Natural disasters, trade and Preferential Trade Agreements

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Abstract

Environmental shocks in the form of natural disasters are well-known for their impact on domestic economies. Less known, however, is their impact on the global economy. The scant existing literature suggests that macro-economic impacts manifest in observed empirical decreases in international trade. The literature, however, does not distinguish between the type of natural disasters driving the observed empirical decrease in traded goods. Moreover, no existing research examines if the impact of natural disasters on trade varies for trading partners with differing levels of market integration. This paper examines if preferential liberalization, i.e. the presence of Preferential Trade Agreements (PTAs), can serve to protect or buffer against the negative economic consequences of natural disasters. I find that two natural disaster types, floods and landslides, drive the observed negative impact of natural disasters on trade. Additionally, I show that deep preferential liberalization can not only protect countries against the negative macro-economic impact of natural disasters but can actually allow countries to increase exports during natural disaster events that otherwise induce trade decline. These findings suggest that by allowing countries to expand the quantity and the range of exports, PTAs lead to enhanced resilience against exogenous economic shocks.

1 Introduction

The increase in intensity and frequency of extreme weather events is arguably the most visible consequence of climate change. In 2012, The Intergovernmental Panel on Climate Change (IPCC) released a special report which noted that climate change could be responsible for alterations in the intensity, spatial extent, duration, and timing of many extreme weather-related events.[1] Even non-experts observe the swelling frequencies and severity of natural disasters: a 2012 poll found that, by a margin of 2:1, U.S. residents feel that natural disaster impacts are getting worse, and a large majority believe that climate change contributes to the increased intensity of recent natural disasters.[2] Projections indicate that the observed trend will continue into the twenty-first century, emphasizing the high probability of growth in both the number and intensity of natural disasters worldwide.[3]

Natural disasters inflict catastrophic social and economic costs on both rural and urban populations. These environmental shocks have the potential to cause drastic declines in international trade, posing a critical threat to macroeconomic stability. Surprisingly, minimal research has addressed whether and how natural disasters impact international trade. For states to effectively adapt their economies to a climate increasingly characterized by such calamities, evidence of their effects is needed. Moreover, research on the relationship between trade and natural disasters is vital to the development of strategies to maintain macroeconomic stability under a changing climate.

In examining the negative effect of natural disasters on trade, I explore if and how international cooperation can mitigate the severity of this exogenous threat. Specifically, I focus on Preferential Trade Agreements (PTAs), the primary tool of trade cooperation over the last two decades. I argue that the existence of PTAs allows trading partners to maintain positive levels of trade during natural disasters that would otherwise result in export reductions. Indeed, I show that in the pres-

[1] IPCC 2012.
[2] Leiserowitz et al 2012.
[3] IPCC 2012.

ence of environmental shocks, PTAs allow countries to increase their exports, as preferential tariffs grant discriminatory market access to partner countries. I argue that this effect operates through the extensive margins of trade, which is supported by existing evidence showing that PTAs increase the quantity and range of products a country can trade.[4] PTAs thereby allow states to substitute sales previously made to the domestic market that are no longer in demand due to disaster induced declines in consumption, with the international market.

I test my argument on a large dataset covering international trade flows between 180 countries from 1979 to 2009. I include data on the occurrence of every natural disaster globally since 1960, taken from the EM-DAT Database.[5] Additionally, using fine-grained data on the design of trade agreements,[6] I differentiate between shallow and deep trade cooperation. As is customary in the empirical literature on trade, I employ a gravity model to estimate trade flows between dyads over time. Following the estimation technique proposed by Baier and Bergstrand,[7] I include three high dimensional fixed effects to account for (un)observable confounders.

The main results are three-fold. First, I show that all three economic sectors are negatively affected by different types of natural disasters, with exports in agricultural and manufactured incurring the greatest losses. Second, I provide evidence that deep PTAs not only mitigate the observed negative consequences but in fact increase exports during natural disasters. These results are robust to the inclusion of other dimensions of the design of PTAs (e.g. flexibility). Third, I show that the PTA mechanism operates through the extensive margins of trade. Put simply, deep PTAs allow countries to avoid a reduction in exports by increasing the range of products traded between partner countries, leading exporters to substitute products affected by the natural disaster with those unaffected.

This paper relates to several branches of the literature on environmental policy and international cooperation. First, I demonstrate that PTAs present a form of

[4]Baier and Bergstrand 2013.
[5]EM-DAT, 2017.
[6]Dür et al 2014.
[7]Baier and Bergstrand 2007.

institutional adaptation to climate change by inducing national economic resilience against the negative effects of natural disasters.[8] This evidence suggests that deepening trade commitments may mitigate the negative effects of climate change. Moreover, my findings are in line with previous studies showing that international trade agreements reduce trade volatility.[9] My contribution to this literature is demonstrating that PTAs are particularly effective in stabilizing trade flows in the presence of negative environmental shocks. Furthermore, my results emphasize the importance of institutional design in cases of high levels of uncertainty due to natural disasters, a finding in line with the seminal work by Koremenos et al.[10]

Finally, this research has important and timely policy implications. The evidence I provide suggests that countries may improve economic resilience to exogenous environmental shocks by deepening their preferential trade commitments. Indeed, countries that are members of deep PTAs are better equipped to endure economic turmoil triggered by climate change than countries with no or shallow PTAs. With adaptation increasingly understood as an essential policy response to climate change,[11] identifying and providing evidence to support the effectiveness of institutional adaption strategies is more salient than ever. By illustrating the potential for international cooperation to reduce the economic impacts of natural disasters, this paper contributes to the development of future international policy responses to climate change.

2 Natural Disasters and Trade Cooperation

In the last several decades, natural disasters have increased by a four-fold,[12] with the average number rising from 23 per year in the 1950s to 150 in the 1980s, to 357 in the period of 2000–2008 (Figure 1).[13] Adverse economic consequences from disaster

[8] Carter et al 1994.
[9] Mansfield and Reinhardt 2008.
[10] Koremenos et al 2001.
[11] Ford et al 2015.
[12] Schwartz 2006.
[13] UN/ISDR 2008.

events have also increased: the average economic loss has risen from approximately 12 billion US dollars per year in the 1970s to 83 billion USD since 2000 (Figure 3). Understanding the connection between the proliferation of natural disasters and climate change is perplexing due to the difficulty in distinguishing long term trends from natural variability. However, the International Governmental Panel on Climate Change (IPCC) reported that given anthropogenic climate change, it is more than likely that the frequency and intensity of hydro meteorological extreme events have increased.[14] Recent disasters have illuminated economic vulnerability at the macro level, through observed implications on international trade. For example, beginning in the early 2000s, the FAO has continuously reported the severe vulnerability of agricultural trade to the impact of natural disasters.[15]

