship between disaster-induced losses and GDP per capita. These are grounded in the hypothesis that the development of a country should eventually lead to enhanced capacity in managing disaster risk. Indeed, the general consensus in the literature seems to be in support of this hypothesis (Khan, 2005; Strömberg, 2007; Toya & Skidmore, 2007; Raschky, 2008, Wen & Chang, 2015). However, these studies mainly examine the global risk–development nexus, without specifically investigating developing countries. In fact, important additions to this literature suggest a negative relationship between economic development and disaster risk reduction in the low- and lower-middle income countries (Kellenberg & Mobarak, 2008; Schumacher & Strobl, 2011). This might be a result of these countries often favoring short-term economic gain over costly disaster mitigation (Kellenberg & Mobarak, 2008; Neumayer, Plümper & Barthel, 2014). Researchers and policy-makers do not yet fully understand the drivers of the losses, and consequently have no evident solution for how developing countries in particular can mitigate disaster risk without compromising economic development.

This study serves to explore a potential determinant of the losses from natural disasters in developing countries that has not been thoroughly studied yet, and which evidently is a function of various policy choices; the trade openness of a country. Specifically, for developing countries, trade openness could affect mitigation of natural disaster impact through, for example, technology transfers, access to capital inflows, exports revenues and humanitarian aid (Benson & Clay, 2003; Toya & Skidmore, 2007; Strömberg, 2007). In addition, there is an extensive body of literature documenting positive effects of increased trade openness on economic growth, and on the reduction of poverty and inequality (Dollar & Kray, 2001; Felbermayr & Gröschl, 2013; Edwards, 1997; Frankel & Romer, 1999). Taking these two points together, if openness indeed reduces the natural disaster risk of countries, openness could be a driver for both simultaneously: natural disaster mitigation *and* economic development.

The objective of this thesis is to contribute to the literature on determinants of natural disaster fatalities in developing countries, thereby adding to the current understanding of how macroeconomic policy choices affect disaster risk. Based on the existing literature, the main objective of this thesis is to empirically investigate the following research question: *Does economic openness reduce the death toll from natural disasters in developing countries?*

We investigate this question using a country-year panel dataset on natural disaster fatalities and macroeconomic and governance indicators, in the 137 nations defined as low- and middle-income countries by the World Bank that reported natural disasters during 1980-2016. Applying fixed effects- and hybrid estimations, we find that increasing trade openness by 10% is associated with a reduction in fatality rates of about 2-3%.[3] This result remains robust to different specifications. The study first discusses the various mechanisms through which trade openness might affect natural disaster mitigation. Furthermore, more detailed analysis of sub-samples and interacting factors are conducted to strengthen the understanding of this overall result. This thorough discussion next to the detailed analysis on trade openness and the emphasis on the developing world are both new to the literature. Lastly, the study provides policy implications for developing countries on how they can mitigate risk without compromising economic development.

The remainder of the thesis is organized as follows. Section 2 presents key terminology for clarifications purposes and reviews the literature on disaster risk mitigation, identifying the deficiencies covered by this study. This section also elaborates on the mechanisms through which trade openness might affect natural disaster risk, drawing on both theory and empirical findings. In Section 3 we describe our empirical strategy, and Section 4 describes our data. We present the results in Section 5, along with robustness checks. Finally, Section 6 discusses the findings in light of the previously presented literature and mechanisms and provide policy implications, whilst Section 7 concludes.

[3] Measured as the trade ratio: Imports plus Exports divided by GDP.

2. Background Information

2.1 Terminology

As there are different ways of defining natural disaster risk and its components, we will for the purposes of this study, employ the terminology provided by the United Nations Office for Disaster Risk Reduction definitions (UNISDR, 2017).

As a preliminary remark, it is useful to distinguish between the three following concepts: natural phenomena; natural hazards; and, natural disasters. These three terms refer to, respectively: a natural process taking place; a natural process posing a threat to human life or capital, and; the natural process overwhelming the society's capacity to cope with its harmful consequences (Raschky, 2008). As such, whether a natural hazard evolves into a *natural disaster* depends on societal factors captured by exposure, vulnerability and capacity, as defined as follows: *Exposure* defines the degree to which people and tangible assets are located in hazard-prone areas. *Vulnerability* refers to the physical, social, economic and environmental factors that determine the likelihood of a hazard negatively impacting the society. Poverty, unsafe construction, and lack of regulations are among these. *Capacity* refers to the ability to manage disaster risk by use of tangible and intangible resources available (UNISDR, 2017).

Natural disaster risk is defined as the probability of loss or damage to life or assets due to natural hazards taking place (UNISDR, 2017). It is a positive function of a location's inherent likelihood of natural hazards occurring, as well as exposure and vulnerability. Furthermore, the society's capacity to mitigate the effects of a hazard, reduce disaster risk (UNISDR, 2017).

From these concepts it follows that a society can influence natural disaster risk through different approaches. *Mitigation* of natural disaster risk refers to efforts directed at minimizing the damages of a disaster both before it strikes (*prevention and preparedness*), and through established action plans for how to effectively cope during, and shortly after, a disaster takes place (*capacity or crisis management*) (UNISDR, 2017).[4] By actively implementing mitigating measures such as relevant physical constructions, forecasting, and policies explicitly aimed at reducing the impacts of natural hazards, a society reduces disaster risk (UNISDR, 2017). Sometimes, a society can *prevent*, that is avoid, a disaster by reducing exposure through relocation (UNISDR, 2017). In this thesis, we address mitigation understood as factors that decrease *exposure* and *vulnerability* or increase *capacity*.

2.2 Economic and Political Determinants of Disaster Risk

The existing literature on natural disasters is mainly concerned with the effects of natural disasters on a country's economy and institutions. However, the specific literature of interest to the paper at hand relates to the pre-disaster economic and institutional factors that are assumed to mitigate losses when natural disasters take place. Although the body of literature on this topic has grown considerably over the past decades, it is still limited in scope. For the reader to better understand the relations between this study and the existing literature, this section presents the most prevailing studies on determinants of natural disasters losses. However, literature concerned with the role of trade openness as a mitigating factor specifically, is saved for the next section, which presents these in relation to theory and literature on trade openness.

The most cited piece of work in the field of natural disaster mitigation is written by Khan (2005), who studies the effect of countries' GDP level, institutions and geography on natural disaster fatalities. Employing data on reported fatalities from the EM-DAT database, he provides evidence that wealth, democracy and strong institutions reduce the death toll of natural disasters, whilst inequality seems to have a worsening effect on the severity of the effects of natural disasters. He hypothesizes that the mitigating effect of stronger institutions, in the form of various measures such as stronger rule of law and lower corruption, which should for example facilitate the establishment and enforcement of building codes and zoning laws restricting people from living in high-risk areas. As will be discussed, the effects of trade openness on natural disaster risk presumably depend on institutional strength.

[4] It should be noted that the above definition of *mitigation* presents how the term is understood and used in natural disaster literature. The same term exists in climate literature, where it refers to reduction of greenhouse gas emissions, and these should not be confused.

Following the work of Kahn (2005), several papers on the determinants of natural disaster risk were published, mainly focusing on the same elements. Most of these studies arrive at the same conclusion regarding the effect of income on the death toll resulting from natural disasters (Strömberg, 2007; Toya & Skidmore, 2007; Raschky, 2008; Wen & Chang, 2015). However, there are important additions to these papers, which suggest a non-linear relationship between income and fatalities resulting from natural disasters. In particular, fatalities seem to *increase* with GDP per capita for the poorest nations before decreasing once a certain development level is reached (Kellenberg & Mobarak, 2008; Schumacher & Strobl, 2011). Kellenberg & Mobarak (2008) suggest a theoretical mechanism in which this finding is explained by behavioral decisions. In particular, they argue that in the poorest nations, citizens will favor consumption over low risk exposure, and thus, for example, settle in hazard-prone areas if these areas provide the scarce employment opportunities. Similarly, governments might prefer, or be financially bound to accept, the short-term revenues of new economic activity, regardless of the effect these activities have on natural disaster risk (e.g. through deforestation, resulting in degradation). The studies by Kellenberg & Mobarak (2008) and Schumacher & Strobl (2011) both suggest that amongst the subset of developing or least developed countries, increased income may initially not be associated with better preparation against natural disasters and lower fatality rates. In the same way, the relationship between trade openness and risk mitigation might depend on development level.

Anbarci, Escaleras & Register (2005) confirm Kahn's (2005) finding that inequality is associated with an increase of fatality rates from natural disasters. Kahn (2005) explains his finding through how an increase in inequality, when controlling for population size and GDP per capita, indicates that more people are living in poverty. Since the very poor in general have lower capacity to cope with natural hazards, and often live more exposed, they experience a higher disaster risk. Closely related, Anbarci et al. (2005) argue that the political system in highly unequal countries frequently serves a small elite rather than the poor. These countries are therefore likely to lack the collective actions needed to enforce, for example, building codes and licenses that could mitigate the effects of natural disasters. These findings relate to how trade openness may reduce risk through reducing the level of inequality (Dollar & Kraay, 2004), and will thus be elaborated on in the next section.

Strömberg (2007) empirically finds a mitigating effect of democracy and government effectiveness. He explains the effect of democracy by associating it with civil liberties, which indicates a more responsible government, and a free press resulting in a better-informed population. Connected to this is the empirically found importance of people's ability to attain and process information. For instance, Toya and Skidmore (2007) find that education decreases natural disaster losses in developing countries, and suggest it leads to better decisions on for example housing location and construction quality. Flores and Smith (2013) explain the mitigating effect of being a democracy with the leader's dependency on political support. They claim that governments in large coalitions are more likely to support the whole population with mitigating measures because it is nearly impossible to distinguish supporters from non-supporters. Flores (2015) explicitly links the quality of mitigating measures to leadership survival, stating that democratic leaders will be more incentivized to invest in disaster mitigation. The author argues that the freedom of assembly in democracies is likely to induce protests resulting in changes of leadership if the administration does not protect their population from natural hazards. It might be that trade openness has a more beneficial effect on disaster risk if the government has the incentive to mitigate disasters.

Natural disaster protection is a public good, and it requires substantial initial costs for future, uncertain benefits. The investment will be worth it only *if* a disaster strikes and only *if* the investment works as expected. Thus, private actors and myopic governments underinvest in mitigation due to underestimating the probability of disaster (Camerer & Kunreuther, 1989; Neumayer et al., 2014). Other public goods that contribute to mitigation, such as investments in infrastructure (Vaillancourt & Haavisto, 2015), also tend to suffer from underinvestment in weak governments.[5] Acknowledging this market failure, the presented findings on the importance of strong institutions and governance are in line with what should be expected. Neumayer et al. (2014) argue that weak governments are not able to correct the market failures that arise from collective action problems, asymmetric information and shortsighted behavior. However, even countries with functional governments might underinvest in mitigation. Since regulations and investments, as explained earlier, depend on political support, there might be little incentive for protective measures when frequency and magnitudes of disasters usually are low (Neumayer et al., 2014). Confirming this assertion, Schumacher & Strobl (2011) find that citizens in hazard-prone countries are less vulnerable than inhabitants in countries where disasters are rare. When governments underinvest in protective measures, disaster mitigation depends more heavily on the private actors. A well-

[5] Unless otherwise stated, 'infrastructure' refers to physical infrastructure, such as roads, ports, etc. throuhgout this paper.

functioning financial system is likely to reduce the market failure, and result in safer and more long-term investments. Toya & Skidmore (2007) find that better financial system quality, measured as money supply as a ratio of GDP, reduces disaster losses. Thus, it is likely that trade openness reduce disaster risk, if it results in capital inflows.

Cohen & Werker (2008) present a theoretical model of how governments optimize disaster relief through investments in different levels of preventive or palliative measures, given the probability of disaster. They argue through the model and preliminary empirics that humanitarian aid distorts this choice and further deepen the problem of underinvestment in mitigation due to moral hazard. They conclude that international support might be more beneficial when it comes through technical transfer, rather than monetary funds. The importance of non-financial cooperation through knowledge transfers and increased technical capacity with respect to disaster risk reduction is emphasized by Djalante (2012). The potential effect of trade on humanitarian aid and international cooperation thus seem important.

There are several studies investigating how different features of governance affect disaster mitigation. For example, Wen & Chang (2015) find that right wing governments experience fewer losses, arguing that this is due to higher growth rates, which result in more revenue to invest in mitigation. Toya and Skidmore (2007) find that smaller governments (as measured by the ratio of expenditure to GDP) see less disaster losses, insinuating that this is due to higher efficiency in mitigation. Lastly, Escaleras & Register (2012) find that fiscal decentralization is a determining factor in reducing natural disaster deaths in developing countries, since the use of local knowledge in risk management improves the efficiency of allocated funds. The trade policies of governments are results of their preferences and features, thus the effect of trade openness likely depends on institutional features as well.

Lastly, geographical factors such as elevation, costal areal, size, and being landlocked, as well as societal factors like population, sector dependency and deforestation, have been shown to have the potential to affect the exposure to different natural hazards. For example, mangroves can protect costal villages from cyclones (Das & Vincent, 2009), and it is commonly known that tree roots hold the earth together and might prevent landslides (Benson & Clay, 2004). The death toll increases with land elevation (Escaleras & Register, 2012) and is higher when being a landlocked country, which in part is because non-landlocked countries are more accessible and receive more relief aid (Cohen & Werker, 2008). Population and geographic size are commonly used control variables in the empirical estimations, as larger and more populated countries are usually more exposed to natural hazards (Schumacher & Strobl, 2011; Guha-Sapir, Hargitt, & Hoyois, 2004). Furthermore, as agricultural land is often more vulnerable to hazards than assets in the form of physical or intellectual infrastructure, countries with economies reliant on agriculture are often more exposed than industry or service-based economies (Benson & Clay, 2004). Again, how these features relate to natural disaster risk might also affect how trade openness affects risk.

In conclusion, the literature does not yet sufficiently cover several interesting factors that possibly affect natural disaster risk. Examples of such are conflict, the economic sectors and trade openness. Moreover, the literature does not fully agree on the importance or direction of other key variables, such as the GDP level, democracy or inequality. Furthermore, few studies manage to control for the physical magnitude of hazard phenomena (Kousky, 2013), and since the key publications on mitigation were published about a decade ago, there seems to be a need for research that exploits more recent data. Lastly, studies covering disaster risk reduction in low-income countries specifically, are needed. These countries are less capable of coping with hazardous events due to, for example, limited technology and funds, and often suffer from weak institutions that are likely to struggle to correct market failures: Investments in risk reduction measures that are beneficial in the long run might not be in line with short-term priorities of economic growth. This highlights the need for more knowledge about policy options that can help developing countries mitigate natural disaster risk without compromising strategies for growth. Trade openness is an interesting feature that potentially contributes to both growth and mitigation in these countries, and that has not been studied thoroughly with respect to mitigation. Our research thus aims to cover a gap in the literature by both addressing developing countries specifically, and by studying the effect of trade openness. In addition, we use updated data, investigate sub-samples and potential contingencies on country-specific factors, and employ hybrid model estimations.

2.3 Trade Openness in Natural Disaster Mitigation

There are only a few studies considering the effect of trade openness on natural disaster risk. Wen & Chang (2015) control for trade in their investigation of the relationship between political orientation and natural disaster losses. In their estimates, the trade ratio significantly reduces risk; however, they do not comment on the finding. Toya & Skidmore (2007) also find that trade has a benign effect on natural disaster losses when performing OLS regressions, but they only briefly comment on the finding. Rather than looking at determinants of direct natural disaster losses, Noy (2009) investigates determinants of the change in GDP growth after a disaster. He finds that trade openness has a stabilizing effect on the economy: the negative impact of natural disasters on GDP growth is smaller in more open economies (Noy, 2009). Benson & Clay (2003) discuss the role of economic globalization on natural disaster risk through case studies of developing countries. However, they lack a comprehensive empirical analysis to support their arguments. Considering the lack of elaboration on the mechanisms through which trade openness might affect natural disaster risk, we dedicate this section to present such mechanisms. These are grounded in a combination of theoretical concepts and empirical findings on the effect of trade openness on several of the determinants of natural disaster risk presented in the previous section.

Trade openness itself refers to a country's trade ratio, the sum of exports and imports to GDP. However, the measure is associated with several factors closely related to it. Trade openness is positively associated with the inflow of foreign direct investment in developing countries in the long run (Liargovas, & Skandalis, 2012). Furthermore, it fosters technological transfers (WTO, 2003) and the inflow of human capital in the form of management practices and technological knowledge (Benson & Clay, 2003; Toya & Skidmore, 2007). Countries that trade more are also more likely to receive humanitarian aid (Strömberg, 2007). Furthermore, countries with higher trade ratios will often have actively engaged in trade facilitation activities (Wilson, Mann & Otsuki, 2004), which when broadly defined includes factors that have been shown to reduce natural disaster risk. Altogether, the size of the trade ratio of a country is likely to be closely correlated with various factors, thus reflect international inclusion in a broader sense. The degree of integration in turn may affect natural disaster risk through several possible mechanisms.

Composition of Economic Sectors

Increased participation in international trade can affect natural disaster risk through changing the economic structure of a country. In theory, opening up an economy can have two opposing effects on its composition: specialization or diversification, as evident within the theories of Heckscher-Ohlin and Rybczynski, respectively, and explained below. Whilst specialization increases the dependency on few products or sectors, thereby increasing vulnerability to hazards, diversification of products and sectors should decrease risk.

Benson & Clay (2004) discuss these two drivers behind the effect if increased participation in international trade on natural disaster losses using case studies of developing countries. In some of the cases under scrutiny, trade openness results in specialization, and increases dependency on a few sectors or products, in line with the Heckscher-Ohlin theorem (Heckscher & Ohlin, 1991). That is, when opening up the economy, it will produce and export more of the goods that rely on input factors it is abundant in (relative to other input factors) and will produce less in other sectors. Most developing countries have a comparative advantage in the production of goods that rely on agriculture or that require vast amounts of unskilled labor. Thus, for these countries, specialization often deepens the concentration on specific crops and simple, light manufactures (e.g. textiles), which may leave a country more vulnerable.

However, opening up the economy also results in improved access to initially scarce goods in these countries, such as capital, knowledge and improved technology (Benson & Clay, 2003; WTO, 2003; Yanikkaya, 2003; Toya & Skidmore, 2007). If these are used as inputs in further production, then, following the logic of the Rybczynski theorem, this should result in diversification, since the increased supply of these inputs through imports and foreign direct investments will develop production that initially were less dominant (Rybczynski, 1955). Benson & Clay (2004) also provide examples of the latter effect of increased openness in developing countries in their case studies. Since the relatively scarce resources in these countries often are financial and human capital and technology, diversification normally implies a transition from agriculture and simple industry towards more advanced production. They discuss how overall sector diversification and diversification within the agrarian sector both suggest a risk reduction, whilst the effect of the new sector composition on risk depends on the specific activities it includes.

Importantly, Benson & Clay (2004) emphasize that country-specific features such as the initial composition of sectors and what type of hazard they are exposed to, determine how a change in their economic structure affects disaster risk. For example, a developing country that reduces dependency on agriculture through industrial transition becomes less vulnerable to floods, but might face an increased vulnerability to earthquakes, due to poor building standards or from locating the industrial zones in exposed areas. As such, the effect of trade openness on disaster risk through economic structure is contingent on several factors, and therefore ambiguous.

GDP, Growth and Poverty Alleviation

There is extensive evidence suggesting a positive effect of trade openness on economic growth as well as poverty- and inequality alleviation in developing countries (Dollar & Kraay, 2004; Felbermayr & Gröschl, 2013; Edwards, 1997; Frankel & Romer, 1999; WTO, 2003). However, the relationship between trade openness and economic growth is not straightforward. The mentioned work on trade, growth and poverty by Dollar & Kraay (2004) emphasizes the importance of institutional quality for trade to create growth in the long run. They postulate that developing countries with better institutions have a superior ability to optimize their outcomes from trade openness by the use of, for instance, trade barriers, subsidies, agreements with other countries and financial regulations. Borrmann, Busse & Neuhaus (2006) find evidence for this too, and further identify efficiency of the tax system among the most important aspects of institutional quality for countries to benefit from trade. Nonetheless, the increase in GDP is believed to reduce natural disaster risk (Kahn, 2005; Strömberg, 2007; Toya & Skidmore, 2007; Raschky, 2008; Wen & Chang, 2015). However, other studies suggest that this is only the case after a certain level of development (Kellenberg & Mobarak, 2008; Schmacher & Strobl, 2011).

Kahn (2005) further elaborates specifically on how an increase in inequality, when controlling for population size and GDP per capita, is associated with higher risk through a higher share of very poor citizens, who are more exposed to risk. Extending the Hechscher-Ohlin theorem presented above by the Stolper-Samuelson Theorem provides theoretical backing for trade openness alleviating poverty: Since an important abundant input factor in most developing countries is unskilled labor, the poor should in theory see increased real wages when the economy specialize in these sectors (Stolper & Samuelson, 1941; Bhagwati & Srinivasan, 2002). As such, trade openness should make the most vulnerable in a country more capable of mitigating their perceived risk.

In conclusion, the effect of trade openness on GDP, growth and poverty alleviation in developing countries is likely to be positive, but contingent on institutional quality. Development is further expected to reduce risk, but possibly conditional on the current level of development. A disaster risk reduction from trade openness through economic growth and poverty alleviation thus seems likely.

Capital Inflow and the Financial System

Neumayer et al. (2014) provides evidence of market failure in the form of underinvestment in natural disaster mitigation. Governments should therefore correct these market failures, however, as discussed earlier, it might not always be in their interest as it depends on political support, frequency of disasters and regime type. Solutions to market failures might instead come through the improvement of the financial system. As open economies have the potential of benefiting from increased financial capital and management expertise through FDI's (Benson & Clay, 2003), it is likely that this could result in an improved financial system. Toya & Skidmore (2007) find that increased money supply reduces natural disaster deaths and economic losses in developing countries, as a result of a more efficient and informed financial system. This, in turn, might reduce the level of information asymmetry and in part lessen the problem of underestimation of small probabilities, as explained by Neumayer et al. (2014), thus improve the assessments of investment risks related to mitigation. Noy's (2009) findings support the notion that more money, in his case in the form of increased domestic credits and larger foreign exchange reserves, also decrease the macroeconomic consequences of natural disasters.

Humanitarian Aid

Cohen & Werker (2008) hypothesize and present suggestive evidence that the expectations of receiving humanitarian aid impedes government spending on natural disaster mitigation, due to the perceived guarantee of free relief. Since countries that trade more, are more likely to receive more humanitarian aid (Strömberg, 2007), and thus expect more aid, trade could potentially worsen this moral hazard problem. However, Noy (2009) attributes his finding of trade reducing the loss in economic output after natural disasters partly to the increased humanitarian aid open countries receive after such events, as this increases the countries capacity to recover after a disaster. In light of this, the effect of trade openness on disaster risk through aid is ambiguous. In the short run, trade should increase aid and facilitate an easier recovery, yet as expectations of receiving aid after disasters increase with trade, open countries seem less likely to invest in mitigation, which in the long run likely induce greater natural disaster losses.

International Cooperation and Collaboration

Cohen and Werker (2008) argue that sharing knowledge related to prevention and preparedness and helping to develop regulations that reduce the disaster risk might be better strategies to reduce disaster losses, as these are not affected by moral hazard. Djalante

(2012), emphasizes the need of collaboration not only locally but also internationally. Several global and regional organizations, including various agencies of the United Nations, work to support developing countries in disaster risk reduction, by facilitating partnership, improving cooperation, and by building technical and financial capacity (Djalante, 2012). Trade openness is associated with greater participation in cooperative efforts (Neumayer, 2002; Hegre, 2000; Oneal, Oneal, Maoz & Russet, 1996). Following this reasoning, trade openness should reduce disaster losses in developing countries.

Technological Improvements

Technological transfers are an important contributor to efficient natural disaster mitigation. Toya and Skidmore (2007) find a significant relationship between trade openness and natural disaster losses. They explain this through higher market competition and transferals of technological knowledge from other countries, which in turn help reduce disaster risk. Yanikkaya (2003) argues that trade openness in developing countries, especially with more developed nations, provides access to new technologies. Moreover, increased domestic competition as a result of trade openness is likely to improve both the quantity and quality of goods and services, as suggested by Toya & Skidmore (2007). Thus, through trade openness, developing countries can import technologies and gain access to products, services and relevant knowledge that the public administration, private actors and households can use to better withstand natural disasters. Furthermore, since trade may induce technological and knowledge transfers, it can positively increase productivity in developing countries (Coe, Helpman, & Hoffmaister, 1997). Following the theory of the Solow growth model augmented by productivity, this will result in long-run economic growth (Solow, 1956).

Trade facilitation

Trade facilitation goes by several different definitions revolving around factors that enable movements of goods across borders, thereby reducing the transaction costs involved in importing to or exporting from a country (OECD, 2005). Iwanow & Kirkpatrick (2007) find that trade facilitation in the narrow sense, meaning simpler regulations (e.g. reduction of the number of documents required to export), do not significantly affect trade ratios, whilst countries that engage in broader trade facilitation measures that include the improvement of logistics and infrastructure, experience increased trade ratios. Vaillancourt & Haavisto (2015) find that improved logistics performance is associated with a reduction of the number of people affected by disasters. Thus, countries actively investing in broader trade facilitation might as a result experience fewer disaster consequences. Moreover, in Wilson et al. (2004)

define trade facilitation including the general regulatory environments and harmonization of international standards and regulations. His findings also suggest that trade facilitation increases trade. The general regulatory environment is an important factor for reducing disaster risk as discussed earlier.

Thus, countries with higher trade ratio might have proactively facilitated this with the intention to benefit from increased trade. However, they may also simultaneously reduce disaster risk through the accompanied improvements in infrastructure and regulations. Furthermore, since one of the objectives of the World Trade Organization (WTO) is to support trade facilitation through technical assistance and capacity building to developing countries (WTOa, 2018), members are likely to benefit from this both in terms of trade, and the disaster risk reduction resulting from improved infrastructure.

Conclusion

There are several theoretical mechanisms through which trade openness could affect natural disaster risk in developing countries. Table 2.1 provides a summary of the mechanisms investigated in this section along with the likely direction of their effect on disaster risk. Based on these mechanisms it is a priori unclear whether increased openness will have a mitigating, a worsening, or no effect at all on natural disaster risk, due to effects in opposite directions cancelling each other out. Furthermore, the observed effects are likely to heavily depend on country-specific factors, such as the initial GDP level and structural composition, hazard exposure, and institutional quality. This ambiguity emphasizes the need for empirical investigations of the relationship between trade openness and natural disaster risk.

Table 2.1: *Mechanisms through which openness may affect natural disaster risk, and the expected direction of the effect. Evidently, for some of the mechanisms the effect on risk is ambiguous.*

Mechanisms	Direction
Composition of economic sectors: diversification / specialization	+/-
GDP, growth and poverty alleviation	- (+)
Capital inflow and improved financial markets	-
Humanitarian aid	- (+)
International cooperation and collaboration	-
Technological improvements	-
Trade facilitation	-

3. Empirical strategy

3.1 Choice of estimation methods

To answer our research questions, we apply panel estimations. This is an improvement to the pooled OLS estimation applied by Skidmore & Toya (2007) in estimating the effect of trade openness on disaster losses. Wen & Chang (2015), however, also use panel data, and employ conditional fixed effects Poisson regressions. As previously mentioned, these two studies are the only ones that include a finding on the effect of trade openness on natural disaster losses. The basis of our analysis is Fixed Effects (FE) estimations, however we compare these findings to estimations from hybrid models (Allison, 2009) and a correlated Random Effects (CRE) estimation (Wooldridge, 2010; Mundlak,1978). The FE estimator obtains the within-country effect on natural disaster fatalities from increasing the degree of economic openness, in the countries in the sample, on average. A standard Random Effects (RE) estimation provides an estimate of the said effect, though weighted with the confounding cross-countries effect of having an open economy versus a closed one. Mixed models allow us to distinguish these two effects and get separate estimates for both within the same model, whilst simultaneously formally test the consistency of the RE estimator.

The mechanisms discussed in the previous section lean more strongly towards a risk reducing effect of trade openness. We thus expect our within-country effect on fatalities from increasing trade openness to support the findings of Toya & Skidmore (2007) and Wen & Chang (2015), although the samples, specifications and estimation methods differ. Through the hybrid estimations we supplement the two existing findings on trade openness in natural disaster mitigation with an estimate of the mitigating effect of between-countries openness levels. Furthermore, we add on the literature by thoroughly investigating the within-country effect in detailed sub-samples, as well as through interactions with relevant factors that we identified in the previous section. All specifications can be summarized as follows, where the country-specific error term, u_i, is pending estimation method:

$$Fatality\ rate = f(Openness_{it}, Controls_{it}, (u_i), \varepsilon_{it})$$

Whether a hazard event happens or not in a given country in a given year is arguably random. However, as the previous sections explained, the extent of the losses are not: The number of fatalities is undoubtedly affected by non-random country-specific features such as development level, investment in disaster preparedness, and quality of infrastructure, as well as innate factors like geography and hazard propensity. Those of such features that are left unobserved will make the country-specific error of the model confound the estimate of openness on fatality rates. Hence, only FE estimation is expected to provide consistent estimates, as the assumption of the RE estimator, $Cov(u_i, X_{it}) = 0$, is likely violated. Thus, our starting point is FE.

Although consistent when specified correctly, our FE estimate omits any time invariant variable that could be of interest, and limits the interpretation of the estimate to the mentioned average within-country effect of increasing a country's degree of openness. This estimated has interesting policy implications. It is nonetheless intriguing to obtain also a descriptive estimate of how the cross-country variation in average levels of trade openness seems to affect losses. By converting our FE model into the mixed models, we obtain this estimate and those of other relevant time invariant controls, whilst keeping the consistent FE estimates of the time-varying variables (Schunck, 2013). The FE estimates in the mixed models are equal to the standard FE estimates, and as argued, likely the only consistent estimates we can obtain. As mention, a valuable feature of the mixed models is that they facilitate a formal augmented regression test of the consistency of an RE, to confirm this.

The mixed models are thus a valuable addition to our analysis, provided the specification is correct. Although the FE part of the hybrid and the CRE is guaranteed uncorrelated with the country-specific error (u_i), reintroducing this part of the error term for the RE part of the model makes correlation between time invariant variables and u_i possible, $Cov(u_i, X_i) = 0$. Thus, to obtain an unbiased (*or as little biased as possible*) estimate of the cross-country variation in trade openness levels, we need to control for all (*as many as possible*) time invariant variables that influence economic openness and natural disaster-related fatalities. We thus include additional country-level time invariant controls in the hybrid estimations, to minimize the risk of endogeneity issues arising from the error term component. However, we are aware that due to the availability and quality of data on developing countries and the complexity of the relationship of interest, controlling for all relevant factors is unlikely. Consequently, we interpret these suggestive findings with caution.

3.2 Identification strategy

3.2.1 Baseline spesification

Our baseline identification strategy is the following, estimated through FE:

$$Fatality\ rate_{it} = \beta_0 + \delta\ \frac{1}{5}\sum_{t=-5}^{t=-1} Openness_{it} + \beta_k C_{it} + \lambda_t + \theta_j + (u_i) + \varepsilon_{it}$$

where the subscripts denote values of the variables in country i in region j in year t. Consequently, λ_t and θ_j represent year- and region fixed effects, where regions are defined as per the World Bank reporting standard. The dependent variable is the natural disaster related death toll measured as the log of fatality rate (to population in millions) in the countries each year, and $Openness_{it}$ measures trade openness as the trade ratio of the same. Hence our parameter of interest, δ, reveals the estimated relationship between trade openness and natural disaster losses. Trade ratio and reported fatalities are originally contemporaneous variables. This simultaneity and potential measurement errors in the variable from year to year might cause endogeneity issues in the trade openness estimate. Suppose the channels through which the trade openness might affecs natural disaster losses take time to manifest (trade-induced changes in technology, infrastructure, sectors, etc.), it makes intuitive sense to assume a lagged effect also on disaster losses. We thus specify the model using the more exogenous moving average of the countries' trade ratios over the past 5 years. The term C_{it} refers to a set of time- and/or country varying control variables. The choice of the specific fatality measure, trade openness measure and control variables are explained in more detail in the next subsection. As follows from the above discussion, the country-specific error term, u_i, is excluded in FE estimation, but present in RE, which we include for comparison reasons. All estimators include the independent and identically distributed idiosyncratic error term, ε_{it}.

The hybrid model (Allison, 2009) is given by:

$$Fatality\ rate_{it} = \beta_0 + \delta_W\left(\frac{1}{5}\sum_{t=-5}^{t=-1} Openness_{it} - \overline{Openness_i}\right) + \delta_B\overline{Openness_i}$$
$$+\ \beta_{kW}(C_{it} - \bar{C}_i) + \beta_{kB}\bar{C}_i + \eta_{kB}Z_i + \lambda_t + \theta_j + u_i + \varepsilon_{it}$$

where the notation is as in the previous expression. The new expression clearly formalize the decomposition of the within (*W)* and between (B) estimates of our time-varying variables. Between estimates use the means of the variables for each country over all years in the panel that the country experienced natural disaster related fatalities. Within estimates are based on the deviation of the variable value in a country each year from these means (i.e. group mean centering), and thus equals the FE estimates in the linear case. We distinguish time-varying controls C_{it} and time invariant controls Z_i to underline how the former will get both within and between estimates, while the latter naturally only provide between estimates.

We mentioned that this hybrid model allows for formal testing of consistency of the RE estimator through an augmented regression test (Schunck, 2013). This is because the difference between the within and between estimates of time-varying variables can be interpreted as the degree to which the cross-countries variation in levels of the variables confound the within-country estimates. Thus, if the between estimate is statistically significantly equal to the within estimate ($\delta_W = \delta_B$), the model collapses back to the random-intercept model of the baseline specification, i.e. RE is consistent. The CRE model (Wooldridge, 2010; Mundlak,1978) is based on the same concept as Allison's hybrid model and mathematically equivalent, but vary in how estimates are obtained. As a consequence, CRE does not provide the actual between estimates like the hybrid, but instead estimates the difference between the between and within estimates needed for the augmented regression test, $\delta_D = (\delta_B - \delta_W)$. Adding a CRE estimation to our analysis thus allow us to read the test result directly from the regression output. (Schunck, 2013; Schunck, 2017)

Given the nature of our macro level panel data, we anticipate serial correlation in the error term due to autocorrelation in the time series of our independent variables. To avoid erroneous inference, we cluster the standard errors at country level in all specifications. This makes the augmented regression test facilitated by the mixed models even more valuable, as the corresponding Hausmann specification test that is normally done for separate RE and FE estimators does not allow clustering, and manually computing the test statistic with cluster-robust standard errors gets tricky in unbalanced panels like ours.

3.2.2 Choice and measurement of key varibles

Dependent variable: The fatality rate

In line with existing literature on natural disaster fatalities, we obtain relative natural disaster losses that are comparable across countries by defining the outcome variable as a ratio to population (Kahn, 2005; Raschky, 2008; Schumacher & Strobl, 2011). The papers further attain an intuitive interpretation and a better distribution by taking the natural logarithm of either the raw data or such ratio (Kahn, 2005; Strömberg, 2007; Toya & Skidmore, 2007; Kellenberg & Mobarak, 2008; Schumacher & Strobl, 2011; Wen & Chang, 2015). Thus, our outcome variable is defined as the log of the number of fatalities to population (in millions). We add the +1 to avoid negative values when log transforming the ratio:

$$\text{Fatality rate:} \quad Y_{it} = \log\left(\frac{fatalities_t}{population_t} + 1\right)$$

Throughout the remainder of this thesis, when referring to reducing or mitigating natural disaster risk, it relates to a reduction in this fatality rate measure.[6]

Trade openness

Yanikkaya (2003) discusses various measures of trade openness. A widely used measure is the trade ratio; imports plus exports over GDP. This measure is basic, however, it is available for many countries and consistent across time, which makes it comparable across nations in a panel. It directly covers exports and imports, of which exports is found to result in economic growth when based on appropriate policy choices (Dollar & Kraay, 2004) and possibly diversification of a countries economic structure (Benson & Clay, 2003). Moreover, imports contribute to the technological advancement in developing countries (Yanikkaya, 2003). Indirectly, the trade ratio can be associated with factors related to economic openness in a broader sense, such as international cooperation and trade facilitation. Trade measured in both exports and imports increase with increased trade facilitation, when broadly defined (Wilson et al., 2004). Countries with higher trade ratio are also more likely to receive humanitarian aid during/after a natural disaster (Strömberg, 2007). Thus, the trade ratio is a useful proxy to capture the effects trade openness is believed to have on reducing natural disaster risk. As specified in section 3.2.1, we average the trade ratio of the past 5 years to

[6] For robustness purposes, an analogous definition of the economic damages from natural disasters is also specified. It log-transforms the ratio of reported economic damages to GDP (both in current USD, and GDP in millions).

reduce endogeneity and capture the prolonged effects trade might have on mitigating disasters. Lastly, we believe the effect of increasing openness on mitigation is diminishing, that is that percentage point changes to the ratio will produce greater benefits on mitigation in countries with a low initial trade ratio than in already open economies. We thus log-transform the trade ratio to interpret the effect as an elasticity.