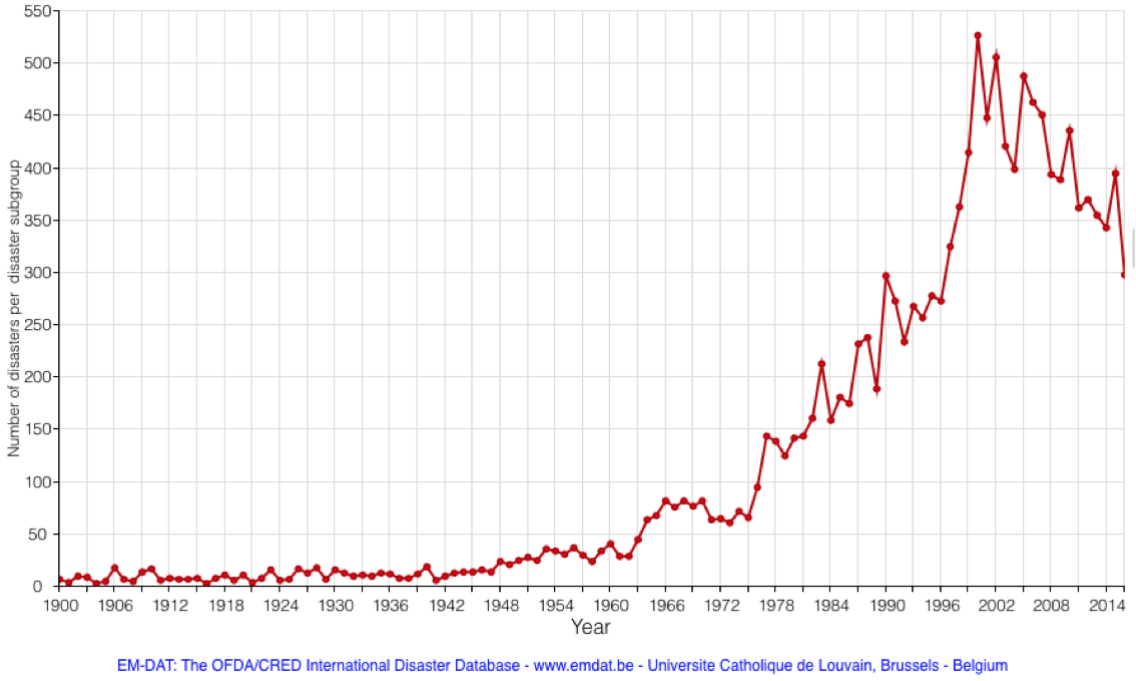

Figure 1: Frequency of natural disasters, 1900-2014

While trade in agriculture is widely understood to be vulnerable to the impacts of natural disasters, more recent natural disaster events illuminate the sensitivity of trade in manufactured products. For example, the World Trade Organization

[14]IPCC 2012.
[15]FAO 2014; FAO 2015; and FAO 2016.

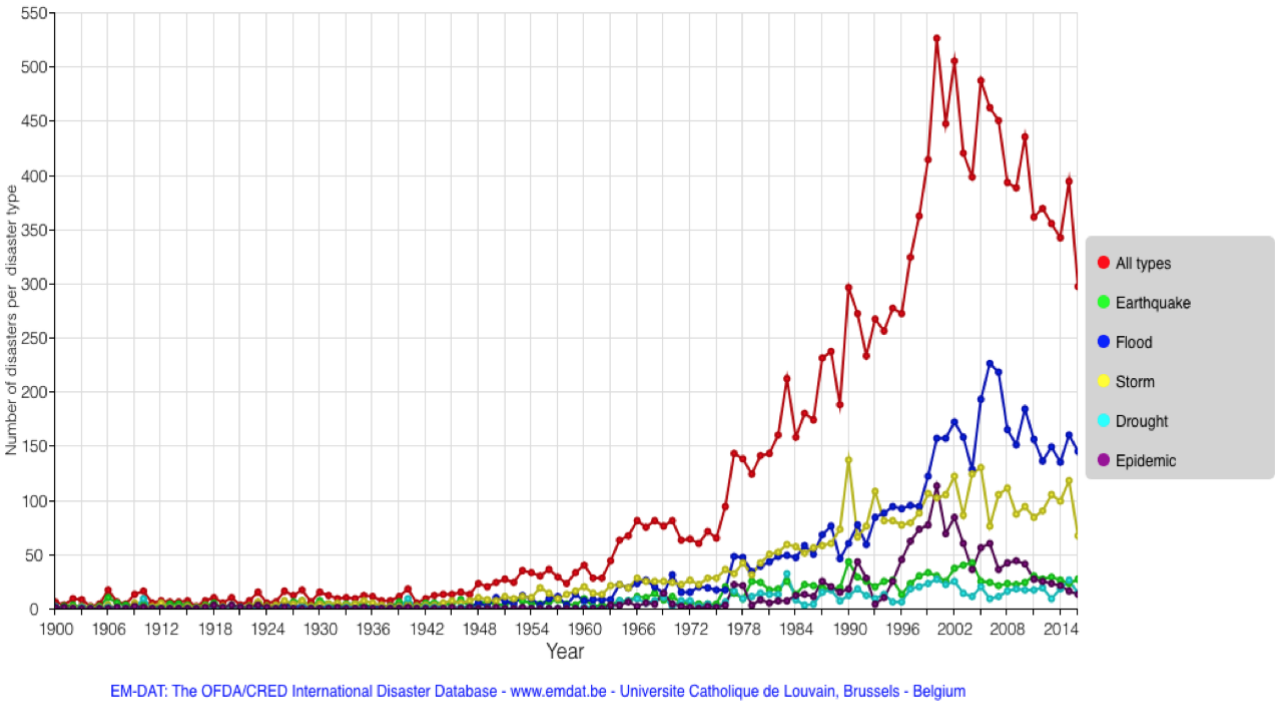

Figure 2: Frequency of natural disasters by sub-types, 1900-2014

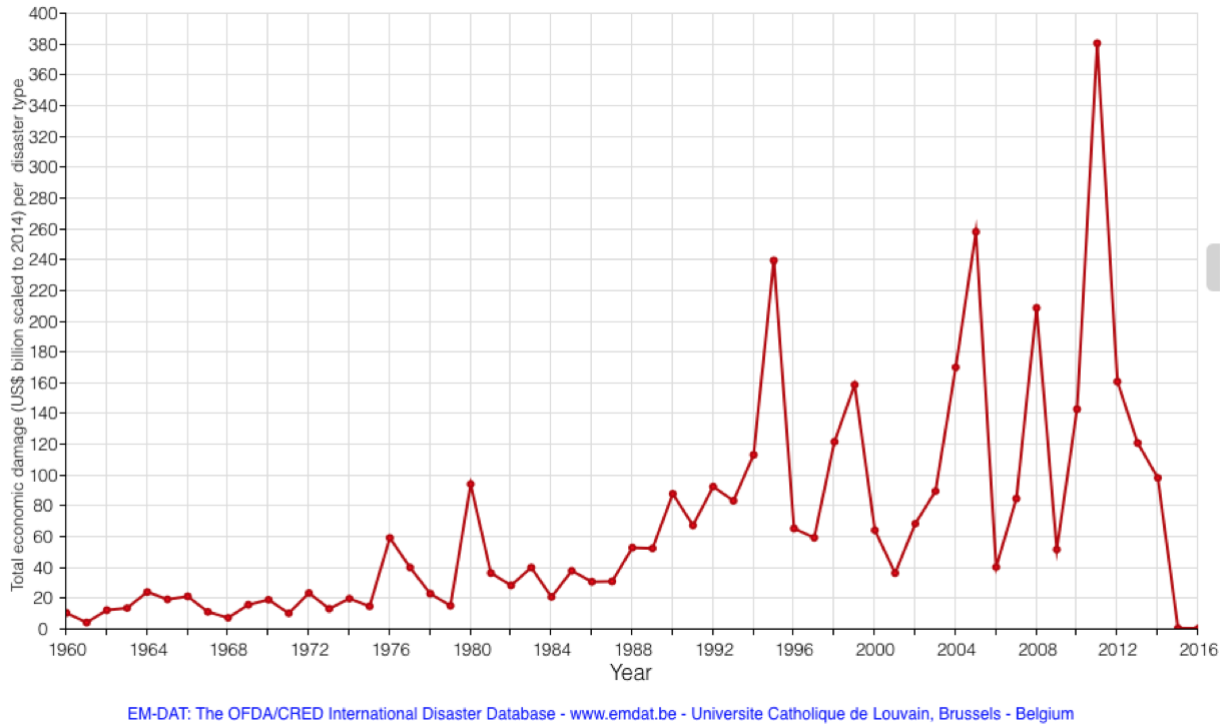

Figure 3: Reported economic damage (USD) from natural disaster events 1960-2016

(WTO) attributed the Tohoku tsunami in Japan and flooding in Thailand to below-average growth in international trade in 2011 because of the damage to global supply chains, in particular the electric, semiconductor and automaker chains.[16] The surge in the regularity of disaster events and their associated costs justifies the growing interest in their economic impact, particularly considering the advancements made in understanding their increased probability under projected climate changes.[17]