Control variables

In the general model that comprises all natural disaster types, we control for number of events within each country-year unit. Unfortunately, we are unable to control for duration and magnitude of the events in our main model, as these measures vary across disaster types. In sub-sample regressions on each disaster types, these controls will be included. Based on the discussed literature on both natural disaster losses and trade, we further include the following controls in the analysis: log of GDP per capita both in levels and squared, log of population size, log of geographical size (km^2), the government expenditure as percentage to GDP, education (gross primary school enrollment), institutional quality measured through a government effectiveness indicator, a democracy index, a binary indicator of being landlocked or not, a hazard propensity measure, and regional indicators.

GDP per capita is in line with the literature used to control for differences in financial capacity and developmental level, and as to Kellenberg & Mobarak (2008) and Schumacher & Strobl (2011) we include the squared term to discover potential nonlinearities within the sample of developing countries. Population and geographic size are commonly used control variables to account for differences in exposure to disasters. Government expenditure should account for spending on public assistance and disaster risk management as explained by Toya & Skidmore (2007), but might also proxy inefficient, bureaucratic governments. Education, institutional quality and democracy control for the increased ability of the state to mitigate disaster risk and at the same time increase their competitiveness on the international market. Lastly, GDP per capita, government expenditure, and enrollment are moving averages over five year, similar to the trade ratio. We expect these controls to remove most of potential confounding factors, though not completely. We want our estimate to pick up on the fact that higher trade ratios might be a consequence of active trade facilitation, and as such a potential correlation between countries' ability to increase its trade openness and the ability to mitigate disaster risk is not problematic in our case.

3.2.3 Sub-samples, interactions and robustness checks

After revealing the general pattern between trade openness and natural disaster losses among all disaster types aggregated, we limit our analysis to various sub-samples. We first run the above specifications for two sub-groups that differ in how the fatalities incur, and subsequently in how trade can mitigate them. The first category includes disaster types where fatalities happen instantly or in a short time frame (earthquake, landslides, storms and volcanic activity), whilst the other includes disaster types that see fatalities gradually increasing (drought, floods, extreme temperature and wildfires): In the latter category both disaster preparedness and disaster management affect losses, thus trade and associated factors can have reducing effects on fatalities during the disaster through for example imports of essential affected commodities or the increased likelihood of receiving humanitarian aid (Strömberg, 2007). In the first category, however, solely preparedness affects the instant direct losses, and as such trade should only mitigate risk through preparedness, for example from improvements in infrastructure, technology and markets.

We then run the specifications for the different disaster types separately, to investigate potentially different patterns between these. As mentioned, an important improvement to the model in these disaster type regressions is that we can control for magnitude, duration and disaster type-specific factors of several of the events, a need repeatedly stressed in the literature (Kousky, 2013).

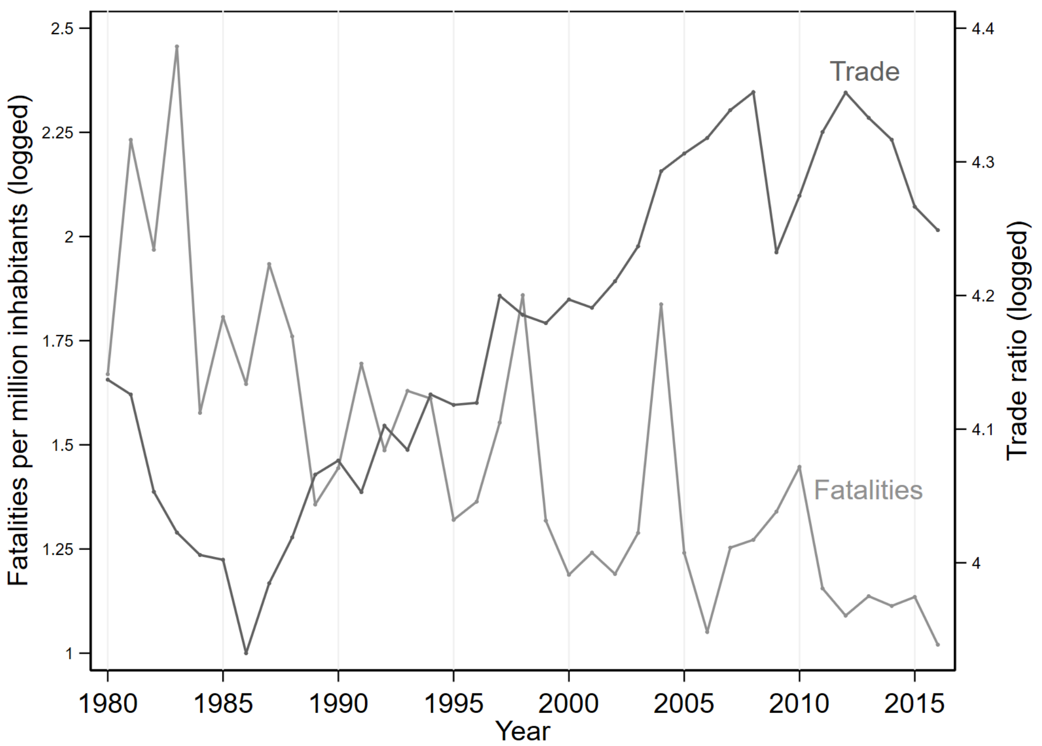
There are also certain interesting interactions to investigate, as the effect of trade openness on mitigation might depend on other factors such as development level, democracy level, government expenditure and economic sector dependencies. We use the above stated variables to account for the first three and include agrarian percentage of the GDP to test for effects due to differences in economic sector.

Lastly, we investigate if our main findings are robust when applying other measures of trade openness than the trade ratio; membership in WTO, and the net inflows of foreign direct investments (FDIs). We also run the same specification as before using 10-year moving averages of the trade ratio instead of the original 5-year average.

4. Data

This section serves to elaborate on the data collected and certain modifications done to these. When illustrating the data on natural disaster fatalities and trade openness, it presents clear trends that are in line with existing literature and prior beliefs. As seen in the graph below, there has been a steep growth in trade among developing countries the last three decades, while natural disaster fatalities (per million inhabitants) have had a decreasing trend, though with more extreme disasters happening occasionally.

Figure 4.1: *The figure shows the time trend of the average death toll (fatalities per million inhabitants) in our sample countries, alongside the time trend of the respective average trade ratio.*



4.1 Disaster impact data

4.1.1 EM-DAT raw data

The disaster data employed in this paper comes the emergency events database (EM-DAT) at the Center for Research on the Epidemiology of Disasters (CRED). The purpose of the database is to facilitate rational decisions in disaster mitigation and provide objective information to assess vulnerability and priority settings (EM-DAT, 2018a).

Data is gathered and reported by several different organizations, such as UN agencies, insurance companies, research institutes and non-governmental organizations (EM-DAT, 2018a). For a disaster to be included in the database it must fulfill at least one of the following four criteria; minimum 10 reported fatalities, minimum 100 people reported affected, a declaration of a state of emergency or a call for international assistance (EM-DAT, 2018b). Next to the elementary information about the disasters such as location, date, disaster type and physical magnitude, there is data on total deaths, total affected, and the estimated economic damage (EM-DAT, 2018b). Total death toll is defined as the number of fatalities, including people that are missing and thus assumed dead after the disaster event. Total affected is the number of people that needed assistance through survival provisions such as shelter, nutrition or immediate medical assistance, and people suffering from injuries or trauma as a result of the disaster. The data on the estimated damage is given in 1,000 USD in current values and includes damage to property, crops and livestock (EM-DAT, 2018b).

The database includes two disaster groups; natural and technological disasters (EM-DAT, 2018c). As this paper is aimed at disasters that are outside of direct human influence, only natural disasters data are of interest. Excluding biological and extraterrestrial disasters, this leaves us with the natural disaster subgroups of geophysical, meteorological, hydrological and climatological disasters normally treated in the presented literature. Not all disaster types within these disaster sub-groups have been reported in our sample countries and years. The disaster types that are eventually included are as follows: earthquakes, storms, floods, landslides, droughts, mass movements, volcanic activity, wildfires and extreme temperature.

4.1.2 Limitations to EM-DAT data

The EM-DAT data comes from several different sources, which might differ in their ways of defining natural disaster as well as collecting and using the numbers. Data from poorer regions, as the sample in this study, might be more prone to measurement errors because of weaker statistical capacity in the public sector, and fewer insurance companies collecting data. The economic damage component is the factor suffering the most from the absence of insurance companies. Furthermore, the component of people affected is generally the weakest amongst the measures due to its unclear definition, and might experience exaggeration as a way to increase sympathy and thus receive more humanitarian aid. Death has a clearer definition, and is often easier to validate, thus it can be assumed to be more reliable than affected and damages (Guha-Sapir et al., 2004).

Furthermore, some countries have certain years where no disasters are reported. Whether a natural disaster hits or not is exogenous, thus the lacking observations are not incentivized and should not cause selection bias. However, if there are reasons determining whether the disaster is reported or not after it hits, it will cause selection bias. The EM-DAT database only contains disasters defined by minimum numbers of deaths or affected, or governments declaring an incident as a disaster. Thus, in countries where hazards occurs and only few dies, and the state does not see the need to report it as a disaster due to actually being able to cope, these hazards will not be reported into EM-DAT. Whilst this is not a problem for our investigation of disasters per se, it is important to note since as countries become more able to cope and report fewer or no disasters, the determinants making these countries better at coping will not be capture in an analysis anymore. However, this issue likely refers more to highly developed countries than developing countries.

Furthermore, there might be differences in reporting disasters between the sample countries as the reporting standards, definitions, and incentives depend on the institutions present in the country. The reporting bias is however likely to be more of an issue through the time period of the sample. Disasters reported has increased considerably from EM-DAT was established in the 1960s. There are various reasons for this. Firstly, the extent of reporting has evolved over time, as a result of improvements in telecommunications, global media coverage, international cooperation and incentives to receive humanitarian aid (Guha-Sapir et al., 2004). Secondly, more people might be located in hazardous zones such as slums, or in buildings that cannot withstand for example storms and earthquakes. Moreover, people are increasingly altering the nature through for example deforestation and the interference with rivers and streams, which can result in natural hazards (Escaleras & Register, 2010). We correct for these factors through the time fixed effects in our model.

There is extensive work being done to verify the data in EM-DAT. However, validity often relies on the suppliers of the data. Data is therefore not entered into EM-DAT unless two or more sources report the disaster. The quality of the data has improved greatly over time, as accessibility and validation has been facilitated by globalization and technical advancement. Still, EM-DAT data should not be used to make exact predictions, but rather to look at relative changes, trends and relationships. (Guha-Sapir, et al., 2004)

4.1.3 EM-DAT modifications

The EM-DAT data is delivered upon the request, in a format where each disaster event within a country is registered with start and end data, disaster type, magnitude if applicable for the disaster type, and the total deaths, affected persons and damages. To exploit the benefits of the fixed effects estimation, we converted the data into a country-year panel by aggregating the disaster deaths into its affiliated country and year combination, for each of the disaster types independently. Accompanying this is a count of the number of disasters within each country-year unit of each disaster type. We further averaged the magnitudes and durations of each of the disaster types, as elaborated on in the next section. Finally, from the data on each disaster type, we aggregated fatalities and frequencies into a total death and frequency count across all disaster types. Since magnitudes and durations have different measurements across disaster types, and need to be interpreted in association with these, these variables were naturally not aggregated. However, each disaster type can be analyzed independently and more accurately by controlling for magnitude, duration, as well as number of events. Due to the low number of observations on some of the disaster types, we run the separate regressions only for floods, storms, landslides, earthquakes and extreme temperatures waves. In practice, the panel is unbalanced when regressing fatalities, due to the absence of disasters in several of the country-year combinations. The summary statistics of the EM-DAT variables can be studied further in Table 4.1 at the end of this sub-section.

Magnitudes

Physical intensity, or magnitude, is given as Richter's scale for earthquakes, Celsius degrees for extreme temperature waves, kilometer per hour for storms, and squared kilometers for floods. For landslides, we disregarded the magnitude measures due to the very few reported magnitudes. However, the problem of scarce reporting is common to all of the magnitude measures. We assume that the magnitudes not reported are missing at random and not systematically, and hence will not induce measurement errors. For floods and storms the magnitudes are simply averaged within the country-year units, while for earthquakes and extreme temperature magnitudes could only be aggregated after modifications, explained in the following paragraphs.

Earthquakes

EM-DAT reports Richter's scale as measure of the intensity of reported earthquakes. As this is a logarithmic scale, the log of the physical energy released, a simple arithmetic mean will not suffice when calculating an average of the physical strain of several earthquakes within a country-year unit. Hypothetically, two earthquakes of 3 and 9 in a year would generate the same average magnitude as two of 6, although the combined physical energy released of the events would be substantially higher in the first case. Therefore, we average the actual physical severity instead, having first converted the magnitudes to energy, using Richter and Gutenberg method: Energy = $10^{(11.8+1.5*\text{Richter})}$ (Spence, Sipkin & Choy, 1989). After obtaining the country-year averages in energy, we convert it back to Richter's scale, by taking the natural log; Richter = $(\log_{10}(\text{Energy})-11.8)/1.5$. This way, country-year units with only one earthquake will remain the same, but we manipulate the units with several earthquakes into an average that is more realistic than a mean of the scale values themselves.

Extreme Temperatures

Extreme temperatures include both cold- and heat waves. Consequently, averaging the temperatures when both types happen within a county-year unit (which is actually the case for several units) cannot be done. However, dividing the two would result in two groups with very few observations. Thus, we convert the temperatures into a relative scale of how extreme the temperatures are instead, where the warmest cold waves and coldest heat waves get a value 1 (least extreme), whilst the hottest heat waves and coldest cold waves get a value 5 (most extreme). When both types happened for a country-year combination, it will then average the severity of the hazards rather than degrees, and we get to keep the higher number of observations. The temperatures range [-57, +9] Celsius degrees for cold periods (mean: -18.1ºC), and [+30, +60] degrees for heat waves (mean: 45.0ºC). We make the scale by simply assigning the values 1-5 for each quintile of observations in the two groups.

Duration

The duration of a disaster might be essential in determining fatalities. We want to control for this in our model, thus generate variables for average and total duration (day count) of disasters within each country-year unit, based on the start and end dates in EM-DAT. However, the whole start- or end date is not always reported, and thus the measure is not perfect. Landslides and earthquakes are by nature one-off incidents with a brief duration, and thus excluded from duration measures. Flood, storms and extreme temperature periods are measured in days. For incidents with exact dates reported, we use the accurate number of days. For those with incomplete dates, we us a minimum number of days based on month switches in the data (two month switches imply the disaster lasted at least the month between).

Table 4.1: *Summary statistics of the natural disaster data.*

Variables	Observations	Mean	Std.Dev.	Min	Max
Total fatalities	1,930	1144.84	11622.61	1	300000
Total frequency	2,575	2.94	3.80	1	43
Total damages (current USD)	1,131	946552.1	4659069	2	111000000
Flood fatalities	1,375	169.96	913.51	1	30005
Flood frequency	1,764	1.95	1.80	1	20
Flood magnitude (km^2)	840	79527.44	172225.50	0.4	1834048
Flood duration (Days)	1,550	14.39	28.40	1	690
Storm fatalities	668	647.93	7641.91	1	138987
Storm frequency	848	2.07	2.15	1	17
Storm magnitude (khp)	333	167.88	73.32	50	408
Storm duration	797	3.80	7.73	1	91
Earthquake fatalities	362	2259.30	16079.10	1	222570
Earthquake frequency	456	1.65	1.27	1	11
Earthquake magnitude (Richter)	438	6.39	0.94	4	9.1
Landslides fatalities	322	84.89	164.59	1	2137
Landslide frequency	336	1.46	0.89	1	8
Extreme Temp. fatalities	203	430.23	3917.41	1	55760
Extreme Temp. frequency	243	1.21	0.48	1	3
Extreme Temp. magnitude (Scale)	142	3.04	1.36	1	5
Extreme Temp. duration (Days)	174	19.21	38.00	1	270
Wildfire fatalities	58	23.21	40.37	1	240
Wildfire frequency	128	1.12	0.46	1	5
Wildfire magnitude (km^2)	61	4463.11	14810.33	1.3	80000
Wildfire duration (Days)	81	16.32	32.57	1	148
Drought fatalities	46	12642.67	50676.39	2	300000
Drought frequency	491	1.03	0.18	1	3
Drought magnitude (km^2)	43	57651.41	119550.50	1	560000
Drought duration (Months)	287	10.42	11.99	1	59
Volcanic activity fatalities	29	876.07	4038.45	1	21800
Volcanic activity frequency	111	1.28	0.59	1	4
Volcanic activity duration (Days)	109	10.98	30.70	1	254
Mass Movement fatalities	33	65.64	77.42	1	300
Mas Movement frequency	34	1.03	0.17	1	2

4.2 Economic and governance data

The independent variables and controls are collected from several different sources, of which the World Development Indicators (WDI) from the World Bank's DataBank is the most actively used source (World Bank, 2018). Trade ratio, the main independent variable employed for trade openness, is measured as exports plus imports as a percentage to GDP. Several of the control variables are also retrieved form the DataBank: GDP per capita in constant USD 2010, government expenditure as percentage of GDP, the GINI index, gross primary school enrollment, geographical size in km^2 and population data. The agricultural percentage of GDP variable for the interaction term analysis and foreign direct investments (FDI) inflows for robustness checks of trade openness is also from the DataBank. The government effectiveness variable is from another World Bank database, the World Governance Indicator (WGI, 2018; Kaufmann et al., 2010). This indicator of institutional quality is widely used in economic literature.[7]

Other indicators of institutional quality are collected based on the literature and intuition behind the relationship of interest, and are collected from University of Gothenburg Quality of Government institutions dataset (QOG) (Dahlberg, Holmberg, Rothstein, Pachon & Svensson, 2018). The democracy indicator employed is a merge of the Polity 2 measure for democracy by Marshall, Jaggers & Gurr (2017) and the indicators of political rights and civil law by Freedom House (2018). Hadenius & Teorell (2005) have proven previous versions of this measure to be of higher validity and reliability than the components for themselves. The variables range from least to most democratic, on a scale from 0 to 10.

Furthermore, a dummy list of landlocked countries is collected from the CEPII database (Mayer & Zignago, 2011) and used to control for differences in exposure to different disaster types and accessibility to international markets. Information on member countries of WTO is retrieved from the organization's historic membership list (WTOb, 2018).

Summary statistics of the mentioned variables are presented in Table 4.2 on the next page.

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[7] WGI Government Effectiveness is an acknowledged measure for institutional quality. It covers many countries and is thus preferable over other measures from the QOG database. However, it lacks observations for large parts of our sample period.

Table 4.2: *Summary statistics of economic and governance data.*

Variable	Observations	Mean	Std.Dev.	Min	Max
Trade (% of GDP)	4,253	75.7	37.6	0	375
GDP per capita (constant USD)	4,470	2900.3	2753.2	116	14779
Government Expenditure (% of GDP)	3,929	15.7	9.1	0	164
GINI Index	2,047	42.5	8.9	16	66
Education (gross primary enrollment %)	3,910	97.4	23.3	14	212
Agricultural land (% of GDP)	3,973	21.2	14.1	1.8	100
Government Effectiveness	2,429	-0.5	0.6	-2	1
Democracy Index	4,549	5.2	3.1	0	10
Geographic size (land area km^2)	5,029	698026.3	1804295	30	16400000
Population	5,044	35800000	138000000	8052	1380000000
Regions					
East Asia & Pacific	5,069	0.16	0.37	0	1
Europe & Central Asia	5,069	0.15	0.36	0	1
Latin America & Caribbean	5,069	0.18	0.39	0	1
Middle East & North Africa	5,069	0.09	0.29	0	1
South Asia	5,069	0.05	0.23	0	1
Sub-Saharan Africa	5,069	0.33	0.47	0	1
Landlocked	5,003	0.2	0.4	0	1
WTO Membership	5,069	0.6	0.5	0	1
FDI net inflows (% of GDP)	4,168	3.4	7.4	-83	218

4.2.1 Data limitations and modifications

Some careful modifications are done to take full advantage of the data at hand. The GINI data is limited in availability for most of the years in the panel, and missing for many of the countries. Extrapolating this variable would reduce its reliability without considerably improving the sample size. We concluded the small gain from the manipulated version of the variable would not be worth the risk of the possibly induces measurement errors.

The landlocked variable was missing for American Samoa, South Sudan and Montenegro. American Samoa being an island was manually listed as non-landlocked. South Sudan became a country during the sample years, and after cross-referencing with contemporaneous and historical maps it was manually listed as landlocked. Montenegro was left missing as the costal area of the country has been under the occupation of different groups during the sample time, and since the country's absence does not affect the FE analysis, as there is only one reported disaster.

The government effectiveness measure from the Wold Governance Indicators covers most countries in a consistent matter but lacks observations for several years, as the WGI data starts in 1996. Moreover, it is only listed every other year from 1996 to 2002. Since the values change little from year to year and show a stable trend, they are interpolated between the observations of 1996 and 2002, thus filling the blanks in 1997, 1999 and 2001.

As an effect of trade openness on natural disaster risk and mitigation is likely to take time, trade and FDI inflows have been modified to represent the 5- and 10-year running average ending on the previous year, using values from the 1970s for the observation in 1980, and so forth. The control variables GDP per capita, education and government expenditure is averaged the same way to better control for the potential confounding effects these variables might have on trade openness. The remaining controls included are only gradually changing over time, and should be able to control for the historical trade ratio averages without being manipulated (for example the democracy index).

5. Empirical analysis & Findings

5.1 General results

5.1.1 Fixed Effects Estimations

As stated in section 3, the starting point of our analysis is Fixed Effect estimations. These are reported in table 5.1 on the next page. Serving as a basis for further investigation, the first column shows a very simplistic model, which confirms a statistically significant relationship between increasing trade openness and a reduction in natural disaster related deaths. The coefficient is most conveniently interpreted as an increase in trade ratio of 10% resulting in an approximately 4,5% reduction in fatality rates, which is qualitatively in line with the data trend and our hypothesis. Increases in GDP per capita reduce fatalities by roughly the same amount, and the number of disasters within a year increases the death toll, as expected. The model treats 1,648 observations with available data on trade ratios and GDP per capita.

However, the estimated relationships in this basic model are certainly spurious, due to omitted variable bias. Based on the previously presented literature on natural disaster mitigation, and the mechanisms through which we think trade openness might affect the natural disaster death toll, we believe the true specification includes several other variables to control for potential confounders. Column 2 presents the estimates from the specification we believe to be as close to the best specification possible, given data- access and quality.

In addition to the variables included in the simplistic model, this specification now controls for squared GDP per capita, a democracy index, government expenditure (% of GDP), education (gross primary enrollment, %), population size (logged), government effectiveness (WGI), and year fixed effects. Since the trade openness measure is a moving average of the past 5 years to reduce endogeneity, some of these controls are averaged in the same way to enable them to control for potential confounding of the trade measure (GDP, government expenditure and education). The other variables are either naturally only gradually changing (democracy index, population and government effectiveness indicator) or not a confounder of historical trade ratios, but solely important variables in determining the losses in a given year (number of disasters). These definitions of the measurements are kept throughout the analysis. The FE estimations also control for unobserved heterogeneity through elimination of the country-specific error.

Table 5.1: *FE estimations of trade openness on fatality rates in various specifications.*

	(1)	(2)	(3)	(4)	(5)
	Basic model	Extended model	Preferred specification	Excluding outliers	Poisson
Trade Openness	-0.451***	-0.321***	-0.314**	-0.298**	-0.212*
	(0.125)	(0.118)	(0.128)	(0.125)	(0.117)
GDP p.c.	-0.490***	0.406	1.540	0.752	0.626
	(0.147)	(1.121)	(1.163)	(1.085)	(1.161)
GDP p.c.^{2}		-0.022	-0.112	-0.052	-0.040
		(0.072)	(0.081)	(0.074)	(0.077)
Democracy Index		0.029	0.036	0.045*	0.022
		(0.028)	(0.025)	(0.025)	(0.020)
Government Expenditure		0.009	0.001	-0.000	-0.001
		(0.011)	(0.007)	(0.007)	(0.007)
Education		-0.001	-0.003	-0.002	-0.001
		(0.003)	(0.003)	(0.003)	(0.003)
Number of Disasters	0.081***	0.106***	0.093***	0.087***	0.061***
	(0.024)	(0.025)	(0.026)	(0.025)	(0.010)
Population		-1.017**	-0.994**	-0.979**	-0.807**
		(0.485)	(0.434)	(0.424)	(0.364)
Government Effectiveness		-0.194			
		(0.138)			
Year fixed effects		X	X	X	X
R^2	0.055	0.105	0.116	0.104	
Observations	1648	1066	1378	1376	1366
Countries	128	111	112	112	102

Notes: The table presents estimates of determinants on natural disaster fatality rates. Column 1-4 present standard FE estimations, and column 5 an FE Poission regression. Jointly significant year dummies are included in specification 2-5. Column 2 presents the model most similar to what we believe to be the true specification. However, due to concerns about sample size and lower within-country variation, our preferred specification (column 3) excludes Government Effectiveness. Our final model, reported in column 4, excludes 2 outliers from the column 3 sample. Robust standard errors are clustered on country level in column 1-4. The Poisson specification in column 5 is included for robustness purposes. This estimation does not allow clustering, and the χ^2-test statistic is omitted. The trade openness estimate is fairly robust, and very similar across estimations 2-5. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

Although the trade estimate is rather similar to that of the simplistic model, the overall results are not robust to this change in the specification: The mitigating effect on fatality rates of increasing the trade ratio by 10% is now reduced to 3,2%, and the GDP level no longer has a significant effect, neither linearly nor jointly with the squared term. Except from the population size, of which an increase is associated with a decrease in fatality rates, none of the control variables are significant. Nonetheless, the overall explanatory ability of the model is considerably higher, and the additional variables seem relevant and likely to have corrected at least parts of the bias observed in the trade openness estimate in the basic model.

Ideally, we would also control for income inequality (Gini coefficient), but the scarce data on this variable for our sample countries would detriment the sample substantially.[8]

Even without the limitations of the Gini index, the statistical power in specification 2 might be impaired from including the Government Effectiveness (WGI) variable. Since the World Governance Indicators exist solely from 1996 onwards, this limits both the total sample and the numbers of observations within each country. Whilst the former might be problematic in general, the latter is especially problematic in estimating within-estimates like the ones we obtain in FE estimation. We therefore investigated to what extent it would harm our specification if one were to remove it, and concluded it does not: When running the same regression excluding Government Effectiveness, but securing the same sample as if it was included, the estimates on all other variables are almost exactly equal to those reported in column 2.[9] This indicates the change in the estimates from column 1 to column 2 materialize from the sampling and from including the relevant controls, but not from including the (insignificant) governance measure. The trade openness estimate specifically is not affected by excluding Government Effectiveness, and it seems some of the reason the measure is redundant is that the democracy index captures parts of what it measures.[10]

Hence, our preferred specification excludes Government Effectiveness, as reported in column 3. With this specification, both sample size and within-country variation are higher, whilst still keeping the relevant control variables. Fortunately, we observe that the results are fairly robust to the change in sampling: The trade openness estimate becomes slightly more conservative and slightly less significant (p-value: 0.016), and all other estimates maintain their direction and significance levels, but vary in magnitudes.[11] Since the sample in this specification includes 2 very prominent outliers (Mozambique, 1981 and Haiti, 2010), we exclude these to arrive at our final model, reported in column 4. Now the trade openness

[8] Not reported in the table: Including the Gini coefficient renders the sample to 698 observations on 89 countries, which implies reducing also the within-country variation. When doing so, all estimates except the frequency of disasters turn insignificant, and some change direction. The estimate of trade openness on fatality rates remains negative, though smaller. We believe this arises from lack of statistical power rather than misspecification, thus resume the analysis without the Gini.

[9] This additional regression is ot reported in the table, as it would be close to a duplicate of column 2.

[10] Despite the Government Effectiveness measure and the Democracy Index not capturing exactly the same, they correlate by 0.46. Furthermore, Kahn (2005) used both, and other variabels, interchangeably when investigating institutional quality.

[11] As mentioned, the same specification for 1996 onwards looks almost identical to column 2. Thus, the differences in the estimates between column 2 and 3 indicate the sensitivity of the findings due to sampling: 1996-2016 vs. 1980-2016.

estimate is further reduced, and becoming more democratic surprisingly is associated with an increase in fatality rates. This is the specification we employ in further FE regressions with interaction terms, in sub-samples, and for the final robustness checks, as well as in the hybrid estimations, where additional time invariant control variables will be estimated along with the between effects of time-varying variables. A table of the 112 countries in the sample in this specification and a table of descriptive statistics of the relevant variables for this sample specifically, are included in the Appendix (A.1-A.2).

Lastly, for robustness purposes, column 5 presents estimates from a FE Poisson regression. The distribution of the raw data on reported fatalities is heavily skewed towards low numbers. Thus, despite making the ratios of fatalities to population and log-transforming the variable, the error term of the standard FE estimation in column 4 still has a slight right-tail, but looks more or less normally distributed except from this tail. Figure A.3 in the Appendix shows the distribution of the estimated standard error from FE, as well as the distribution of the log-transformed fatality rates. As the estimated standard error looks acceptable, but the dependent variable still quite skewed, we wanted to confirm the robustness of our results with a regression based on another distribution than the Gaussian. Based on the shape of the distribution of the dependent variable and that Wen & Chang (2015) use a Poisson regression in their study with the same raw data, we decided on a Poisson regression. As column 5 shows, we obtain a more moderate estimate of the effect of trade openness on fatality rates. However, the directions, magnitudes and significance levels are fairly similar to the standard FE estimates for all variables in the regression. Given that the results remain robust, and that for example Toya & Skidmore (2007) employ standard OLS on the same data, we thus decide to stick with the FE estimations for the remainder of the analysis.

The evident conclusion is that trade openness indeed seems to significantly reduce natural disaster fatality rates in developing countries. This finding is robust to various specifications, though with varying significance levels. For developing countries, increasing their trade ratio by 10% is associated with a subsequent reduction in natural disaster fatality rates of 2,1-3,2%. For the average country in our sample in terms of population size and fatality rates, this translates to reducing the death toll from natural disasters by 23 lives each year, from originally 757 people to 734.[12] Considering the many more people affected by the same

[12] When excluding the populous China and India from the calculation, and estimated as in column 4 in Table 5.1.

disasters, and the vast economic damages associated with them, a yearly reduction of this size is substantial for society.[13]

5.1.2 Hybrid Estimations

We continue with the specification from column 4 in Table 5.1 as we amplify our analysis with Allison's (2009) hybrid model. In addition to the time-varying variables already reported on in the FE estimations, we include time invariant control variables for the geographic size (log of km^2), as well a binary indicator of being landlocked, and region fixed effects. These are estimated along with the between effects of the time-varying variables.

The hybrid estimations are reported in Table 5.2 (p.46), which also include the standard FE (column 2) to be able to more easily compare the estimations. Since one of the advantages of the mixed models is that it enables us to formally perform an augmented regression test of whether an RE would be biased, we also include the RE estimation of the same specification (column 1). Columns 3-6 present the hybrid estimates. For the hybrid estimations, the table is divided into 2 main panels: The upper half presents within-estimates of the effect on fatality rates from a country *changing its degree of trade openness*, GDP level, degree of democracy, and so forth, over time, similarly to the FE interpretations. The lower half, however, presents the between-estimates of the effect on fatality rates from *being a more open*, more developed, more democratic, etc. country compared to others, on average over the whole time period. For the CRE estimation in column 5, the between-estimates of time-varying variables are replaced by estimated differences between the within- and between-effects. These serve as the augmented regression test, and thus separated in a box to more easily distinguish them from the between-estimates. The estimates in the RE estimation is neither within- nor between-estimates, but a weighted average of both, and as such column 1 is not divided into panels. Lastly, certain variables that are included in the specification are omitted from the table, to improve readability.[14]

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[13] In the same sample, there are about 1.800 people affected and 1.200 USD worth of damages for every reported death.

[14] Included variables that are excluded from the table: GDP^2 (not significant, nor jointly significant with GDP), Government Expenditure (not significant), and region fixed effects, which are jointly significant in all specifications. The findings suggest that countries in South Asia, East Asia and the Pacific on average experience higher fatality rates than countries in the benchmark region; Europe and Central Asia. Countries in Latin America, the Caribbean, Middle East and North Africa do so only in the non-linear models, and Sub-Saharan Africa never significantly differ from Europe and Central Asia.

There are two changes in interpretation of estimates from the included variables to how they were in the FE estimation that are worthy of mentioning. First, the hybrid estimations treat the population variable as time invariant, due to very limited within-country variation in it. This indicates the significant estimates of a growing population size on fatality rates in the FE estimations might have been misleading. It is now only interpreted as the effect on fatality rates from being a populated country versus a smaller one. Secondly, the "Number of Disasters" variable now gets two distinct interpretations: The within-estimates is the effect on fatality rates from one additional disaster happening in a country in a year compared to years the same country experience one disaster less. As such it indicates the effect of stronger disaster years. The between estimate, however, is a Disaster Propensity measure, as it estimates the effect on fatality rates of a country normally experiencing more disaster every year than other countries. Both significantly increase fatality rates in all estimations.

Column 3 presents the first hybrid estimation, which assumes a Gaussian distribution of the dependent variable. The fact that the within-estimates are very similar, but not exactly equal to the standard FE, reveals that the true model include additional nonlinearities. Nonetheless, the augmented regression test in this specification already rejects consistency of the RE estimation reported in column 1, as do a standard Hausmann test of (unclustered versions) of the RE and FE estimations reported in columns 1 and 2. Interestingly, the hybrid model reveals a strongly significant relationship between higher trade openness and lower fatality rates also across countries. Furthermore, more populated nations and landlocked nations see fewer fatalities, all else equal. Between-countries differences in GDP levels, democracy levels, education and geographic size, however, are insignificant.

Suspecting that the true model indeed includes further nonlinearities, column 4 further advances the hybrid model by including squared terms of all variables. A likelihood-ratio test (LR test) confirms the non-linear model is a better fit.[15] Most of the estimates are robust to this change in specification, except for the between estimates of education and trade ratios: It renders the trade openness estimate insignificant, whilst fatality rates are now increasing with school enrollment.

[15] A likelihood-ratio test (LR-test) rejects that the linear specification is sufficient at the 1% level.

Table 5.2: *Comparing hybrid model estimations of the chosen specification to FE and RE estimates.*

	(1)	(2)	(3)	(4)	(5)	(6)	
	RE (Gauss)	FE (Gauss)	Hybrid (Gauss)	Hybrid (Gauss)	CRE (Gauss)	Hybrid (Poisson)	
Trade Openness	-0.220***	-0.298**	-0.300**	-0.302**	-0.302**	-0.203**	**Within**
	(0.067)	(0.125)	(0.119)	(0.118)	(0.118)	(0.091)	
GDP p.c.	0.914	0.752	0.537	-0.029	-0.029	0.019	
	(0.632)	(1.085)	(0.998)	(0.210)	(0.210)	(0.137)	
Democracy Index	0.041**	0.045*	0.042*	0.041*	0.041*	0.019	
	(0.018)	(0.025)	(0.024)	(0.024)	(0.024)	(0.017)	
Education	-0.000	-0.002	-0.002	-0.001	-0.001	-0.001	
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	
Number of Disasters	0.087***	0.087***	0.088***	0.088***	0.088***	0.061***	
	(0.024)	(0.025)	(0.024)	(0.025)	(0.025)	(0.014)	
Trade Openness			-0.169***	0.258	0.560*	0.018	**Between**
			(0.061)	(0.315)	(0.330)	(0.220)	
GDP p.c.			0.595	0.138	0.166	-0.344	
			(0.870)	(0.587)	(0.663)	(0.557)	
Democracy Index			0.032	0.059	0.018	0.038	
			(0.022)	(0.095)	(0.097)	(0.070)	
Education			0.001	0.036***	0.038***	0.046***	
			(0.003)	(0.010)	(0.010)	(0.009)	
Disaster Propensity			0.079***	0.144***	0.056	0.065**	
			(0.020)	(0.037)	(0.040)	(0.028)	
Landlocked	0.027		-0.276**	-0.451***	-0.451***	-0.404***	
	(0.109)		(0.130)	(0.103)	(0.103)	(0.070)	
Population	-0.434***		-0.444***	-0.411***	-0.411***	-0.326***	
	(0.053)		(0.054)	(0.069)	(0.069)	(0.052)	
Geographic size	0.024		0.022	-0.044	-0.044	0.008	
	(0.041)		(0.051)	(0.050)	(0.050)	(0.034)	
Polynomials				X	X	X	
Observations	1376	1376	1376	1376	1376	1376	
Countries	112	112	112	112	112	112	

Notes: In columns 2-6, the upper half of the table represents the within effects of the countries changing degree of trade openness (etc.) on natural disaster fatality rates, whilst the bottom half of the table show the descriptive cross-country correlations between average trade openness (etc.) and natural disaster fatalities. The Gaussian hybrid estimation in column 3 presents estimates that are very similar, but not exactly equal to the standard FE reported in column 2, which tells us the true specification have additional nonlinearities. Specifications 4-6 thus add polynomials to improve the model fit, and an LR-test confirms that the non-linear model in column 4 is a better fit than the model in column 3. Column 5 further reports the same specification, but as a CRE. The boxed section of this estimation thus reports the augmented regression test coefficients, which jointly rejects the consistency of an RE estimation of the same specification. As with the FE estimations, we include a Poisson specification for robustness purposes. Region- and year fixed effects are jointly significant in all estimations. Other variables that are not are GDP^2 and government expenditure. Robust standard errors are clustered on country level. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

Column 5 reports the same specification, but estimated as the correlated RE model (the Mundlak/Wooldridge CRE). The boxed section of this estimation thus reports the augmented regression test coefficients. The null hypothesis implies that an RE estimation of the specification in column 4 is consistent. Some of the estimates separately show that there are significant differences between the within- and between effects of the variables, among them the trade ratio. All the estimates from the time-varying variables combined also jointly significantly rejects the consistency of an RE estimation of the same specification.[16] We can trust our within- and hybrid estimates to be more reliable than findings from OLS or RE.