Given the topics salience, preceding work has already explored the relationship between natural disasters and trade. Gassebner et al find that natural disasters reduce trade in both exporter and importer countries.[18] Similarly, Hoon Oh and Reuveny conclude that an increase in climatic disasters in either importer or exporter countries reduces their bilateral trade.[19] Da Silva and Cernat's work suggests that observed declines in exports during natural disasters are driven by the exports of small developing countries.[20] Using gravity models of trade, the aforementioned studies each illuminate the potential negative influence of disasters on bilateral trade. Yet, this earlier literature fails to consider the heterogenous character of natural disaster types, ignoring how this could differentiate their effect on trade. This paper aims to offer insight on if and how the various types of extreme weather events uniquely effect trade, refining our understanding on the relationship between international trade and natural disasters.

First, I demonstrate that the negative effect of natural disasters occurs as the result of two mechanisms, damage to human capital and economic damage. Next, I argue that PTAs buffer against the potential negative effect of natural disasters by reducing the fixed and variable costs associated with trade. In particular, by increasing the extensive margins of trade, PTAs allow exporters to substitute the domestic market, where demand has been disrupted by the disaster, with the foreign market, which in turn leads to trade growth during natural disasters. In this sense,

[16] WTO 2012.
[17] Ruck 2006
[18] Gassebner, Keck and Teh 2006.
[19] Oh and Reuveny 2010.
[20] Da Silva and Cernat 2012.

PTAs can be understood as a form of institutional adaptation to climate change; by allowing countries to avoid potential economic losses during natural disasters, international cooperation in the form of PTAs provides enriched economic resilience to climate related exogenous shocks.

2.1 The effect of natural disasters on trade

The potential impact of natural disasters on trade is two-fold. First, reductions in trade may occur when disasters destroy and or reduce human capital (e.g., kill people, induce human injury, leave people with minimal resources). As a result, the labor supply collapses, leading to a reduction in output and subsequently trade. Additionally, domestic demand decreases as consumers are pre-occupied with post disaster recovery rather than ordinary consumption activity.[21] Second, reductions in trade arise as a result of damage to physical capital (e.g., destroy plants, and damage storage and transportation infrastructure). With a fall in production, income may decline, which shrinks private spending and investments. Tax revenues likely also decline, which reduces public spending. By inducing physical damage, disasters can raise the cost of trade; producers may need to rely on lengthier routes or inconvenient export sites to reach markets. Insurance premiums may also grow, as insurers seek to protect against any increased risk. An upsurge in costs in turn raises the price of goods, leading to a decrease in (total) demand.

There is, however, an important caveat to this argument. Consider a country that loses its share of exports in a given product as an outcome of a natural disaster that prompts loss of capital, production means and trade routes. Yet it is likely that a share of the country's productive capacity remains unscathed, as most natural disasters do not wipe out the majority of a country's economy. Hence, when human casualties and asset loss lead to a halt in consumption in the market where the natural disaster occurred, as is typical for disaster events under our definition, unaffected sectors may substitute domestic sales with sales to the international market.[22] In

[21] Oh and Reuveny 2010.

[22] Oh and Reuveny 2010 also point to the increase in humanitarian relief aid, entry of foreign

the section below, I argue that the capacity of a firm to switch from domestic to foreign sale depends on the presence of international economic agreements.

2.2 The role of preferential trade agreements

A form of trade institution, PTAs yield effects on a multitude of economic, political, social phenomena. They do so through various mechanisms, including the liberalization of previously protected sectors, enhanced cooperation between states and changes in the intensive and extensive trade margins. Although research on how PTAs influence domestic economic variables has in recent years taken a prolific character,[23] the interaction between PTAs and exogenous shocks has been overlooked. The question is whether PTAs can serve to buffer against some of the negative economic consequences that exogenous shocks induce. I argue that in the presence of environmental shocks, PTAs allow countries to continue exporting due to the discriminatory market advantages they provide. I posit that this mechanism operates through the extensive margins of trade, the range of goods exported, for dyads that sign particularly deep PTAs.

Designed to lower trade costs, PTAs have been lauded by trade scholars for inducing significant reductions in tariffs, as well as synchronizing standards between trading partners. Average tariff cuts alone were the original determinant of the depth of a trade agreement, where depth can be understood as the extent to which an agreement constrains state behavior.[24] More recently, however, the scholarship has illuminated how PTAs contribute to liberalizing trade relations between states through the synchronization of standards. For example, by allowing foreign companies to bid for tenders for government procurement contracts. [25] Other behind-the-border obstacles that a deep trade agreement may remove are burdensome technical standards, inadequate protection of intellectual property rights, and competition rules

business and foreign currency stimulus, as possibilities for trade promotion under extreme weather events.

[23] Baier and Bergstrand 2007.

[24] Downs, Rocke and Barsoom 1996.

[25] Rickard and Kono 2014.

that discriminate against foreign traders. [26] Cooperation on competition policy, for example, is critical to addressing unfair business behavior by state enterprises and private firms that otherwise present huge market costs.[27] Trade agreement depth is therefore a function of both tariff cuts and provisions concerning services, government procurement, investments, standards, intellectual property rights and competition, which all lead to a reduction in trade costs.

A *deep* trade institution, one that includes a various and profound forms of trade liberalization, is more likely to induce a substantial reduction in both fixed and variable costs. A reduction in these costs makes entrance into the export market economically feasible for a larger number of producers. This is best explained by Melitz, who introduces firm heterogeneity into a model of trade.[28] Entry into the domestic market depends on sunk entry costs and fixed production costs, where firms who cannot pay must leave. At the international level, firms face fixed and variable export costs, which are always greater than the fixed costs in the domestic market. Thus, exporters self select into the international market, as only the more productive firms can afford the additional costs of entry. However, in the presence of a PTA that reduces the fixed and variable costs of trade, domestic firms face lower foreign market entry costs, making it feasible for more firms to become exporters (extensive margins) and for existing exporting firms to increase their sales to foreign markets (intensive margins). As PTAs get deeper, more costs are reduced, which can induce greater increases in trade. Indeed, the effect of PTAs and in particular, deep PTAs, on the extensive margins of trade is well documented.[29]

The argument for how deep PTAs facilitate increased exports during a natural disaster proceeds as follows. A natural disaster event leads domestic demand to plummet due to damage to physical and human capital. The sole option for domestic firms to preserve their productivity is to substitute the loss in domestic sales with an export market that is unaffected by the exogenous shock. However, entering the

[26] Piermartini and Budetta 2009.
[27] Dür, Baccni and Elsig 2014.
[28] Melitz 2003.
[29] Baier, Bergstrand and Feng 2014.

foreign market entails larger fixed and variable costs relative to the domestic market and thus, the substitution of domestic with foreign markets is considered unfavorable to domestic producers. Accordingly, in the absence of the natural disaster, most firms prefer to serve the local economy alone. Remaining domestic allows them to evade the additional entrance costs the foreign market entails and thereby ensures greater profits. During a natural disaster, however, the domestic market fails to absorb all of the firm's products. Since deep PTAs lower both fixed and variable costs, they make it conceivable for exporters to substitute domestic demand with international demand. Deep PTAs can therefore facilitate positive trade flows even in the presence of an economic shock that otherwise generates export declines.