The hybrid estimations reported in columns 3-5 are based on a Gaussian distribution of the dependent variable. Based on the same reasoning as in the previous FE estimations, column 6 presents the nonlinear hybrid (as columns 4 and 5) based on a Poisson distribution with a log link.[17] As with the FE Poisson, the direction and significance levels of all significant variables remain robust to this change, with the exception of the democracy index. Again, the estimate on the mitigating effect of increases in trade ratio is also slightly more conservative. The between-effect of trade openness also stays insignificant.

Importantly, the within-estimates of trade openness on fatality rates remain robust across all hybrid estimations. Furthermore, the within-estimate of the democracy index remains positively correlated with losses, and stays significant at the 10% level in all, but one estimation, and the number of disaster events within a year significantly increases the death toll. The between-countries estimates of trade openness, GDP level and the democracy index, however, are insignificant, whilst disaster propensity, population size and being landlocked all significantly determine natural disaster fatalities.

In conclusion, increasing the trade ratio by 10% in the hybrid estimations still reduces the fatality rates by 2-3%, in line with the FE estimations. Since the between-estimates of trade openness resulted insignificant, the estimates remain robust the change to Poisson regression, and we have formally confirmed the inconsistency of RE estimates, we resume the analysis employing only standard FE estimation.

[16] Consistency of RE estimations of the nonlinear specification in column 4 is rejected at the 1% level through the augmented regression test: A joint significance χ^2-test of the difference-estimates in the boxed part of the CRE estimation.

[17] This in line with the estimation choices of Wen & Chang (2015), who regress the log of natural disaster fatalities on political orientation and various controls, among them the logged trade ratio.

5.2 Sub-samples of Disaster Types

5.2.1 Instant Damages vs. Gradual Damages

The general results presented so far are based on reported fatalities from nine different disaster types. Since these disaster types behave differently in terms of how often they occur, where they occur and how the losses arise and accrue, they likely depend on different determinants. This section investigates the mitigating effect of trade openness more detailed.

The previously presented mechanisms through which trade openness might reduce risk refer to building preparedness or improving crisis management, or a mixture of both. The first sub-sample split thus contrasts disaster types of short durations that induce more or less instant fatalities (earthquake, landslides, storms, volcanic activity and mass movements) with durable disaster types where fatalities accumulate over the whole period of the disaster (floods, droughts, wildfires and extreme temperature waves).[18] Whereas the first category depends almost exclusively on a country being prepared to withstand the disaster, the latter depends both on preparedness and on crisis management during and after the disaster. This analytical division based on how losses accrue is, as far as we know, new to the literature.

Interestingly, Table 5.3 on the next page demonstrates that the estimate of trade openness on fatality rates is both larger and more significant in the instant losses-sample than in the overall findings, and not significant at all for disaster types where losses gradually accumulate. This indicates that for developing countries, the mechanisms through which trade openness increases natural disaster preparedness seem to be the driving mechanisms in disaster risk reduction. Examples of such would be knowledge and technology transfers and improvements in infrastructure and regulations. The mechanisms that hypothetically would secure relief during and after a disaster, however, such as relief aid and easier imports to even out food deficits from crop losses, surprisingly seem of no significant importance.

[18] This is our own division of natural disaster types into the two categories, based on the reported durations in EM-DAT.

Table 5.3: *FE estimations of trade openness on fatality rates of disaster types where losses either occur instantly or in a short time frame, versus disaster types where losses accumulate gradually.*

	(1)	(2)
	Disaster types: Instant losses	Disaster types: Gradual losses
Trade Openness	-0.504***	-0.029
	(0.136)	(0.114)
Number of Disasters	0.070***	0.033**
	(0.015)	(0.015)
R^2	0.116	0.098
Observations	768	1081
Countries	91	104

Notes: The table presents estimates of trade openness on natural disaster fatality rates. The specification is still the main model (Column 4 from Table 5.1), and includes the log of GDP p.c., GDP p.c.^{2} and population, and measures of education and democracy and government expenditure, of which none are statistically significant and thus not reported, as well as jointly significant year dummies. Robust standard errors are clustered at country level. The trade openness estimate is both larger and more significant in the instant losses-sample than in the overall findings, and not significant for disaster types where losses gradually accumulate. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

5.2.2 Disaster types

The above separation of disaster categories with instant and gradual fatalities brings us to even more detailed investigations of each disaster type. Since the mitigating effect of trade openness might vary across all disaster types, we analyze floods, storms, earthquakes, landslides and extreme temperature waves independently.[19] We now use the disaster type-specific fatality rates and number of disasters, but with respect to all other variables, maintain the same specification as before. Furthermore, whilst the aggregated disaster analysis did not allow for controlling for magnitudes and duration due to the unfeasibility of comparing these across disasters, these sub-sample analyses allow us to do exactly that.

We employ the disaster type-specific magnitude measures explained, in the data section, for floods, storms, earthquakes and extreme temperature periods, as well as a duration variable measured in days for floods, storms and extreme temperatures. However, including the controls reduces the sample size considerably, and for that reason, each disaster type is

[19] As shown in the data section, the other disaster types (wildfires, droughts, volcanic activity and mass movements) suffer from very small samples, which is likely to compromise the validity of the models if one were to investigate them.

analyzed both with and without magnitude and duration (except landslides, which do not have reported magnitudes, and only last an instant). Table 5.4 on the next page presents these estimations.

As the table shows, increasing trade openness by 10% is associated with a statistically significant reduction in fatality rates of storms, earthquakes and extreme temperature periods, ranging 4.3-11.3%. For the other disaster types, the effect of trade openness is insignificant. Worthy of noticing, including the magnitudes and duration measures substantially increase the explanatory power of every disaster type regression, and in the case of floods more than doubling it. Furthermore, the frequency of disasters for each disaster type is significant for nearly every regression, but the significance is usually reduced when controlling for magnitude and duration. This indicates that magnitudes and duration might be more critical than the number of disasters in determining the fatality rates. Indeed, duration significantly increases the fatality rates of both floods and storms, whilst the physical magnitude measures are significant for storms and earthquakes. Importantly, the direction and magnitude of the significant trade openness estimates are robust to the extended specification for both storms and earthquakes. The same estimates in the extreme temperature regressions are less robust, and are statistically weaker, due to the small sample.

Table 5.4: *FE estimations of trade openness on disaster type-specific fatality rates, with and without controls for hazard magnitude and duration.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Flood	Flood (km^2)	Storm	Storm (kph)	Earthquake	Earthquake (Richter)	Landslide	Extreme temperature	Extreme temperature (Scale)
Trade Openness	-0.060	0.044	-0.474**	-0.750**	-0.500**	-0.425*	0.049	-0.676*	-1.130**
	(0.095)	(0.120)	(0.218)	(0.336)	(0.250)	(0.258)	(0.122)	(0.347)	(0.424)
Magnitude		0.027		0.984***		0.666***			-0.019
		(0.021)		(0.275)		(0.155)			(0.176)
Duration (Days)		0.010***		0.059***					0.008
		(0.002)		(0.016)					(0.009)
Number of Disasters	0.066***	0.073***	0.082**	0.040	0.327***	0.285**	0.164***	0.414*	0.342
	(0.022)	(0.021)	(0.033)	(0.047)	(0.113)	(0.108)	(0.040)	(0.227)	(0.282)
R^2	0.111	0.269	0.223	0.403	0.208	0.321	0.347	0.328	0.544
Observations	1015	569	488	220	276	270	238	168	88
Countries	103	85	77	44	52	52	44	32	23

Notes: The table presents estimates of trade openness on natural disaster fatality rates. The dependent variable is the log of the disaster type-specific fatality rates, and columns 2, 4, 6 and 9 includes measures of the physical magnitudes of the hazard event itself (km^2, kph, Richter scale and our extreme temperature scale), and the average duration of such disasters for each country every year, measured in days. With the exception of earthquakes, the inclusion of such controls substantially reduces the sample size. However, the trade openness estimates remain rather robust. The specification is elsewise similar to the main model (Column 4 from Table 5.1), and still includes the log of GDP p.c., GDP p.c.^{2} and population, and measures of education, democracy and government expenditure, as well as jointly significant year dummies. These controls in general do not have significant effects on the fatality rates. Exceptions are weakly significant reducing effect on storm fatalities from education, and the same on extreme temperature fatalities from development level and government expenditure, of which all three are rendered insignificant when standard errors are not clustered. The reported standard errors are robust and clustered at country level, but as some of the regressions are reduced to a relatively low number of countries to cluster on, the significance levels in the smallest samples need to be interpreted with caution. The trade openness estimate is larger than our initial finding and significant for storms, earthquakes and extreme temperature periods. Though: the latter has a small sample of few countries. The trade openness estimate in column 8 remains significant at the 10% level when not clustering, whilst the one in column 9 turns insignificant. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.

5.3 Interactions with Trade Openness

To facilitate a better understanding of the effects of trade on natural disaster risk depending on country-specific factors, estimations using interaction terms are conducted. Specifically, we investigate whether the risk mitigating effect of trade is conditional on the countries development and democracy level, the size of government expenditure, WTO membership and dependency on agriculture (measured as the agricultural percentage of GDP). The interactions are shown in the Table 5.5 below. The interaction between trade openness and the respective variables are presented in the regression output line named "Trade Interaction", and the title of each column states the term which trade is interacted with. Lastly, the table provides the results from testing joint significance of the interactions.

Table 5.5: *FE estimations of trade openness on fatality rates, including interactions terms.*

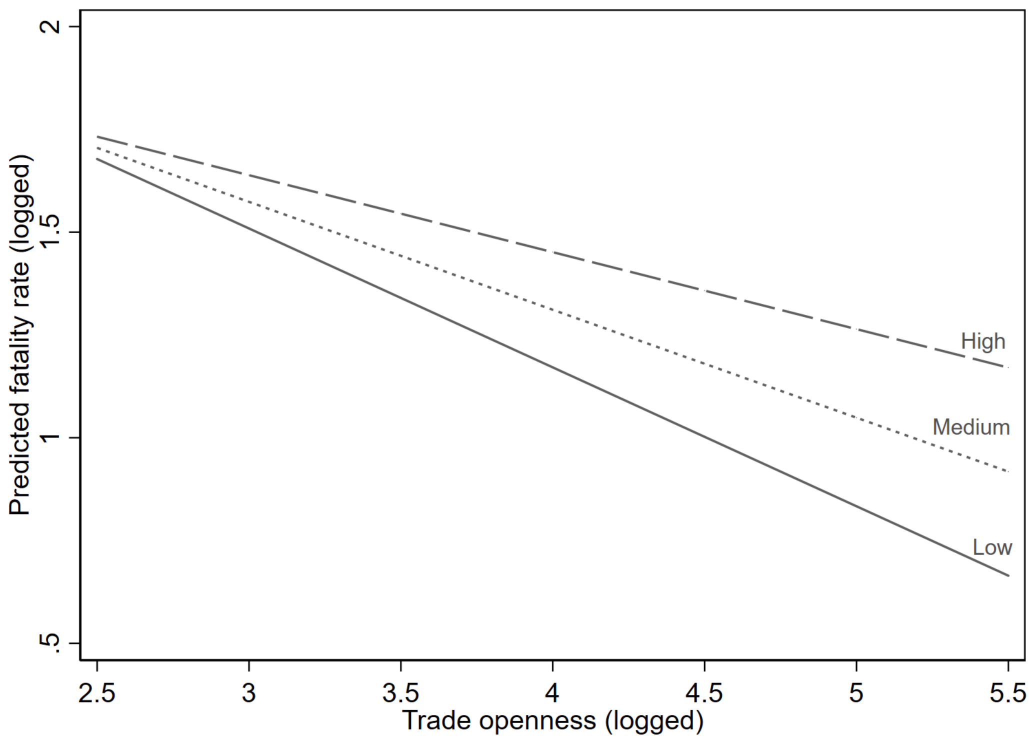
	(1)	(2)	(3)	(4)	(5)
Interaction variable:	Democracy Index	Government Expenditure	GDP per capita	WTO	Agriculture GDP
Trade Interaction	0.025	0.035***	-0.083	0.050	-0.000
	(0.026)	(0.011)	(0.147)	(0.282)	(0.009)
Trade Openness	-0.388***	-0.850***	0.350	-0.331	-0.261
	(0.138)	(0.237)	(1.190)	(0.254)	(0.172)
Democracy Index	-0.054	0.046*	0.045*	0.044*	0.031
	(0.100)	(0.025)	(0.025)	(0.024)	(0.026)
Government Expenditure	-0.000	-0.134***	-0.007	0.000	-0.004
	(0.007)	(0.043)	(0.007)	(0.007)	(0.007)
GDP p.c.	0.647	0.714	0.331	0.785	0.764
	(1.082)	(1.069)	(0.591)	(1.117)	(1.046)
WTO				-0.399	
				(1.233)	
Agriculture (% of GDP)					0.014
					(0.032)
Number of disasters	0.089***	0.088***	0.088***	0.088***	0.083***
	(0.023)	(0.024)	(0.022)	(0.025)	(0.026)
Joint significance	**	***	**	*	*
R^2	0.104	0.110	0.104	0.105	0.104
Observations	1376	1376	1376	1376	1271
Countries	112	112	112	112	109

*Notes: The table presents estimates of trade openness on natural disaster fatality rates, and estimates of trade openness interacting with various variables. The specification is still the main model (Column 4 from Table 5.1), and includes the log of GDP p.c.[2] and population and a measure of education, of which none are statistically significant and thus not reported to improve readability, as well as jointly significant year dummies. Robust standard errors are clustered at country level. All interaction estimates are jointly significant with the trade openness estimate. Significance levels are denoted *p<0.1, **p<0.05, ***p<0.01.*

The estimates of trade openness on fatality rates are significant only in the specifications where trade openness interacts with the democracy index and government expenditure (column 1 and 2). Moreover, the only interaction term that is statistically significantly different from zero is the one with government expenditure. However, all interaction estimates are jointly significant with the trade openness estimate, though in the case of WTO membership and dependency on agriculture, only at the 10% level.

The democracy interaction has a joint significance of 2%, and the coefficients indicate that the mitigating effect of trade on disaster risk is stronger in less democratic countries. The margin slopes in Figure 5.1 on the next page illustrate this, graphing the effect of trade openness on fatality rates contingent on index scores of the level of democracy. The three lines represent the predicted effect of trade on natural disaster fatality rates for little, average and very democratic countries in the sample. As suggested from the coefficients, the effect of trade on natural disaster risk is diminishing with higher levels of democracy, but still negative for all countries in our sample.

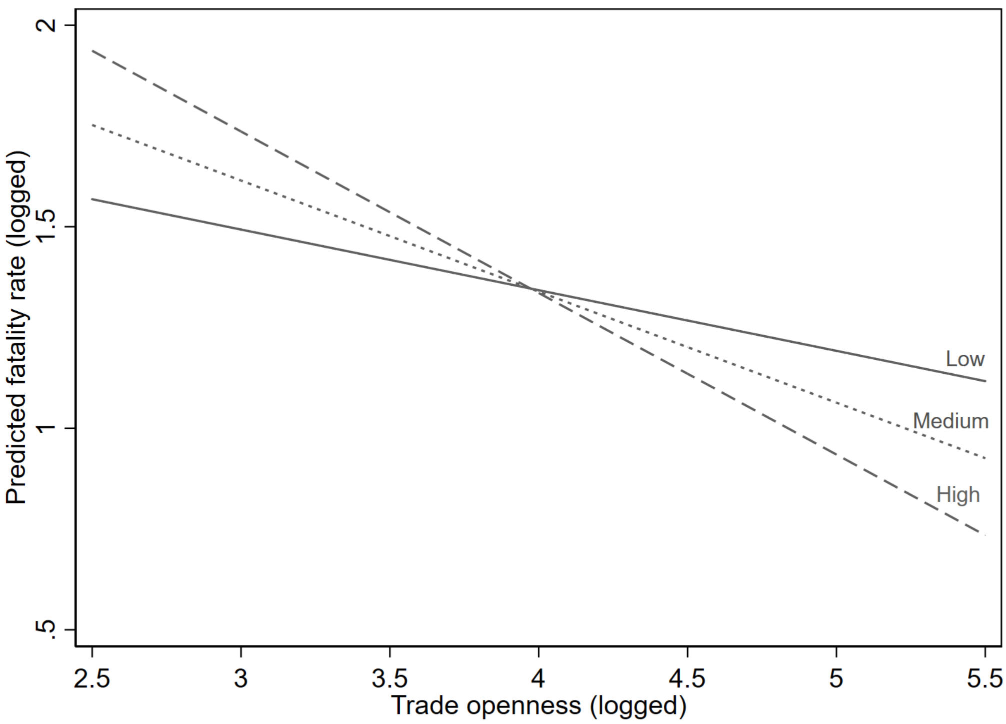
Figure 5.1: *Predictive margins of trade openness, given levels of democracy.*



Notes: The figure presents the predicted effect of trade on natural disaster fatality rates for little, average, and very democratic countries in our sample (index values of 2=low, 5=average, and 8=high on the 0-10 democracy scale). The axes of both predicted fatality rates and trade openness show log-transformed values, of the same-year fatality rate against the 5-year averaged trade ratio, receptively. The effect of trade on natural disaster risk is diminishing with levels of democracy.

All countries in the sample also see a negative effect on fatality rates from trade openness also with respect to development levels. However, in this case, higher levels of GDP per capita indicate a stronger mitigating effect of trade openness. This relationship also see a jointly significance level of 2%, and is illustrated in Figure 5.2 on the next page. The lines show the predicted effect of trade on natural disaster fatality rates at low, average and high GDP per capita levels in our sample (log-transformed GDP per capita equal to 6, 7.5 and 9). These lines thus refer to the benefits of trade in terms of mitigation for low-, lower middle- and upper middle-income countries as per the World Bank standards. Evidently, upper middle-income countries seem to benefit from trade in ways that also support disaster risk mitigation to a greater extent than less developed countries.

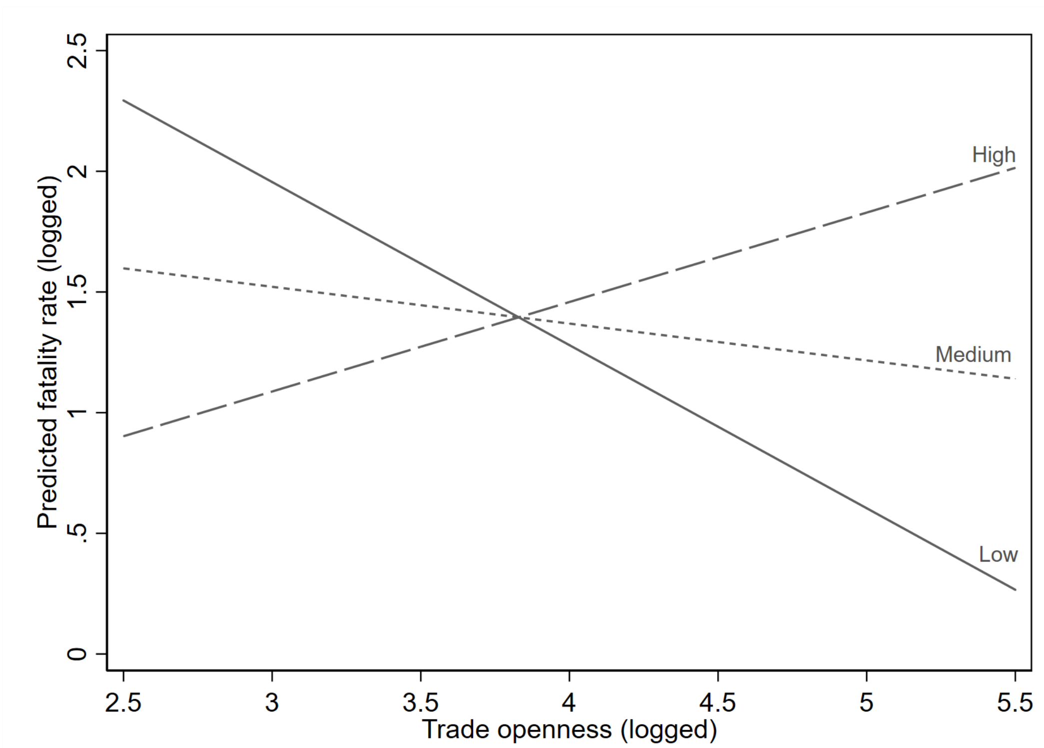
Figure 5.2: *Predictive margins of trade openness, given levels of GDP per capita.*



Notes: The figure presents the predicted effect of trade on natural disaster fatality rates for low, average, and high levels of GDP per capita in our sample. These thus represent low-, lower middle- and upper middle-income countries as per the World Bank standards. The axes of both predicted fatality rates and trade openness show log-transformed values, of the same-year fatality rate against the 5-year averaged trade ratio, receptively. Upper middle-income countries seem to benefit from trade in ways that also support disaster risk mitigation to a greater extent than less developed countries.

Lastly, the most robust and statistically significant finding on the conditionality of trade openness in mitigation, is the dependency on government expenditure. Similarly to the democracy estimation, there are diminishing effects of trade openness on risk reduction. However, this time the breaking point of the relationship is within the range of government expenditure observed in our sample. We thus see that in our sample, the countries with the highest percentage of government expenditure to GDP, experience *increasing* fatality rates with increases in trade openness. Figure 5.3 on the next page present the margins plot of low (5%), medium (20%) and high (35%) levels of government expenditure to GDP. It should be noted that the majority of the countries in our sample have government expenditure shares that are lower than the threshold (that is, below approximately 25%), and indeed experience reduction in fatality rates from increases in trade openness. As such, we still find it more likely for developing countries that trade openness reduces fatality rates, despite this dependency on government expenditure.

Figure 5.3: *Predictive margins of trade openness, given levels of government expenditure (of GDP).*



Notes: The figure presents the predicted effect of trade on natural disaster fatality rates for low, average, and high levels of government expenditure to GDP, in our sample. The axes of both predicted fatality rates and trade openness show log-transformed values, of the same-year fatality rate against the 5-year averaged trade ratio, receptively. Whilst trade openness indeed is associated with an increase in fatality rates for countries with a high percentage of government expenditure to GDP, this applies to only few countries in our sample. The majority of developing countries experience a reduction in natural disaster fatality rates with increases in trade, despite the presented dependency.

In conclusion, the mitigating effect of trade openness on natural disaster fatalities in developing countries is conditional on levels of democracy, development and the size of the public sector relative to the economy. Furthermore, as presented in Table 5.5, the effect also depends on membership in WTO and the country's dependency on agriculture. These effects are not elaborated on, as both are only weakly jointly significant, and since the effects are very small: margins plots of the two show close to parallel downward slopes.[20] However, trade openness should still reduce the fatality rates for most developing countries, as the mentioned dependencies in general only the size, and not the direction, of the effect.

5.4 Robustness

As a robustness check of the trade openness estimates obtained throughout this analysis, the main specification is run with other related independent variables: The 10-year running average of the trade ratios, WTO membership, and a 5-year moving average of net FDI inflows. Whilst the 10-year running average of the trade ratio should capture effects of trade on risk that might takes longer than 5 years to manifest in society, the WTO variable is included to pick up trade liberalization policies from the countries' administrations and willingness to participate in international organizations and collaborations. The FDI inflow is a more direct measure of the inflow of capital than the trade ratio, and thus more connected to some of the mechanisms discussed.

Table 5.6 on the next page presents the results from these estimations. Whilst the estimate of the 10-year running average of trade openness on fatality rates is negative and significant, and in line with the magnitude of the previous findings, the estimates of the other two alternates are insignificant. However, the WTO estimate's p-value of 0.14 is not very far from the 10% significance level. This estimate origins from the 63 countries in our sample that became members during 1980-2016, and although the estimated 20% reduction in fatality rates from becoming a member has little validity, the negative direction of it is likely correct. Interestingly, the positive relationship between increasing degree of democracy and fatality rates is again significant at the 10% level in both the trade and the FDI specification.

[20] The lack of any clear relationship might be due to limitations in variation in the sample data, as the FE estimation of the WTO specification captures an effect only from the countries that joined between 1980 and 2016.

Table 5.6: *FE estimations of different openness-related measures on fatality rates.*

	(1)	(2)	(3)
Independent variable:	Trade 10 years	WTO	FDI inflows 5 years
Independent variable	-0.267*	-0.207	0.018
	(0.147)	(0.138)	(0.036)
Democracy Index	0.042*	0.034	0.047*
	(0.024)	(0.024)	(0.026)
Number of Disasters	0.088***	0.083***	0.077***
	(0.022)	(0.025)	(0.024)
R^2	0.104	0.096	0.098
Observations	1412	1435	1304
Countries	116	114	112

Notes: The table presents robustness estimates of openness on fatality rates. The specification is still the main model (Column 4 from Table 5.1), and includes the log of GDP p.c., GDP p.c.^{2} and population, measures of education and government expenditure, and jointly significant year dummies. The GDP p.c. variables, government expenditure and education are averaged over to the same time period as the respective independent variables of the estimation. Robust standard errors are clustered at country level. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Lastly, since a reduction in fatalities does not necessarily mean fewer disasters or lower overall disaster risk, we checked if trade openness mitigates the economic cost of natural disasters as well as the fatality rate. This is motivated by the fact that natural disasters are defined not only by fatalities, but also by the economic damages and the people who are affected (for example injured or homeless). Numbers on damage and affected persons, however, are considered weaker measures of disaster losses, as they are vaguely defined and hard to inspect, and the prospects of humanitarian aid incentivize inflated reporting. Trade openness might make natural disasters less fatal, but still induce more damage. We find that trade openness indeed also mitigating economic damages, however, that this effect takes longer than the effect on fatalities. These estimates are reported in Table A.4 in the Appendix.

5.5 Summary of findings

The empirical analysis provides evidence that for developing countries, increasing the trade ratio by 10% is significantly associated with a 2-3% reduction in subsequent natural disaster fatality rates. This finding is robust to various specifications and estimation methods. Furthermore, the mechanisms through which trade openness improves natural disaster preparedness, rather than post-disaster management, seem to be driving the result, as disaster types that rely solely on preparedness experience an even more significant reduction of 5% in fatality rates from the same increase in trade openness. Prolonged disaster types that depend heavily on crisis management over time do not see a reduction in fatality rates from trade. Supporting this finding, both earthquakes and storms see strong significant fatality rate reductions in separate disaster type regressions. Furthermore, fatality rates of extreme temperature waves, where fatalities accumulate gradually, also see a strong and significant reduction. These findings will be thoroughly discussed in light of the presented theoretical mechanisms in the next section. For the other disaster types, the relationship is either insignificant, or the disaster type is not included due to sample size restrictions. Lastly, the findings suggest that the mitigating effect of trade openness is dependent on several factors, among them the levels of democracy and development, and the size of the public sector relative to the economy. However, trade openness still reduces the fatality rates for most developing countries, as the mentioned dependencies in general only change the magnitude of the effect, and not the direction. As such, our finding of a negative and statistically significant effect of trade openness on natural disaster fatalities in developing countries remains robust across the various investigations, but depend on the disaster type.

6. Discussion

6.1 Discussion of the results

Our findings suggest that trade openness reduce disaster risk, which is in line with the majority of the mechanisms through which we thought trade openness would affect risk, as presented in section 2.3. It is also in line with the only disaster mitigation studies that include trade openness in their findings, Toya & Skidmore (2007) and Wen & Chang (2015). As none if these studies elaborate on how or why trade indeed seem to mitigate risk, the main contribution of our study to the literature is the thorough investigation of sub-samples and interactions, as presented in the previous section. Importantly, our main finding, that countries see significant reductions in natural disaster fatality rates from increasing trade openness, remains robust to various specifications and the interactions. Moreover, we provide evidence that the strength of trade policy as a tool in mitigation depends on the disaster types the country typically is exposed to.

We have previously presented several mechanisms through which trade openness can affect disaster risk reduction, alongside their anticipated effect, as summarized in Table 2.1 on page 23. The discussion in this section largely refers to these, as to elaborate on the findings of the analysis. We recall that as trade openness increase, a country is likely to experience changes to its economic sectors, which might affect disaster risk in both beneficial and adverse ways. Furthermore, trade can induce economic growth and is also likely to reduce poverty, given the expected increase in real wages for low-skilled workers. Both of these should reduce disaster risk, but as repeatedly stated, the direction of this effect becomes clear only after a certain level of GDP per capita, making it ambiguous in our sample. Financial and human capital inflows as well as technological transfers are likely to improve for example building standards and regulations that improve the investment climate, creating a private market that possibly lessen the importance of strong government institutions. International cooperation and collaboration induced by greater relationship with other countries might improve knowledge and practices to mitigate disaster risk, while increased technical capacity in the form of trade facilitation can directly contribute to an increase in trade, and indirectly mitigate disaster risk. While our main finding suggests the mitigating effect of at least some of these mechanisms, the sub-sample analyses facilitate a more detailed discussion of which mechanisms are in place.

Before elaborating on the sub-samples and interactions, we briefly discuss some general findings from our analysis that seem to contrast some of the existing literature. As our analysis revolves around only low- and middle-income countries, these findings might not be as surprising as they seem at first glance. For example, several of the estimations suggest that the death toll from natural disasters increases as the countries become more democratic, which is not in line with Khan (2005) and Strömberg (2007). The reason for the adverse effect of this variable might be due to inefficiency and bureaucracy of some democratic governments. A transition into democratic governance is a challenging process for any country, and for those already budget-constrained and often of low capacity, even more so. This reasoning will be discussed further later on, alongside the other findings from interactions with trade openness.

Moreover, our between countries estimates, though statistically weaker and less reliant than the within estimates, do not support the notion that education should reduce risk. However, since the between effects are interpreted as the difference in levels between the countries, and the specific measure is gross primary education enrollment, this estimate probably also picks up the effect of differences in demographics. Thus, it might as well indicate that a younger population result in higher disaster risk.

Furthermore, the disaster propensity estimate shows the effect of being a country that on average experience disasters more often. Our findings suggest these countries are more vulnerable to disasters. At first glance, this is not in line with the findings and reasoning of Schumacher & Strobl (2011) and Neumayer et al. (2014), that countries with higher hazard exposure are more prepared, due to how the anticipation of disasters drives investments in mitigation. However, their samples cover all income levels, and our findings might differ mainly because of developing countries' restricted financial capacity to invest, even when disasters are anticipated. Indeed, Schumacher & Strobl (2011) find a nonlinear relationship between fatalities and the interaction of GDP levels and hazard exposure that is in line with our finding: that for developing countries, the hazard exposure do not drive investments.

Instant fatalities vs. accumulation of fatalities

The division of the disaster types into two categories by how the fatalities arise and accumulate, allows us to better understand through which mechanisms trade openness reduces disaster risk. This has not previously been done in the literature on disaster mitigation, and is thus an interesting addition. Disasters that strike instantly or last for only a short period cause fatalities mostly in this short period; such as earthquakes, storms, volcanic activity, landslides and mass movements. Disasters that last longer, however, such as floods, droughts, extreme temperature waves and wildfires, see fatalities to accumulate over time.

The trade-induced mechanisms affecting the fatality rates of the instant disaster types are presumably those that increase preparedness, such as improvements in markets, regulations and infrastructure as well as technology and knowledge transfers. Our findings indicate that these mechanisms are the dominant ones in risk mitigation in developing countries, as only disaster types of instant losses see significantly reduced fatality rates from increases in trade.

The death toll from gradual disasters, however, is likely mitigated not only through preparedness, but also crucially depend on increased capacity of crisis management and resource reserves, especially of food. As such, a lower dependency on domestic agriculture would mitigate risk through both directly limiting the damages, as these disaster types often harm the agricultural sector more than the industrial, as well as through improving access to and reliability of imports to cover the domestic demand when the crops are destroyed. This is in line with the stabilizing effects of trade in lessening demand shocks, as described by Noy (2009). These disaster types easily last for a month, and in the case of droughts several months or sometimes years, and are often accompanied by famine. Timely humanitarian aid in the form of financial support and supplies thus has the power to mitigate fatality rates of these gradual disasters. As previously discussed, trade openness can induce changes in sector dependency and in humanitarian aid inflows. Whilst the effect of the trade-induced changes in sectors on risk is ambiguous according to both theory and Benson & Clay's (2004) case studies, humanitarian aid likely reduces fatalities during a gradual disaster. We recall that aid might discourage investments in mitigation due to moral hazard (Cohen & Werker, 2008), and as such potentially have an adverse effect on fatality rates. However, since such investments mainly are targeted at increasing preparedness (physical infrastructure, etc.), the adverse effect of aid is likely limited to the instant disaster types.

Despite the expected benign effect of trade through increases in humanitarian aid, we do not find a significant relationship between trade openness and these gradual disasters. This might be due to the mentioned mechanisms not having an effect, *or* from the mechanisms cancelling each other out; for example if trade has increased the dependency on agriculture through specialization, and this increase in risk cancels out the likely mitigating effect of humanitarian efforts induced by trade openness. Thus, despite the fact that our findings do not confirm that trade openness affect fatality rates through these mechanisms, they do not reject the effect of them either. However, our significant finding on the instant disaster types strongly suggests that trade policy choices that should increase trade openness might simultaneously be tools in mitigating disasters in countries that mainly experience these types of disasters.

Disaster types

As already suggested, each disaster type is likely to differ in what the most efficient way of mitigating a disaster is. It is for example reasonable to assume that earthquake disasters are most efficiently mitigated through policies that enforce building codes, and floods through infrastructural planning and zoning laws. Moreover, storm disasters can be mitigated through warning systems, physical infrastructure and public information, while landslide disasters through restrictions on deforestation, zoning laws and public information. The mechanisms through which trade might reduce natural disaster risk are therefore also likely to differ depending on the disaster type. The analysis suggests that disasters from storms, earthquakes and extreme temperatures are mitigated through the mechanisms of trade openness. The findings of extreme temperature disasters should however be treated with care as the sample size was small.

Storms and earthquakes are two of the most studied disaster types, due to better data quality and availability on reported physical magnitudes.[21] Both disasters affect the countries more instantly than several of the other disasters, as discussed in the above section. Preparedness in the form of building codes, physical infrastructure, warning systems and public information are therefore likely to be of most importance. The trade openness mechanisms of increasing capital inflow, technological improvements and knowledge transfers through international cooperation and collaboration should therefore be most prevailing. By improving investment decisions and introducing new technologies, infrastructure and knowledge, countries should be better prepared to withstand storms and earthquake fatalities.

Higher standards for buildings can better withstand certain degrees of earthquakes and wind speeds. Warning systems and public information assures that people can prepare themselves for storms, or escape from the exposed area, before the hazardous event hits. Though

[21] These are mainly studies of solely one incident (a random shock and its' consequences), or case studies limited to specific countries, and thus not elaborated on in the earlier literature review.

statistically a weaker finding, extreme temperatures waves are also likely to be affected by several of the same mechanisms as earthquake and storms, even through these often are of longer duration, and kill gradually. Technologies that provide cool shelter and easy access to water reduce fatalities from heat waves, while better buildings and clothing reduce the risk of cold waves. Countries that do not have such technologies and equipment at necessary standards themselves might therefore benefit from accessing other markets through trade.

Floods might be hard to mitigate as they often occur unexpectedly, as flash floods or as a result of the formation of new waterways exposing new areas. Even in countries with higher level of institutions, developed infrastructure and functional markets such as the USA, floods cause many fatalities yearly (Statista, 2018). Flood is seemingly a disaster type that is hard to mitigate, as the natural process itself simply depends on country-specific geographic components. As such, reducing flood risk often requires relocation of already established cities and villages (*prevention*) rather than improving the safety of them (*preparedness*). From this, it seems expected that trade openness do not have any effect, except from perhaps weakly through improvements of regulations, if such regulations specifically address zoning laws. Landslides are a known problem in many developing countries, especially during rainy seasons. The lack of findings on this disaster type might also arise from general difficulties in predicting where they strike.

Interactions

After finding that trade openness indeed reduces disaster risk both overall and for certain disaster types individually, we further examined if the strength of this relationship depends on levels of certain country-specific factors. As stated in section 2.3, the effect of trade openness on natural disaster mitigation is likely to depend on several different country-specific factors. Institutional quality is the most emphasized factor of conditionality in the literature of both natural disaster mitigation and trade openness: For a country to actively mitigate natural disasters throughout the country, the administration must both desire to serve the majority of the people, and be able to enforce such measures. For a country to benefit from trade, in terms of economic growth, the country needs be able to apply trade policies successfully. Moreover, the ability to collect taxes and tariffs from trade is likely to be important for a financially constrained country, which the majority of the countries in our sample are, to be capable of invest in mitigation. Our findings indeed suggest that the mitigating effect of trade openness on fatalities depend on institutional and governance aspects, specifically measured by the level of democracy and the size of the public sector relative to the country's economy. Furthermore, we find that the effect depend on the country's level of development.