Not all natural disasters, however, are made equal. There exist natural disasters so vast and intense in nature that no trade agreement could save the implicated country from export loss. The Haitian earthquake of 2010, for example, was responsible for over 300 thousand lives, with the estimated total value of damage equal to 100% of the country's GDP in the year prior to the disaster.[30] It would be unreasonable to expect a political agreement to protect a country from economic destruction of such magnitude. Indeed, for a PTA to grant economic benefits during a natural disaster, a sizeable portion of the economy must remain relatively unscathed.

A necessary assumption of my argument is that during the average natural disaster event, aggregate domestic demand dwindles, while a considerable share of economic production endures. Indeed, a plethora of studies detail domestic demand declines during natural disasters.[31] Nakamura et al report that after a natural disaster, average consumption can fall upwards of 30% in the short run, and up to 15% in the long run.[32] However, although aggregate consumption levels decline, the consumption of several specific goods may rise. Commodities and essential goods, such as water, basic clothing and medical supplies commonly grow in demand both during, after and even prior to the natural disaster event. Final goods, on the other

[30] Bellerive 2010.
[31] Yezer and Runin 1987; Ellson et al.1984; Dacy and Kunreuther 1969.
[32] Nakamura et al. 2010.

hand, such as designer clothing and electronics, as well as intermediate goods decline as consumers tend only to their most basic needs.

For example, in 2017, a series of high intensity earthquakes subsumed Mexico. However, because core infrastructure was largely unaffected, the earthquakes did not weaken the productive capacity of the economy. The core economic outcome stemmed instead from the loss of domestic property, which stranded assets, displaced thousands of people and thereby drove down domestic demand for consumer goods.[33] Of course, this is in part due to chance; where a natural disaster hits a country is almost entirely exogenous. But because in most countries the ratio of land occupied by domestic residents is typically larger than private enterprise, there is a greater chance that residential areas experience much of the effects of an exogenous shock.

2.3 An illustrative case: Japan 2011

In disaster scenarios where a sizeable portion of private production remains intact but domestic consumption has shrunk, firms may face incentives to turn to the international market. This decision, however, depends on whether the existing trade framework renders it financially feasible. There exists considerable anecdotal evidence of trade fluctuating during natural disasters in a way consistent with my hypothesis. The potential explanatory power of my argument is best demonstrated by considering the following example of when a country with a number of deep trade agreements was faced with an unprecedented environmental catastrophe. When Japan found itself at the center of its most dramatic crisis since World War II in 2011, exports were shockingly resilient.

The nation was struck by a three-way disaster; a devastating tsunami, nuclear disaster and 9.0 magnitude mega-earthquake that spewed off the northeastern shore of Japan. The greatest earthquake in record history to have hit Japan, the tsunami waves it created were so vast they spilled over huge stretches of the shoreline. Coastal cities and towns were ripped apart by the great inundation of seawater, which carried

[33] Amador et al. 2017.

ships inland, flattening thousands of homes and washing mass quantities of debris and vehicles back into the ocean. Finally, a third disaster erupted when damage to the reactors at TEPCO's Fukushima Daiichi Nuclear Power Plant led to a contamination of an area so wide that even to this day 100,000 Japanese residents are forced to live as evacuees. The earthquake and its subsequent catastrophes led to damage worth tens of billions of dollars and over 16,000 lives./footnoteKajitani et al. 2013.

In the time following the disaster, exceptional downward pressure on economic activity occurred as a result of the deterioration in household sentiment, as well as the diminishing number of tourists arriving from abroad. Voluntary restraint by consumers spread nationwide immediately after the earthquake, dampening spending, particularly for luxury goods. Exports, however, grew as a percentage of GDP, raising from 28.61% to 30.39% in 2010 and 2011.[34] Total export value also increased, moving from $769, 774 million in 2010, to $823, 184 million in 2011. These numbers substantiate the argument presented here; Japan is a member of several deep PTAs with an extensive range of trading partners.

Importantly, Japan managed to increase trade exclusively with those partners that the country shares deep agreements with. Trade flows with Australia, a deep trading partner with Japan, for example, increased from $3 billion in the first quarter, to over $5 billion by the third quarter, a few of months after the March disaster.[35] The trade patterns of OECD countries that do not have a deep agreement with Japan attest to my argument; Ireland, Israel, Italy, Korea, Luxembourg, Mexico, the Netherlands, New Zealand and Norway all imported a reduced or equivalent quantity of goods from Japan in 2011. Although quarterly trade data could not be obtained for Non-OCED countries, yearly trade fluctuations for another deep PTA partner with Japan, Thailand, also support my argument. In 2010, Japan exported $34 billion worth of goods to Thailand, which increased to $37 billion in 2011, and by 2012 had rose to $43 billion.[36]

[34]WITS 2019.
[35]OECD 2019.
[36]WITS 2019.

In sum, Japan's experience in 2011 provides an illustration of the otherwise counter intuitive argument I bring forward. When domestic economic conditions took a turn for the worst, Japanese producers looked to their deep trade linkages to maintain sales. The abovementioned case of Haiti demonstrates that this is not always a country's experience during natural disasters. I argue, however, that on average, deep PTAs afford countries significant economic resilience during natural disasters.

2.4 Empirical Implications

I test two main empirical implications of my argument. First, I expect that natural disasters negatively effect trade. More formally,

Implication 1: Natural disasters reduce the exports of the effected country.

Second, I predict that countries with particularly deep trade agreements maintain positive export levels during natural disasters. By lowering the cost of trade, deep PTAs increase both intensive and extensive trade margins. A deep PTA thereby allows producers to substitute domestic sales with international sales during an adverse economic event in the domestic market.

Implication 2: Deep PTA agreements allow countries to maintain positive export levels in the presence of natural disasters that otherwise result in export declines.

3 Description of the Data

The final dataset employed in this study is the product of four merged databases. To estimate the effect of natural disasters on trade flows, Harmonized System 1992 trade classification data of bilateral trade values at the six digit were taken from the Observatory of Economic Complexity (OEC). The data from OEC comes from

the United Nations Statistical Division (COMTRADE), but is cleaned up by the BACI International Trade Database. Our classification of agricultural, mining and manufacturing products comes from WTO International Trade Statistics.[37]

Gross domestic production (GDP) measures, population size and GATT/WTO membership variables were obtained from the data set used by Dür, Baccini, and Elsig.[38] To minimize the number of missing values, the dollar value of countries' bilateral trade flow in their database is a combination of IMF's Direction of Trade Statistics (DOTS) and the dataset by Gleditsch et al.[39] The GDP variables are primarily from the Tomz GDP data of constant 1967 US dollars, however since the Tomz data stops at 2004, a new GDP variable was created with missing data filled in with the World Bank's WDI GDP data, converted using the CPI with 1967 as the base year.[40] The main dependent variables, lnExport, is the log yearly value of exports from country A, the country which experienced the natural disaster, to the importer, country B. The final analysis includes panel data of yearly import and export quantities from 1995 to 2009 and the unit of observation consists of up to 22,690 directed dyads comprising the 179 countries for which we were able to obtain data.

3.1 Natural Disasters Data

The data for natural disasters is from the Emergency Events Database (EM-DAT).[41]. EM-DAT collects data from a wide array of national sources that report natural disaster events, including climatic, geophysical, and biological events. The database qualifies a disaster as an event that fulfills at least one of the following criteria: (1) 10 or more people are reported killed or missing and assumed dead; (2) 100 or more

[37]WTO 2015.
[38]Dür, Baccini and Elsig 2015.
[39] Dür, Baccini and Elsig 2015.
[40]World Bank 2011.
[41] EM-DAT 2017.

people are reported affected (require immediate help, including medical treatment, food, water, shelter); (3) The regime asked for external help; or (4). The regime declared a state of emergency.

I include 8 types of disasters that could hypothetically impact trade: droughts, extreme temperatures, floods, landslides, earthquakes, wild fires, storms, and insect infestations. The yearly total number of the occurrence of each individual natural disaster by country since 1979 was exported and merged with our panel data of bilateral trade flows and country level statistics. To estimate the impact of natural disasters on trade, I create 8 dummy variables, *"ND"* or *drought*, *extreme temp*, *flood*, *landslide*, *earthquake*, *wildfire*, *storm*, *insect infestation*, for each of the ten natural disaster types. The natural disaster dummies are coded as 0 if the respective natural disaster did not occur in country j for any given year, and 1 if the respective natural disasters did occur. Correlations between the natural disaster types are displayed in Figure A.1, Appendix A.

I also incorporate into my analysis two measures that capture the magnitude of a natural disaster event and that attempt to test the mechanism responsible for export losses, total damage and total deaths.[42] *Totaldamage* is a continuous variable that measures the value of all damages related to the disaster. *Totaldeaths* is a continuous variable that measures the sum of individuals reported dead or missing. I log transform both variables, *lnTotaldamage* and *lnTotaldeaths*. These two variables, while controlling for the magnitude of natural disasters, test the mechanism responsible for observed export losses during natural disasters; if economic damage or reductions in human capital interact negatively with the natural disaster event this indicates that economic damage or reductions in human capital, respectively, account for the observed losses. The correlation between the two variables is presented in Figure A.2, Appendix A, showing a small correlation, indicating the variables are appropriate to include in the same model.

[42] EM-DAT 2017.

3.2 Data on PTAs and PTA design

For the empirical analysis of the relationship between international trade during natural disasters and the design of trade agreements, I rely on the dataset on the Design of Trade Agreements (DESTA). Dur, Baccini and Elsig show that PTAs vary in terms of overall ambitions and commitments reflected in depth of concessions and flexibility of clauses or opt outs with the creation of DESTA. [43] DESTA reveals that Preferential liberalization alone does not explain the PTA-trade nexus, but that important differences in provisions between PTAs allow for new and increased market access and thus design dimensions' matter for trade. The substantial contribution of their research is that not only do agreements differ in "depth," but that depth is an important driver of earlier discoveries showing that PTAs increase trade. DESTA includes 587 PTAs signed between 1945 and 2009, 358 of which are bilateral and 229 plurilateral.

To capture PTA depth I rely on, *deepPTA*, fa dummy variable based on an additive index that combines seven key provisions that can be included in PTAs.[44] The first provision captures whether the agreement foresees that all tariffs (with limited exceptions) should be reduced to zero (that is, whether the aim is to create a full free trade area). The other six provisions capture cooperation that go beyond tariff reductions, in services trade, investments, standards, public procurement, competition and intellectual property rights. *deepPTA* is coded 1 if the agreement scores a 7, and 0 otherwise, thus capturing the "deepest" agreements.

3.3 Data on extensive margins

To create the extensive margins variables, I used the Harmonized System 1992 trade classification data of bilateral trade values at the six digit, taken from the Observa-

[43] Dür, Baccini and Elsig 2014.
[44] See Dür, Baccini, Elsig 2014.

tory of Economic Complexity (OEC). I follow the previous literature on Extensive Margins of Trade in order to create the adequate variables. Specifically, following Baier and Bergstrand, I apply the Hummels-Klenow Margin Decomposition from Hummels and Klenow,[45] which was the first paper to highlight a tractable method for decomposing transparently the extensive and intensive goods margins of trade for a large set of countries' bilateral trade flows using publicly available disaggregate trade data.

Let X_{ijt} denote the value of country i's exports to country j in year t. Following HK, the extensive margin of goods exported from i to j in any year t is defined as:

$$EM_{ijt} = \frac{\sum_{m \in M_{ijt}} X^m_{Wjt}}{\sum_{m \in M_{Wjt}} X^m_{Wjt}}$$

where X^m_{Wjt} is the value of country j's imports from the world in product m in year t, M_{Wjt} is the set of all products exported by the world to j in year t, and M_{ijt} is the subset of all products exported from i to j in year t. Hence, EMijt is a measure of the fraction of all products that are exported from i to j in year t, where each product is weighted by the importance of that product in world exports to j in year t. Alternatively, one could use an unweighted average, which would then be simply the fraction of all products exported from i to j. However, HK – as well as researchers since then – use the weighted average. A weighted average seems more appropriate since cars and pencils do not have the same values in trade.

In order to account for the large number of trading dyads with little to no trade in a large number of products, we use a dummy variable to capture trading dyads extensive margins. *Logem_two* is coded 1 if dyads fall into the 50th percentile distribution of extensive margins, and 0 otherwise.

[45] Hummels and Klenow 2005.

4 Model Specification

The following section discusses methodological aspects related to the estimation of the model. The empirical model used to test for natural disaster impacts on trade flows and the interaction of PTAs is a gravity model with controls for exporter and importer observed and unobserved time variant heterogeneity, and trading dyad heterogeneity. The methodology applied expands that initially developed by Abowd et al, who presented a statistical framework permitting two high dimensional fixed effects to be estimated simultaneously in linear regressions. However, as elaborated upon below, I include a third fixed effect for trading dyads and use a different algorithm to obtain an exact solution for the estimation problem.

4.1 Gravity Model

The gravity model introduced by Tinbergen has long been the most prominently used method of measuring the trade effects of regional trade agreements.[46] The gravity model in its most simplistic form assumes that trade between two countries depends on the distance between them, the size of the countries' economies measured by population and GDP, and other variables presumed to affect bilateral trade, such as whether the countries share a common language and or border. Equation (1) displays a typical gravity model specification:

$$lnExports_{ijt} = \alpha + \beta_1\ ln(Distance_{ij}) + \beta_2\ ln(GDP_{it}) + \beta_3\ ln(GDP_{jt}) + \beta_4 \\ (NaturalDisaster_{it}) + \beta_5\ deepPTA_{ijt} + \alpha \mathrm{X} + \varepsilon \quad (1)$$

Where i and j represent the exporter and importer, respectively, and t represents time, $LnExports_{ijt}$ is the exports from country i to j in year t. $Distance_{ij}$ is the

[46] Tinbergen 1962.

bilateral distance between trading partners, Y_{it} and Y_{jt} are the GDP levels of the two countries, $NaturalDisaster_{it}$ is a dummv variable that equals 1 if country i, the exporter, experiences a natural disaster at time t-1, zero otherwise, and $deepPTA_{ijt}$ =1 if countries i and j belong to a deep PTA, 0 otherwise.

However, the validity of gravity equation estimates of partial effects of PTAs on pairs of countries' trade flows has been re-evaluated. Baier and Bergstrand showed that self-selection of country-pairs into PTAs creates a significant endogeneity bias in previous gravity-equation estimates of the (partial) effects of PTAs on trade flows.[47] Dyads with strong cultural and historical ties are likely to have greater than normal trade and are also more likely to form a PTA. Thus, the error term is correlated with the PTA variables and the coefficient estimates are biased. Instead, lagged influences can be captured by incorporating bilateral fixed effects and exporter-year and importer-year effects. These fixed effects account for time-invariant bilateral unobservable RHS variables and capture time-varying unobservable "multilateral price/resistance" terms of the exporter and importer, respectively.

4.2 Estimation Strategy

The first model in the analysis examines the relationship between natural disaster types and trade. It does not include importer-year and exporter-year fixed effects, only dyad and year fixed effects, and thus does not test the PTA interaction. The second model includes dyad, importer-year and exporter-year fixed effects to examine the relationship between PTAs and natural disasters. It is necessary to keep these models separate as the inclusion of the PTA as the main independent variable requires importer-year exporter-year year fixed effects, which correlate perfectly with natural disaster events in the data as they vary by country and year. Exporter-year and importer-year effects are important in gravity models primarily when exam-

[47] Baier and Bergstrand 2007.

ining variables that correlate with the error terms, here PTAs, as they capture time-varying unobservable "multilateral price/resistance" terms of the exporter and importer, respectively.