As explained earlier, democratic countries should in theory be more prone to actively invest in protection for the whole population. However, in our sample, democratic countries experience higher death tolls from disasters. Though at first glance counterintuitive, it makes sense, given that a transition to democracy is extremely challenging, and that it likely induces bureaucracy that risk mitigation suffer from. As such, this can still be in line with the findings of Kahn (2005) and Strömberg (2007), that *globally* fatalities are lower in more democratic countries. The interaction of democracy with trade openness serves to examine the difference in the effect of trade openness on disaster mitigation in developing countries depending on the level of democracy, which in part accounts for differences in institutional quality: the index includes civil liberties and political rights, and we saw in the analysis that it also correlates with the Government Effectiveness indicator from WGI.

We find that the relationship between trade openness and fatalities given different levels of democracy is in line with the overall 'inefficiency-effect' of democracy on risk. It suggests that less democratic countries experience a stronger reduction in disaster fatalities from trade openness, whilst the most democratic countries seem to experience the lowest effect of trade on mitigation. One would think that democratic institutions imply trade policies that are designed to assure benefits of trade for the whole population; however, this is not the case in our sample. Rather, it seems the lower efficiency of democratic administrations results in an inferior capability to assure the benefits of trade.

However, the diminishing effect of trade on disaster risk with higher levels of democracy can also be explained by the relatively higher importance of the private sector in the less democratic countries. As discussed in section 2.3, protection against disasters is a public good, which democratic, though inefficient, states in general will strive to provide, but they might fail to tackle collective action problems. In more autocratic states, however, where there is less incentive for the government to invest in public goods, private markets might be more important in reducing disaster risk. As such, the improved private markets and increased competition induced by trade, which we know from Toya & Skidmore (2007) should reduce asymmetric information and improve private investment decisions, might be a more important driver of mitigation in autocratic than in democratic countries. It seems these two trade-induced mechanisms in favor of more efficient disaster mitigation in more autocratic states are stronger drivers in developing countries than our initial hypothesis and global findings of strong democracies being more able to benefit from trade.

In part building on the same reasoning, we investigated the relationship between trade openness and fatality rates given levels of government expenditure. Government expenditure is considered by Toya & Skidmore (2007) as a proxy for government efficiency, insinuating that smaller governments in terms of expenditure are more efficient at mitigating disasters. Government expenditure in developing countries largely consists of salaries and other spending on public goods. It is thus possible to argue that a large share of government expenditure indicates higher employment and a responsible government, which successfully collect taxes and convert these funds into investments that should benefit society, and consequently reduce risk. However, this is undeniably also closely connected to bureaucracy and inefficient systems. In the same way as with democracy, we find that governments with high expenditure benefit less from trade openness with respect to disaster mitigation. This supports the above reasoning on both the inefficiency of big public sectors and the importance of private markets in disaster risk reduction. However, and importantly, only a few countries in our sample have large enough public expenditures to see increasing death rates from trade. Also, all countries experience reductions in fatality rates from trade, regardless of their level of democracy. As such, these contingencies only affect the extent to which developing countries benefit from trade openness with respect to risk mitigation, but do not change the key finding: That trade openness in developing countries is associated with lower fatality rates.

The most widely discussed determinant of natural disaster losses in the literature on mitigation is GDP. Although not significant in our analysis of solely developing countries, it is interesting to note that the qualitative direction of our estimate of the effect of GDP on fatalities is in support of the non-linear findings from Kellenberg & Mobarak (2008) and Schumacher & Strobl (2011): Increasing fatality rates from increases in GDP levels, though at a diminishing rate as the country develops. As evident in the presented literature, the benefits from trade with respect to growth, poverty and inequality also depends on development levels. It was thus a natural extension of our analysis to investigate whether the potential benefits from trade openness with respect to risk mitigation also depend on this. We found that the negative effect on fatality rates from trade openness is robust across varying levels of GDP per capita. However, higher levels of GDP per capita indicate a stronger mitigating effect of trade openness. Evidently, the upper middle-income countries seem to benefit from trade in ways that support disaster risk mitigation to a greater extent than the less developed countries do.

This might be explained by the least developed countries using trade policy mainly to boost short-term economic growth, more than securing longer-term benefits from technological knowledge, international standards of regulation or collaboration. With a higher GDP level, more efforts might be directed towards risk reduction, as the basic needs of food and shelter for the majority of the population is accounted for. Moreover, the government might be more induced to engage in international cooperation for long-term benefits, such as research projects in the field of natural disaster mitigation, after they have achieved a certain development level. Lastly, capital inflows might not be as likely for low-income countries as for middle-income countries, as the domestic market is constrained by low purchasing power. As the GDP level increase, the domestic market becomes more attractive to foreign investors, and thus attracts human and financial capital.

Lastly, we investigated whether the effect of trade openness on natural disaster fatalities depends on membership in the World Trade Organization, and on dependency on the agrarian sector. WTO not only promotes trade, but also actively works to assure that its developing members benefit from technological transfers and capacity building. As these are believed to be important components in reducing disaster risk, one could expect member countries to benefit more from trade. Interestingly, our empirical analysis could not provide any evidence of such effects. Surprisingly, we also do not find that dependency on agriculture of an economy have implications for the effect trade openness has on disaster risk. This despite of several of the countries in our sample relying on agriculture, and that theoretically, increases in trade should strengthen this specialization, following the Heckscher-Ohlin theorem, and thus increase risk.

With respect to the robustness checks, a significant, but slightly smaller estimate on the 10-year running average of the trade ratio suggests that the majority of the effects of trade openness on mitigating natural disasters already come within 5 years. We further investigated if membership in WTO reduces fatalities (that is, the membership itself on risk, not trade on risk given membership, as discussed above). Countries joining the WTO have taken an active choice towards trade liberalization. As this is an indicator of a willingness to open the country’s economy, it should proxy how open it is, with respect to both trade and collaboration, of which both should help a country advance technically. The empirical finding is insignificant, though not far from significant on the 10% level, and indicates such an effect. The last robustness check replaced the trade ratio with FDI inflows. As repeatedly mentioned, the inflow of capital can support a country in mitigating natural disaster through an improved financial system. This effect might be more accurately measured by FDI inflow than trade ratio itself. However, the analysis does not provide any empirical evidence to support this mechanism through the direct FDI inflow measure.

6.2 Implications for policy-makers

Our findings suggest that increased trade openness could be a potential priority for government administrations wanting to reduce disaster risk without directly investing in disaster mitigation. As developing countries often lack the financial capacity for long-term investments in mitigation, trade policy targeted at increasing trade openness (for example the simplification of import and export procedures, investments in trade facilitation programs or efforts to improve cooperation with trading partners) could potentially serve as an alternative. From our more detailed analyses, we find that the mitigating effect of trade openness likely arises from knowledge- and technology transfers, international collaboration, and improvements in infrastructure and investment climate. Moreover, although our findings do not confirm that trade openness affects fatality rates through more humanitarian assistance or structural transformation, they do not reject these possible channels either.

However, the mitigating effect of trade depends on disaster type. As such, countries should consider the type of hazard they are normally exposed to before integrating trade policy options in their disaster risk reduction strategies. Our findings suggest that trade openness significantly and to a stronger degree reduces the fatality rates of storms, earthquakes and extreme temperature waves, while we do not detect a significant relationship between trade openness and fatality rates from floods and landslides. The remainder of disaster types could not be investigated separately due to data limitations, but as a general indicator disaster types where fatalities happen instantly seem to benefit more from trade than disasters resulting from longer-lasting underlying causes (such as droughts).

Furthermore, the effect of trade openness on disaster mitigation depends on country-specific factors, such as the development level of a country. The implications of our findings are that on average developing countries can expect a reduction in natural disaster fatality rates from trade, however middle-income countries see a steeper reduction than the least developed countries. As such, using trade policy for disaster risk mitigation seems to be a better option for countries in the middle-income class than for low-income countries. In addition, the mitigating effect of trade seems more favorable in states that are less democratic and with smaller public sectors, which assumingly provide less public and civil services, but that might be more efficient in benefiting from trade due to less bureaucracy. The countries with smaller public sectors also seem to gain more from trade with respect to risk mitigation, potentially due to a relatively higher standing of private markets. Importantly, the effect on risk is still expected to be negative for all countries, but to varying extents.

Thus, before aligning trade policy choices with disaster risk reduction strategies, a country should consider the disaster types they are prone to, if they are organized in a sufficiently efficient manner to truly benefit from the openness with respect to risk reduction, and their overall macroeconomic performance. Despite finding that trade openness reduces fatality rates irrespective of these factors in almost all developing countries, results are particularly interesting to less democratic administrations in middle-income countries that are prone to storms, earthquakes and/or extreme temperature disasters.

Lastly, and before concluding, we want to caution our main implication with the remark that the effects of increased openness on risk might further depend on the types of policies employed to achieve this goal. Our analysis does not distinguish between these, and despite finding that the average effect of increasing openness is a reduction in natural disaster risk, some of the policy options might also have detrimental effects on the losses. To illustrate, consider the following two policies, which are likely to lead to an increase in the trade ratio of a country: investments in infrastructure that facilitate cross-border trade, *or* elimination of duties imposed on imports. It is hard to think of ways the first option could lead to higher fatality rates in the case of a natural disaster. However, the second option likely results in a loss of government revenue due to missing income from import taxes, which potentially could reduce the government's capacity to mitigate natural disasters. This illustrates that the specific policies through which increased openness is achieved may matter substantially. As such, countries need to consider also how the specific options are likely to affect them, which relates back to the discussed contingency of institutional quality to benefit from trade.

7. Conclusion

Many low and middle-income countries around the world are not only constrained by low levels of development, but also by natural disasters that inhibit them from developing. This study empirically tests the relationship between trade openness and disaster fatality rates in developing countries and discusses the mechanisms through which trade openness might affect disaster risk. Through fixed effects estimations and supporting findings from a hybrid model, increases in trade openness are found to significantly decrease subsequent fatality rates. This finding is robust to various specifications. However, more detailed analysis suggests that the found effect is robust only for some of the investigated disaster types, and that it depends on country-specific factors such as institutions quality and development level.

The objective of this study is to better understand how the developing world can increase natural disaster preparedness without compromising short-term development. Trade openness is a subject that has been touched upon, but not yet discussed, in the existing literature on natural disaster mitigation. This study contributes with an extensive presentation and discussion of the hypothetical mechanisms through which trade openness can mitigate natural disaster risk, supported by empirical findings. Furthermore, it aims at enhancing the understanding of which country-specific factors might determine the effect trade policy choices have on disaster mitigation in developing countries, and at providing a better understanding of mitigation of different disaster types. Since trade openness can actively be influenced by a country's administration, the findings also offer feasible policy implications. Despite finding that trade openness reduces risk regardless of the investigated interactions, results are particularly interesting to less democratic governments in middle-income countries that experience storms, earthquakes or extreme temperature disasters.

As a concluding note, trade openness and disaster mitigation are both complex fields. This study has discussed the mechanisms between the two in a broad manner, thus serving as an introduction to the subject. Several of the mentioned mechanisms deserve closer attention and specific empirical investigations of their own. The role of trade openness on disaster risk through changes to economic sectors, foreign direct investments and non-financial international cooperation requires deeper understanding. Furthermore, as there has been uncertainty of the effect government expenditure has on disaster mitigation in the literature there appears to be a need for further elaboration on this feature.

8. References

Allison, P. D. (2009). *Fixed effects regression models* (Vol. 160). SAGE publications. Retrieved from https://uk.sagepub.com/en-gb/eur/fixed-effects-regression-models/book226025

Anbarci, N., Escaleras, M. & Register, C. A. (2005). Earthquake Fatalities: The Interaction of Nature and Political Economy. *Journal of Public Economics, 89(9 – 10),* 1907–33. Retrieved from https://www.sciencedirect.com/science/article/pii/S0047272704001525

Belasen, A. R., & Polachek, S. W. (2008). How Hurricanes Affect Wages and Employment in Local Labor Markets. *American Economic Review, 98(2),* 49-53. Retrieved from https://www.jstor.org/stable/pdf/29729993.pdf

Benson, C., & Clay, E. (2003). Disasters, vulnerability and the global economy. *Building Safer Cities: The Future of Disaster Risk, 3,* 3-32. Retrieved from https://elibrary.worldbank.org/doi/abs/10.1596/0-8213-5497-3#page=27

Benson, C., & Clay, E. J. (2004). *Understanding the economic and financial impacts of natural disasters (No. 4).* World Bank Publications. Retrieved from http://documents.worldbank.org/curated/en/146811468757215744/pdf/284060PAPER0Disaster0Risk0no-04.pdf

Bhagwati, J. & Srinivasan, T. N. (2002). Trade and Poverty in the Poor Countries. *The American Economic Review 92(2),* 180-183. Retrieved from https://www.jstor.org/stable/pdf/3083398.pdf?refreqid=excelsior%3Afe0dcd75c06e4043a6707f86346daacb

Borrmann, A., Busse, M., & Neuhaus, S. (2006). Institutional quality and the gains from trade. *Kyklos*, *59*(3*),* 345-368. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-6435.2006.00336.x

Camerer, C. F., & Kunreuther, H. (1989). Decision processes for low probability events: Policy implications. *Journal of Policy Analysis and Management, 8(4),* 565-592. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.2307/3325045

Coe, D., Helpman, E. and Hoffmaister A. (1997) North-South R&D Spillovers. *Economic Journal, 107,* 134-149. Retrieved from https://www.jstor.org/stable/pdf/2235275.pdf?refreqid=excelsior%3Ac9e02543fc7d8e42dcfc74ff0e57743a

Cohen, C. & Werker, E. (2008). The Political Economy of ``Natural'' Disasters. *Journal of Conflict Resolution 52(6),* 795-819. Retrieved from http://www.jstor.org/stable/pdf/27638641.pdf?refreqid=excelsior%3Adc875821f895935f98e5877e69d8f524

Dahlberg, S., Holmberg, S., Rothstein, B., Pachon N.A., & Svensson, R. (2018). The Quality of Government Basic Dataset, *Jan18. University of Gothenburg: The Quality of Government Institute.* Retrieved from http://www.qog.pol.gu.se doi:10.18157/QoGBasJan18

Das, S., & Vincent, J. R. (2009). Mangroves protected villages and reduced death toll during Indian super cyclone. *Proceedings of the National Academy of Sciences, 106(18),* 7357-7360. Retrieved from http://www.pnas.org/content/106/18/7357.full

Djalante, R. (2012). Adaptive governance and resilience: the role of multi-stakeholder platforms in disaster risk reduction. *Nat. Hazards Earth Syst. Sci., 12,* 2923-2942, Retrieved from https://www.nat-hazards-earth-syst-sci.net/12/2923/2012/

Dollar, D. & Kraay, A. (2002) Institutions, Trade, Growth. The World Bank. *Econ. Lett. 94(1),* 20-25. Retrieved from http://siteresources.worldbank.org/DEC/Resources/Institutions,Trade_and_Growth.pdf

Edwards, S. (1997). Trade Policy, Growth and Income Distribution. *The American Economic Review, 87(2),* 205-210. Retrieved from https://www.jstor.org/stable/2950914?seq=5#page_scan_tab_contents

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium

EM-DAT (2018a). The International Disaster Database: Center for Research on the Epidemiology of Disasters. Retrieved January 20, 2018 from http://emdat.be/

EM-DAT (2018b). The International Disaster Database: Center for Research on the Epidemiology of Disasters. Explanatory Notes. Retrieved February 18, 2018 from http://emdat.be/explanatory-notes

EM-DAT (2018c). The International Disaster Database: Center for Research on the Epidemiology of Disasters. Classification. Retrieved February 18, 2018 from http://emdat.be/classification

Escaleras, M. & Register, C. A. (2012). Fiscal decentralization and natural hazard risks. Public Choice *151,* 165–183. Retrieved from https://link.springer.com/article/10.1007/s11127-010-9740-4

Felbermayr, G. & Gröschl, J. (2013). Natural disasters and the effect of trade on income: A new panel IV approach. *European Economic Review*, *58*, 18–30. Retrieved from https://www.sciencedirect.com/science/article/pii/S0014292112001547

Felbermayr, G., & Gröschl, J. (2014). Naturally negative: The growth effects of natural disasters. *Journal of Development Economics, 111,* 92-106. Retrieved from https://www.sciencedirect.com/science/article/pii/S0304387814000820

Field, C. B., Barros, V., Stocker, T. F., & Dahe, Q. (Eds.). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change*. Cambridge University Press.

Flores, A. Q. (2015). Protecting People from Natural Disasters: Political Institutions and Ocean-Originated Hazards. *Political Science Research and Methods, 1-24*. Retrieved from https://doi.org/10.1017/psrm.2015.72

Flores, A. Q., & Smith, A. (2013). Leader Survival and Natural Disasters. *British Journal of Political Science 43(4),* 821-843. Retrieved from https://www.cambridge.org/core/journals/british-journal-of-political-science/article/leader-survival-and-natural-disasters/4B2098E72474AA77302ECD6D21EBAC79

Frankel, J. A. & Romer, D. H. (1999). Does Trade Cause Growth? *American Economic Review*, 89, (3): 379-399. Retrieved from https://www.aeaweb.org/articles?id=10.1257/aer.89.3.379

Freedom House. (2018). Methodology. Retrieved May 25 2018 from https://freedomhouse.org/report/methodology-freedom-world-2018

Guha-Sapir, D., Hargitt, D., & Hoyois, P. (2004). Thirty years of natural disasters 1974-2003: The numbers. *Presses univ. de Louvain.* Retrieved from http://pdf.usaid.gov/pdf_docs/PNADL369.pdf

Hadenius, A., & Teorell, J. (2005). Assessing Alternative Indices of Democracy. *Political Concepts, Committee on Concepts and Methods, 6.* Retrieved from http://www.concepts-methods.org/Files/WorkingPaper/PC%206%20Hadenius%20Teorell.pdf

Heckscher, E. F., & Ohlin, B. G. (1991). *Heckscher-Ohlin trade theory.* The MIT Press.