Model 1 is thus an approximation of Equation (1), a standard gravity model, shown in Equation (2):

$$lnExports_{ijt} = \alpha + \beta_1\ ln(GDP_{it}) + \beta_2\ ln(GDP_{jt}) + \beta_3\ (GATT/WTO_{ijt}) + \beta_4\ (NaturalDisaster_{it}) + \beta_5\ deepPTA_{ijt} + \gamma_{ij} + \varepsilon_{ijt}\ (1)$$

Where i and j represent the exporter and importer, respectively, and t represents time, $LnExports_{ijt}$ is the exports from country i to country j in year t. ε is the error term, γ represents dyad fixed effects that capture all time in-variant unobservable bilateral factors influencing nominal trade flows and ν represents year fixed effects. $lnGDP_{it}$ and $lnGDP_{jt}$ are the GDP of the exporter and importer in time t, respectively. $GATT/WTO_{ijt}$ is a variable to capture whether the two dyads both held GATT/WTO membership in year t. $Distance_{ijt}$ is not included in this specification as it is fully absorbed in the dyad fixed effects term.

Controlling simultaneously for dyad year, importer year, and exporter year specific effects requires the introduction of three high-dimensional fixed effects in the linear regression model. Equation (2) is the main (baseline) model:

$$lnExport_{ijt} = \alpha + \beta_1\ DeepPTA_{ij,t-1} + \beta_2\ DeepPTAxNaturalDisaster_{ij,t-1} + \gamma_{ij} + \theta_{jt} + \phi_{it} + \varepsilon_{ijt}\ (2)$$

where *lnExport* is the dependent variable, log exports to country j from country i in period t. The variable *NaturalDisaster* is a dummy variable capturing whether country i, the exporter, experienced one of the eight natural disasters at time t-1.

PTA is a dummy variable capturing whether two countries form part of a PTA at t-1. The interaction term *PTAxNaturalDisaster* aims to capture the effect of natural disasters on export flows for trading dyads who have a PTA. To further examine how PTAs may influence trade flows during the occurrence of a natural disaster, I examine the depth of agreements through *DeepPTA*. PTA variables are interacted with the natural disaster dummy variable, *NaturalDisaster*. Relevant control variables are included only in the model with two fixed effects, dyad and year, and not when testing the PTA interaction as three fixed effects are included which together account for the relevant control parameters.

X_{ij} are vectors of control variables, 1, 2 3 4 5 6 7 8 9 are the coefficients of interest, α is the constant and ε is the error term. γ, θ, and ϕ are respectively, dyad fixed effects to capture all time in-variant unobservable bilateral factors influencing nominal trade flows, exporter-time fixed effects and importer-time fixed effects, to capture time-varying exporter and importer multilateral price resistance terms as well as other time-varying country specific unobservable factors in i and j influencing trade. To illustrate the estimation strategy, consider the linear regression in matrix notation, as the form:

$$\mathrm{Y} = \mathrm{X}\beta + \mathrm{D}\theta + \mathrm{F}\phi + \mathrm{L}\lambda + \varepsilon \quad (3)$$

In this equation Y is a (N$*$ x 1) vector of trade values flowing from country j to country i (in logs), X is a (N x X) matrix with of time-varying explanatory variables, D is a (N$*$ x j) matrix for the exporter effects, F is a (N$*$ x I) design matrix for the importer effects, L is a (N$*$ x ji) matrix for dyad effects. θ is a (J X 1) vector of exporter effects, ϕ is a (I x 1) vector of importer effects, λ is a (JI x 1) vector of dyad effects, and ε is a (N$*$ x X1) vector of disturbances (I assume that conditional on X, D, F, and L, trade is exogenous, in order to make the design matrices orthogonal to the vector of disturbances). Equations 2 and 3 can be interpreted as the conditional

expectation of trade given the observable characteristics of countries, the date of observation, the importer, the exporter, and the trading dyad.

However, the high-dimensionality of D, F and L prevents the application of the conventional least squares formula. Estimating all the parameters would require the inversion of a huge matrix. This is impossible to achieve using standard software routines and present- day computers. In the present treatment, I follow an alternative methodology that provides the exact solution for the linear regression with three high-dimensional fixed effects. Guimaraes and Portugal introduce an iterative approach for the estimation of linear regression models with high-dimensional fixed effects that rivals alternative methods in terms of time and memory required. [48] In brief, this methodology is based on a partitioned algorithm strategy and follows an iterative procedure that leads to the exact solution of the least squares problem. While computationally intensive given its iterative nature, the approach imposes minimum memory requirements. For a detailed description of this methodology, see Guimaraes and Portugal. [49]

The empirical estimations are thus organized as follows. As the natural disaster dummy variable is a yearly observation at the country level, the variable correlates perfectly with the exporter year fixed effects. The models testing natural disasters individually therefore cannot produce rigorous estimations when exporter year fixed effects are included. I instead test the effect of natural disasters on trade using panel techniques and data with directed dyad fixed effects and year fixed effects. I first examine which natural disasters account for observed export declines, without country-year fixed effects due to their correlation with the natural disaster variables. Second, I test the mechanisms responsible for observed export declines and the level of PTA depth that can mitigate the observed export declines by sector using marginal effect plots, shown in Figures 4 and 5. Finally, models estimating three

[48] Guimaraes and Portugal 2010.
[49] Guimaraes and Portugal 2010.

high level dimensional effects, Equation 2, are run for the interaction of natural disasters and PTAs by sector. This model provides the most rigorous estimate of PTA -natural disaster interactions and is thus the primary test relied on to assess my main argument.

5 Empirical Results

The main empirical results for equation (2) are presented in Table 1, which offers support for my argument. Here the effect of eight natural disaster types on exports are shown. Following the first empirical implication, Table 1 shows in Column (9) that when controlling for all natural disaster types together, landslides and floods lead to a significant decrease in trade (at the 99% confidence level). Specifically, floods and landslides lead to a 0.1% and 0.2% decrease in exports, respectively. Here I include year and dyad fixed effects but cannot run country year fixed effects as natural disasters will correlate perfectly with these controls. Although the observed effect is relatively small, given the absence of fixed effects for each country by year, the evidence is strong. These results therefore provide evidence that two natural disaster types, floods and landslides, are driving the negative effect of natural disasters on trade documented by previous studies.

To provide evidence of the mechanism responsible for declines in international trade during natural disasters, I rely on marginal effect plots (Figure 4 and 5). These figures show the marginal effect of natural disasters on trade by levels of *lntotaldamage* and *lntotaldeaths* by plotting the interaction terms for *naturaldisasters* with *lvntotaldeath* and *lntotaldamage*. The corresponding table is included in the Appendix (Table A1). Figure 4 illustrates the marginal effect of a natural disaster on exports along the range of economic damage based on the estimates reported in Table A1. Economic damage decreases the exports of the effected country, and

Table 1: Natural Disasters and Trade

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
landslide	-0.02***								-0.02***
	(0.02)								(0.01)
insect		0.03**							0.03**
		(0.01)							(0.02)
drought			0.01**						0.01
			(0.02)						(0.01)
earthquake				0.01***					0.01***
				(0.03)					(0.02)
wildfire					0.01**				0.01**
					(0.01)				(0.01)
extreme temp						-0.01			-0.01
						(0.01)			(0.01)
flood							-0.01***		-0.01***
							(0.01)		(0.02)
storm								-0.01	-0.01
								(0.01)	(0.01)
GDP (Country A)	0.07***	0.07***	0.07***	0.07***	0.07***	0.07***	0.07***	0.07***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
GDP (Country B)	0.24***	0.24***	0.24***	0.24***	0.24***	0.24***	0.24***	0.24***	0.24***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
deeppta	0.14***	0.13***	0.13***	0.14***	0.13***	0.13***	0.13***	0.13***	0.13***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
gattwto	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	-5.62***	-5.61***	-5.62***	-5.62***	-5.61***	-5.61***	-5.59***	-5.61***	-5.60***
	(0.32)	(0.32)	(0.32)	(0.32)	(0.32)	(0.32)	(0.32)	(0.32)	(0.32)
Observations	240,902	240,902	240,902	240,902	240,902	240,902	240,902	240,902	240,902
R-squared	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Dyads	27,725	27,725	27,725	27,725	27,725	27,725	27,725	27,725	27,725
Year Fe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dyad Fe	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

the marginal effect of natural disasters on exports turns negative and is statistically significant at around 1.2 million USD of economic damage (ln14). The number of reported human casualties also decreases the exports of the effected country, where the marginal effect of natural disasters on exports becomes negative at around 20 total reported deaths (ln3). These results indicate that damage to capital, as well as declines in labour are central to the destructive effects of natural disasters on trade.

It is important to note that the inclusion of economic damage and human casualties as control variables substantially reduces our sample size, potentially biasing our results. However, our data source specifies that the large number of missing values is due to prioritizing the figures reported by international agencies, as national agencies are beholden to political limitations that may bias their reporting. This means the distribution of data on economic damage and human casualties is likely random.

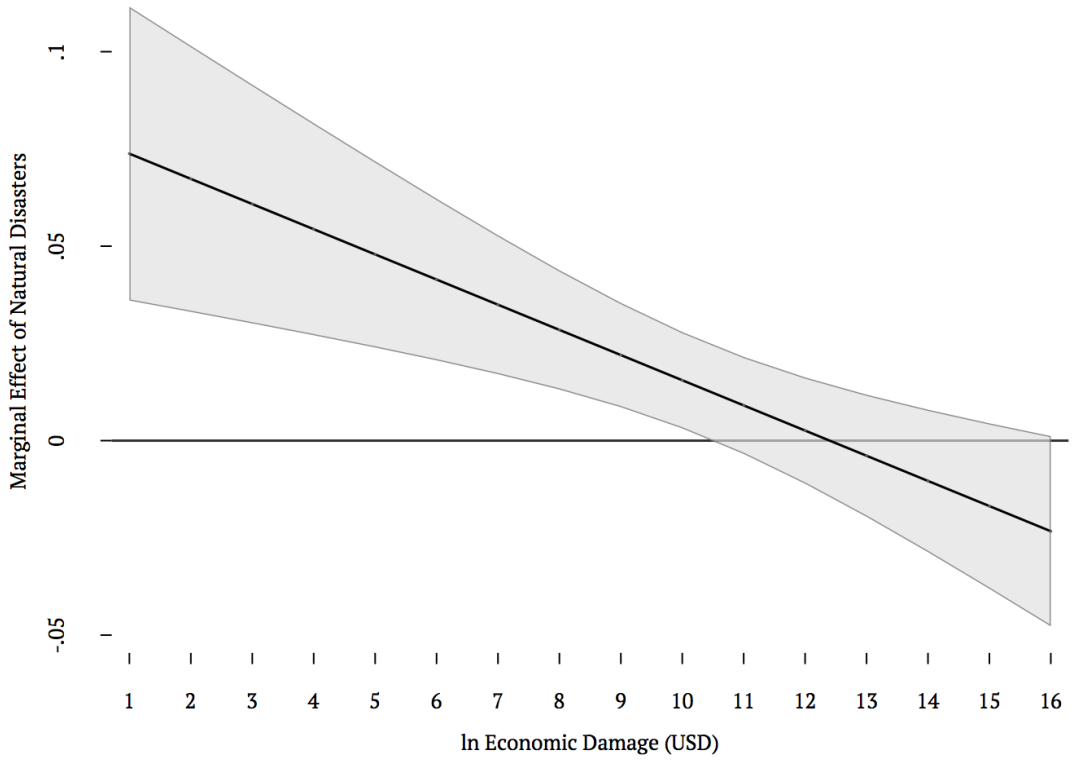

Figure 4: Marginal Effect of Natural Disasters on Exports for Economic Damage

Finally, in Table 2, testing Empirical Implication (2), I examine the effect of

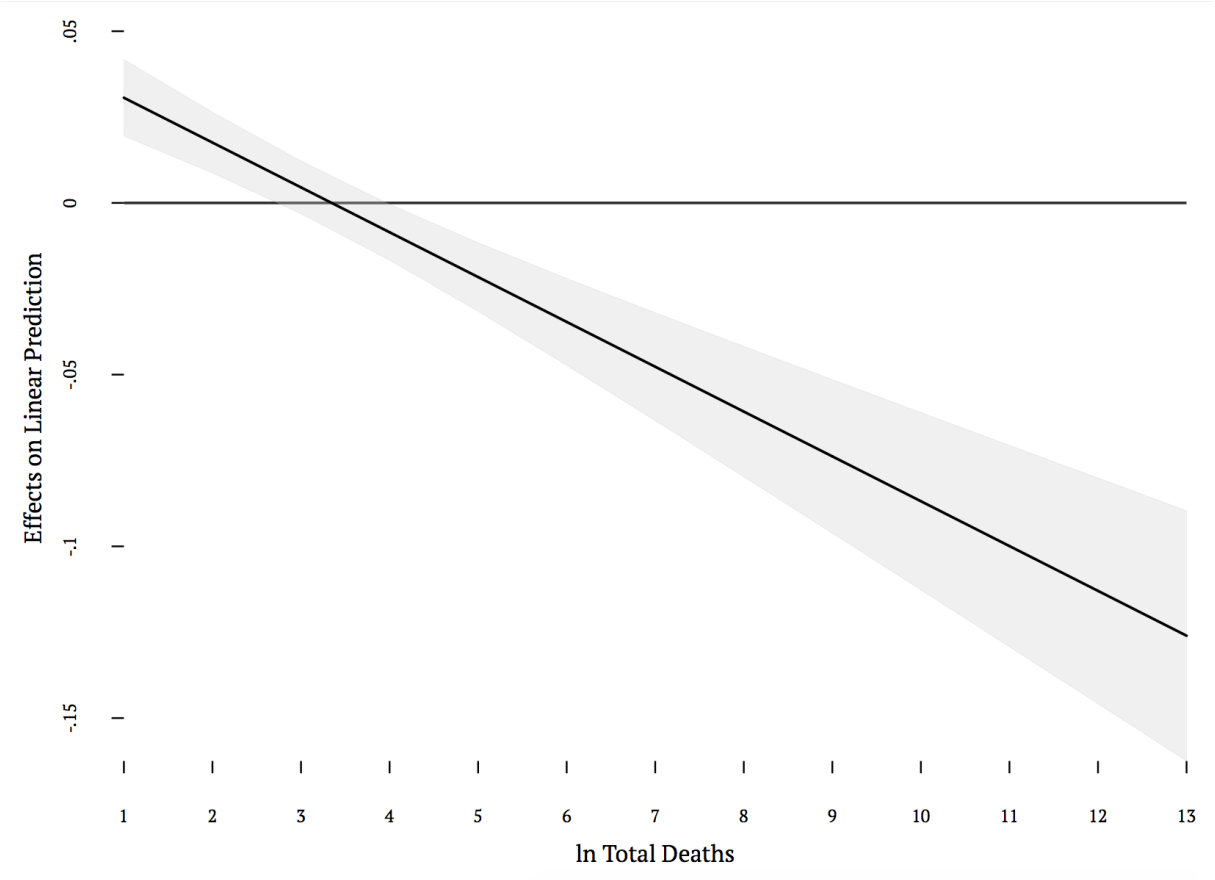

Figure 5: Marginal Effect of Natural Disasters on Exports for Total Deaths

natural disasters on exports for trading dyads engaged in deep preferential trade liberalization. Here I use three high dimensional fixed effects; year, country-year and dyad fixed effects. I find that *deepPTA* PTAs that liberalize in 7 out of 7 provisions identified in the DESTA dataset are associated with significant increases in trade during natural disasters. All else equal, the presence of a deep PTA is associated with a 18