Hegre, H. (2000). Development and the Liberal Peace: What Does it Take to be a Trading State? *Journal of Peace Research, 37(1),* 5-30. Retrieved from http://www.jstor.org/stable/425723

Iwanow, T., & Kirkpatrick, C. (2007). Trade facilitation, regulatory quality and export performance. *Journal of International Development*, *19(6),* 735-753. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1002/jid.1399

Kahn M. E. (2005). The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions. *The Review of Economics and Statistics, 87(2),* 271-284. Retrieved from http://www.jstor.org/stable/40042902

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2010). "The Worldwide Governance Indicators: Methodology and Analytical Issues". *World Bank Policy Research Working Paper, 5430.* Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1682130)

Kellenberg, D. K. & Mobarak, A. M. (2008). Does rising income increase or decrease damage risk from natural disasters. *Urban Econ. 63(3),* 788-802. Retrieved from https://doi.org/10.1016/j.jue.2007.05.003

Kousky, C. (2013). Informing climate adaptation: A review of the economic costs of natural disasters. *Energy Economics, 46,* 576-592. Retrieved from http://www.sciencedirect.com/science/article/pii/S0140988313002247?via%3Dihub

Liargovas, P. G., & Skandalis, K. S. (2012). Foreign direct investment and trade openness: The case of developing economies. *Social indicators research, 106(2),* 323-331. Retrieved from https://link.springer.com/article/10.1007/s11205-011-9806-9

Marshall, M. G., Jaggers, K., & Gurr, T. R. (2017). Polity iv project, political regime characteristics and transitions, 1800-2016. *Center for Systemic Peace*. Retrieved from http://www.citeulike.org/group/582/article/369537

Mayer, T. & Zignago, S. (2011). Notes on CEPII's distances measures: the GeoDist Database. *CEPII Working Paper, 25*. Retrieved from http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=6

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica: journal of the Econometric Society*, 69-85. Retrieved from http://www.jstor.org/stable/1913646

Nandi, A., Mazumdar, S., & Behrman, J. R. (2018). The effect of natural disaster on fertility, birth spacing, and child sex ratio: Evidence from a major earthquake in India. *Journal of Population Economics, 31(1),* 267-293. Retrieved from https://rd.springer.com/article/10.1007/s00148-017-0659-7

Neumayer, E. (2002) Does trade openness promote multilateral environmental cooperation? *World economy, 25(6).* 815-832. Retrieved from https://doi.org/10.1111/1467-9701.00464

Neumayer, E., Plümper, T., & Barthel, F. (2014). The Political Economy of Natural Disaster Damage. *Global Environmental Change, 24*, 8-19. Retrieved from https://doi.org/10.1016/j.gloenvcha.2013.03.011

Noy, I. (2009). The macroeconomic consequences of disasters. *Journal of Development. Economics, 88(2),* 221–231. Retrieved from https://doi.org/10.1016/j.jdeveco.2008.02.005

OECD. (2005). The costs and benefits of trade facilitation. *Policy Brief.* Retrieved from http://www.oecd.org/trade/facilitation/35459690.pdf

Oneal, J. R., Oneal, f. H., Maoz, Z. & Russett, B. M., (1996), The Liberal Peace: Interdependence, Democracy, and International Conflict, 1950-85'. *Journal of Peace Research*, *33(1),* 11-28. Retrieved from http://www.jstor.org/stable/425131

Raschky, P. A. (2008). Institutions and the losses from natural disasters. *Natural hazards and earth system sciences*, *8(4),* 627-634. Retrieved from https://www.nat-hazards-earth-syst-sci.net/8/627/2008/nhess-8-627-2008.pdf

Rybczynski, T. M. (1955) Factor Endowment and Relative Commodity Prices. *Economica, New Series, 22(88),* 336-341. Retrieved from http://www.jstor.org/stable/2551188

Sawada, Y. & Takasaki, Y. (2017). Natural Disaster, Poverty, and Development: An Introduction. *World Development*, *94*, 2-15. Retrieved from http://www.sciencedirect.com/science/article/pii/S0305750X1630585X?via%3Dihub

Schumacher, I. & Strobl, E. (2011). Economic development and losses due to natural disasters: The role of hazard exposure. *Ecological Economics, 7(1*5), 97-105. Retrieved from https://doi.org/10.1016/j.ecolecon.2011.09.002

Schunck, R. (2013). Within and between estimates in random-effects models: Advantages and drawbacks of correlated random effects and hybrid models. *Stata Journal, 13(1),* 65-76. Retrieved from https://www.stata-journal.com/article.html?article=st0283

Schunck, R., & Perales, F. (2017). Within-and between-cluster effects in generalized linear mixed models: A discussion of approaches and the xthybrid command. *Stata Journal, 17(1),* 89-115. Retrieved from https://med.mahidol.ac.th/ceb/sites/default/files/public/pdf/stata_journal/sj17-1.pdf#page=95

Solow, M.R. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70(1), 65*-94. Retrieved from https://www.jstor.org/stable/1884513?origin=JSTOR-pdf&seq=1#page_scan_tab_contents

Spence, W., Sipkin, S.A., & Choy, G.L. (1989). Measuring the Size of an Earthquake. *Earthquakes & Volcanoes 21(1),* 58-63. Retrieved from https://pubs.usgs.gov/unnumbered/70039068/report.pdf

Statista. (2018). Floods in the U.S. - number of fatalities from 1995 to 2017. Society: Geography & Environment. Retrieved June 6, 2018 from https://www.statista.com/statistics/203709/number-of-fatalities-caused-by-floods-and-flash-floods-in-the-us/

Stolper, W. F. & Samuelson, P. A. (1941). Protection and Real Wages. *The Review of Economic Studies, 9(1),* 58-73. Retrieved from https://doi.org/10.2307/2967638

Strömberg, D. (2007). Natural disasters, economic development, and humanitarian aid. *Journal of Economic perspectives*, *21(3),* 199-222. Retrieved from https://www.aeaweb.org/articles?id=10.1257/jep.21.3.199

Toya, H. & Skidmore, M. (2007). Economic Development and the impacts of natural disasters. *Economic Letters, 94(1),* 20-25. Retrieved from https://doi.org/10.1016/j.econlet.2006.06.020

UNISDR (2017, February 5th). Terminology. Retrieved April 29, 2018 from https://www.unisdr.org/we/inform/terminology

Vaillancourt A. & Haavisto I. (2015). Country logistics performance and disaster impact. *Disasters, 40(2),* 262-283. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/disa.12146

Wen, J. & Chang, CP. (2015). Government ideology and the natural disasters: a global investigation. *Natural Hazards 78(3),* 1481–1490. Retrieved from https://doi.org/10.1007/s11069-015-1781-z

Wilson, J. S, Mann, C. L & Otsuki, T. (2004). Assessing the Potential Benefit of Trade Facilitation: A Global Perspective. *World Bank Policy Research Working Paper 3224.* Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/14733/wps3224TRADE.pdf

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

World Bank. (2018). DataBank. Retrieved March 15, 2018 from http://databank.worldbank.org/data/home

World Bank. (2018). World Bank Country and Lending Groups. Retrieved January 15, 2018 from https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

World Governance Indicators. (2018). World Governance Indicators project. Retrieved March 15th from http://info.worldbank.org/governance/wgi/#home

WTO. (2003). *World Trade Report 2003.* Retrieved from https://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report_2003_e.pdf

WTO. (2018a). Trade topics: Trade facilitation. Retrieved May 7, 2018 from https://www.wto.org/english/tratop_e/tradfa_e/tradfa_e.htm#III

WTO. (2018b). Members and Observers. Retrieved April 19, 2018 from https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm

Yanikkaya, H. (2003). Trade openness and economic growth: a cross-country empirical investigation. *Journal of Development Economics 72(1),* 57-89. Retrieved from https://www.sciencedirect.com/science/article/pii/S0304387803000683

9. Appendix

A.1: *List of countries with descriptive statistics of fatality rates and 5-year averaged trade ratios for the sample of the main specification (Column 4 of Table 5.1).*

Country	Fatality rates			Trade % GDP 5-year average		
	Frequency	Mean	Std. Dev.	Frequency	Mean	Std. Dev.
Afghanistan	14	350.3	334.11	14	85.3	27.01
Albania	6	5.0	3.63	6	63.0	17.54
Algeria	25	170.9	492.69	25	58.1	9.16
Angola	12	56.3	47.66	12	130.5	18.65
Armenia	2	2.5	2.12	2	86.1	15.92
Azerbaijan	7	9.7	14.64	7	87.4	10.38
Bangladesh	36	5082.4	23180.30	36	27.4	9.05
Belarus	5	3.6	1.52	5	128.8	5.65
Belize	1	8.0	0.00	1	118.1	0.00
Benin	11	16.7	19.34	11	53.2	4.80
Bolivia	19	60.5	48.85	19	60.2	14.43
Bosnia and Herzegovina	6	7.7	9.14	6	94.4	11.30
Botswana	4	10.8	7.18	4	102.7	12.02
Brazil	17	160.0	233.56	17	24.3	3.07
Bulgaria	14	12.5	14.91	14	95.6	13.99
Burkina Faso	11	15.5	13.57	11	42.5	10.28
Burundi	10	35.1	42.47	10	37.3	9.42
Cabo Verde	3	13.7	13.61	3	99.5	5.13
Cambodia	16	99.1	148.66	16	102.4	29.07
Cameroon	15	128.7	447.55	15	49.4	6.86
Central African Rep.	10	2.5	1.96	10	40.1	5.09
Chad	10	332.6	937.65	10	67.4	23.52
China	36	4441.9	14503.27	36	35.3	15.11
Colombia	34	830.6	3713.43	34	33.6	3.55
Comoros	2	3.0	1.41	2	59.3	6.86
Congo Dem. Rep.	16	50.9	63.83	16	55.3	17.33
Congo	4	7.0	8.29	4	135.3	2.74
Costa Ric	17	16.2	16.38	17	80.9	7.74
Cuba	22	8.7	11.34	22	46.0	18.84
Côte d’Ivoire	7	23.0	12.53	7	83.5	9.86
Djibouti	2	98.0	66.47	2	104.3	27.11
Dominica	4	9.0	14.00	4	102.0	16.28
Dominican	18	77.6	178.23	18	70.8	9.66
Ecuador	5	151.0	297.07	5	60.2	1.55
Egypt	15	111.9	192.15	15	50.7	7.73
Eritrea	1	3.0	0.00	1	56.4	0.00
Ethiopia	1	128.0	0.00	1	43.1	0.00
Fiji	21	13.5	11.36	21	112.2	13.89
Gambia	7	10.7	18.84	7	61.8	10.25
Georgia	8	8.5	13.01	8	85.2	16.27

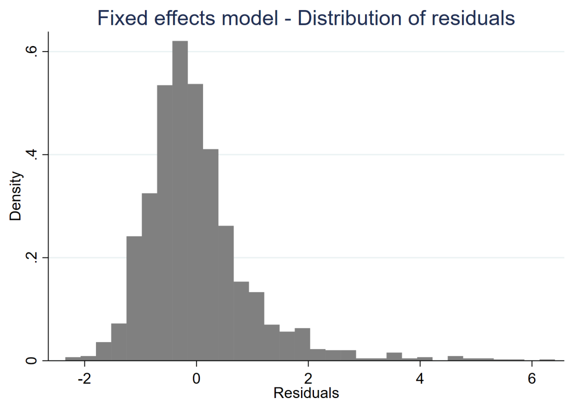
Grenada	1	39.0	0.00	1	92.5	0.00
Guatemala	24	135.3	327.75	24	52.4	12.87
Guinea	5	7.0	4.00	5	53.9	10.73
Guinea-Bissau	3	2.7	0.58	3	50.4	1.70
Haiti	21	418.7	1181.72	21	52.2	12.89
Honduras	22	711.4	3103.41	22	98.5	27.33
India	36	3885.8	4599.49	36	27.0	14.30
Indonesia	32	5887.9	29237.91	32	51.5	7.02
Iran	26	2992.7	9191.00	26	38.1	9.84
Iraq	4	11.5	9.85	4	93.3	38.42
Jamaica	11	7.6	5.82	11	93.5	6.56
Jordan	6	8.3	4.46	6	117.5	6.57
Kazakhstan	10	23.0	35.97	10	92.9	22.50
Kenya	18	85.4	58.03	18	56.6	3.92
Kyrgyzstan	10	41.6	49.47	10	90.6	18.47
Lao Dem. Rep.	7	16.3	17.00	7	82.5	9.59
Lebanon	1	1.0	0.00	1	78.1	0.00
Lesotho	1	26.0	0.00	1	148.4	0.00
Liberia	5	12.0	19.38	5	182.3	73.52
Libya	1	16.0	0.00	1	102.7	0.00
Macedonia	9	7.2	8.07	9	92.0	14.43
Madagascar	17	97.0	93.07	17	64.8	10.91
Malawi	16	88.2	171.67	16	58.9	5.29
Mali	7	14.3	13.45	7	58.2	1.19
Mauritania	8	7.3	7.80	8	92.3	17.24
Mauritius	1	11.0	0.00	1	114.1	0.00
Mexico	13	77.8	63.49	13	57.2	5.19
Micronesia	1	5.0	0.00	1	106.6	0.00
Moldova	7	5.6	4.96	7	128.5	7.68
Mongolia	11	23.6	20.74	11	103.2	12.43
Morocco	15	124.9	240.26	15	59.4	9.60
Mozambique	25	90.0	165.03	25	61.3	22.73
Myanmar	14	9968.6	36955.42	14	4.4	9.19
Namibia	7	37.7	44.87	7	95.2	8.50
Nepal	33	513.2	1550.76	33	43.4	9.34
Nicaragua	21	199.8	719.93	21	71.3	20.40
Niger	18	22.2	25.26	18	50.2	9.78
Nigeria	18	83.7	91.87	18	56.5	11.96
Pakistan	35	2610.4	12461.16	35	34.0	2.05
Panama	20	9.9	11.42	20	130.2	16.10
Papua New Guinea	18	167.2	506.16	18	106.1	13.86
Peru	23	209.0	245.49	23	39.9	10.20
Philippines	21	1122.4	1735.71	21	86.1	13.99
Romania	24	42.0	43.25	24	65.0	11.28
Russia	23	2675.8	11601.57	23	55.3	6.76
Rwanda	12	55.3	69.38	12	36.8	5.86
Saint Lucia	3	7.0	6.56	3	102.4	3.90

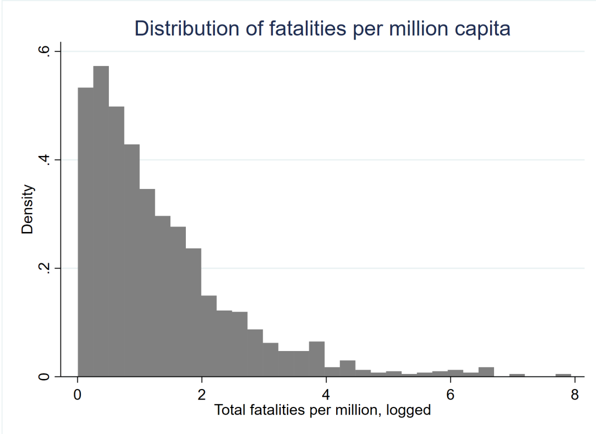
St.Vincent & the Grenadines	3	6.3	4.93	3	102.6	16.81
Samoa	3	52.7	82.66	3	84.3	5.00
Senegal	11	24.9	54.36	11	68.6	3.75
Sierra Leone	6	30.0	36.07	6	49.0	14.75
Solomon Islands	3	22.0	21.66	3	122.8	2.85
South Africa	29	57.8	97.76	29	51.7	7.33
South Sudan	2	73.0	36.77	2	90.2	5.47
Sudan	21	54.6	54.88	21	27.6	10.03
Suriname	2	2.5	0.71	2	78.1	11.06
Swaziland	5	113.4	217.16	5	150.0	26.89
Syria	4	29.5	35.16	4	66.4	3.41
Tajikistan	2	8.0	5.66	2	75.5	2.14
Tanzania	10	30.5	22.85	10	45.2	5.63
Thailand	31	415.5	1490.68	31	92.0	32.02
Timor-Leste	2	2.0	1.41	2	167.2	48.95
Togo	4	18.0	17.45	4	88.1	13.77
Tunisia	3	15.0	2.65	3	89.6	7.60
Turkey	29	775.7	3323.03	29	39.5	9.32
Turkmenia	1	11.0	0.00	1	134.5	0.00
Ukraine	12	97.8	228.23	12	92.3	15.69
Uzbekistan	3	15.7	7.37	3	67.0	10.70
Vanuatu	11	21.4	30.98	11	100.5	6.23
Viet Nam	17	254.1	170.10	17	131.9	22.91
Yemen	15	197.5	390.44	15	67.2	12.80
Zimbabwe	9	64.7	88.18	9	80.6	7.11
Total	1,376	903.1	7957.41	1,376	65.1	33.07

A.2: *Summary statistics of the main specification with the associated sample.*

Variable	Observations	Mean	Std.Dev	Min	Max
Fatalities p.c. (log)	1,376	1	1.19	0	7.9
Trade 5-years average (log)	1,376	4.0	0.60	0.2	5.6
GDP p.c. 5-year average (log)	1,376	8	0.99	5.2	9.6
Democracy Index	1,376	6	2.70	0.3	10
Government expenditure 5-year average	1,376	16.3	10.53	4.0	145.1
Education 5-year average	1,376	99	20.37	24.9	165.6
Frequency of Disasters	1,376	4	4.73	1	43
Geographic size (log)	1,376	13	1.77	5.8	16.6
Population (log)	1,376	17	1.74	11.2	21.0
Landlocked	1,376	0	0.38	0	1
Regions					
East Asia & Pacific	1,376	0	0.38	0	1
Europe & Central Asia	1,376	0	0.34	0	1
Latin America & Caribbean	1,376	0	0.41	0	1
Middle East & North Africa	1,376	0	0.28	0	1
South Asia	1,376	0	0.32	0	1
Sub-Saharan Africa	1,376	0	0.45	0	1

A.3: *The distribution of residuals of the fixed effects model estimation & the distribution of the dependent variable, fatalities per million capita.*





A.4: *Fixed effects estimations of trade openness on economic damages as percentage of GDP.*

	(1)	(2)
Dependent variables:	Damages to GDP	Damages to GDP
(Length of running average of trade ratio)	(5 years)	(10 years)
Trade Openness	-0.289	-0.768**
	(0.286)	(0.344)
GDP p.c.	4.427	5.776*
	(3.777)	(3.207)
Number of Disasters	0.104***	0.109***
	(0.036)	(0.034)
R^2	0.086	0.088
Observations	804	824
Countries	100	100

Notes: The table presents estimates of trade openness on natural disaster-related economic damages. The specification is still the main model (Column 4 from Table 5.1), and includes the log of GDP p.c.^{2} and population, and a measure of education, democracy and government expenditure, of which none are statistically significant and thus not reported, as well as jointly significant year dummies. The GDP p.c. variables, government expenditure and education are averaged over to the same time period as the respective trade variable in the two estimations. The sample sizes for the damage estimations are considerably lower than the sample using fatalities. The estimate of the effect of trade openness on reported economic damages (as a percentage of GDP) is significant only when the trade variable is a 10-year running average. A 10% increase in the average trade ratio of the last 10 years, decrease the economic damages to GDP by 7.68%. This suggests that trade openness reduce damages, but it takes longer for it to have an effect on these then on fatality rates. GDP per capita is significant showing a 1 % increase in GDP per capita on the 10-year average increase damages of GDP with 5.7%. This suggests a large effect of increasing GDP per capita on damages. Through this effect seems exaggerated, increased disaster damages for countries with higher GDP is in line with intuition as these countries have more capital in the form of physical structures that can be damaged. The number of disaster coefficient are in line with previous findings and significant. The reported standard errors are clustered on country level. Significance levels are denoted $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$.