Table 2: Natural Disasters and Deep PTAs

	(1) lnExports
deepPTA	0.18***
	(0.01)
naturaldisaster X deepPTA	0.06***
	(0.01)
Observations	409,057
R-squared	0.95
Year Fe	Yes
Dyad Fe	Yes
Importer-Year Fe	Yes
Exporter-Year Fe	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results reported above present a striking puzzle; events that threaten human life and induce substantial capital damage reduce the exports of the effected country, conditional on membership to exclusively deep trade institutions. To further understand the relationship between export quantity, natural disasters and trade agreements, I attempt to identify the mechanism that allows members of deep PTAs to increase their exports during natural disasters. I argue that deep PTAs encourage trade during natural disasters because they lower trade costs, providing firms with an attractive substitute for the domestic market where the catastrophe has reduced consumer demand. If this is so, countries with deep PTAs should experience an increase in the extensive margins during natural disasters. I test the effect of *deepPTA* on the extensive margins with an Error Correction Mode (ECM) that includes dyad and year fixed effects. The idea is that if deep PTAs increase

trade during natural disasters by increasing the range of products a country trades, this should only be a short term effect, as products substitute the domestic market temporarily with the foreign market. Indeed, Table 3 shows that for countries that experience natural disasters, deep PTAs lead to a short-term increase in the extensive margins, but not a long-term increase. In Column (2), for countries that do not experience natural disasters, I find both a long and short term effect of PTAs on the extensive margins, in line with previous research.[50]

In sum, the results of my analysis of trade and natural disasters are consistent with my conjecture that all else equal, specific natural disaster types reduce trade. Indeed, I show that floods and landslides lead to a reduction in the exports of the effected country. However, in line with my argument, I highlight an important caveat to this relationship: deep liberalization, as provided by PTAs, allow countries to continue to export at a positive rate during natural disasters. In other words, trade agreements can protect states against the harmful effects natural disasters imposes on trade.

6 Discussion and Conclusions

Natural disasters have become a significant feature of the global economy. Here, I assess their impact on it, and the extent to which international trade agreements can offer economic defence. Previous research on the relationship between international trade and natural disasters has shown that natural disaster events negatively impact trade, and in particular the exports of the country where the natural disaster occurred. However, no study to date has explored how the effect of natural disasters on trade varies between natural disaster types. This is an important oversight, as there is substantial evidence that the different natural disaster types create heterogeneous economic outcomes. Additionally, I argue that the existence of deep

[50] Baier and Bergstrand 2013.

Table 3: The Extensive Margins of Trade and Natural Disasters

	(1) Δ lnEM	(2) Δ lnEM	(3) LRM	(4) LRM
$\ln EM_{t-1}$	-0.33***	-0.34***		
	(0.01)	(0.02)		
Δ deepPTA	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
$deepPTA_{t-1}$	0.02	0.01**	0.01	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Δ lnPopulation (Country A)	-0.00***	-0.00	-0.00***	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$\ln Popluation\ (Country\ A)_{t-1}$	0.00***	0.00***	0.00***	.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Δ lnPopulation (Country B)	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$\ln Population\ (Country\ B)_{\ t-1}$	0.00	-0.00***	0.00	-0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Δ gattwto	0.00***	0.00**	0.06***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
$gattwto_{t-1}$	0.00***	0.00**	0.00	0.00
	(0.00)	(0.00)	(.00)	(0.00)
Constant	-0.01***	0.01		
	(0.00)	(0.00)		
Observations	127,774	141,632	125,045	138,924
R-squared	0.193	0.208		
Dyads	19,088	21,583	16,359	18,875
Year Fe	Yes	Yes	Yes	Yes
Dyad Fe	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Preferential Trade Agreements (PTAs) between trading dyads creates economic resilience to these natural disasters by allowing countries to substitute sales to the domestic market with exports abroad. I suggest that such economic resilience is afforded only by exceptionally deep PTAs that significantly lower the variable costs of trade.

An analysis of country level export data on 179 trading dyads strongly supports this argument. I investigate the macro economic consequences of natural disasters by analyzing how eight natural disaster sub-groups effect export quantities between trading dyads. Drawing on evidence from previous natural disaster events and the economic literature on natural disasters, I show that natural disaster sub-groups have heterogeneous effects on international trade. Namely, that international trade reductions occur during two natural disaster types, floods and landslides. By including measures of the economic damage and human casualties incurred during natural disaster events, I provide evidence that export declines during natural disasters are related to both the quantity of economic damage the natural disaster created and the human lives it stole. This is an important implication for natural disaster vulnerable countries; a great deal of harm could be avoided through investments in response strategies that focus on mitigating potential economic damage and human deaths during natural disasters. For example, it may be worthwhile for states to invest in extensive evacuation protocols, which could substantially reduce the number of human lives lost during disasters. Likewise, sea walls and flood resilient factory infrastructure could save states from substantial declines in economic output by reducing the total economic damage.

Perhaps the contribution that is most interesting, and most relevant to trade relations under a changing climate change, is the potential for PTAs to create economic resilience against exogenous environmental shocks. Specifically, I show that exceptionally deep PTAs allow countries to increase exports during natural disasters that otherwise lead to export decline. I argue that PTAs have this effect because

they allow countries hit by a natural disaster to substitute the domestic market, where consumer demand has been squashed due to disaster impacts, with the international market. Indeed, PTAs create economic resilience by making it financially feasible for firms to sell to an export market that remains unaffected by the disaster. However, I argue and demonstrate that only significantly deep PTAs provide enhanced economic resilience because such agreements substantially reduce the cost of trade.

These findings speak to the potential for PTAs to provide economic protection against climate change impacts. Both the enhanced severity and occurrence of natural disasters has been increasingly associated with climate change. These events create substantial economic damage, generating domestic demand declines and dampening overall economic productivity. I show that PTA membership may mitigate these impacts. By inducing economic resilience to extreme events that are projected to increase into the 21st century, PTAs may present an option for countries to adapt their economies to better cope with the economic consequences of climate change. Importantly, future research should investigate if the mechanism identified here can be generalized to exogenous shocks in general. Indeed, an assortment of political and economic factors can impair domestic consumption. Thus, the question is whether deep trade agreements can afford producers enhanced resilience against domestic economic turbulence in general.

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Appendix

Table 1: Natural Disaster Magnitude and Mechanisms

	(1) lnExports	(2) lnExports	(3) lnExports
naturaldisasters	0.11***	0.06***	0.11***
	(0.03)	(0.02)	(0.03)
Ln(Total damage)	0.01***	0.00**	0.01***
	(0.01)	(0.02)	(0.01)
Ln (Total deaths)	-0.01***	-0.01	-0.01**
	(0.01)	(0.01)	(0.01)
Natural disaster damage	-0.01***		-0.01**
	(0.02)		(0.02)
Natural disaster deaths		-0.01***	-0.01
		(0.02)	(0.01)
GDP (Country A)	0.01	0.01	0.01
	(0.03)	(0.03)	(0.03)
GDP (Country B)	0.41***	0.41***	0.41***
	(0.03)	(0.03)	(0.03)
deeppta	0.03	0.03	0.03
	(0.06)	(0.06)	(0.06)
gattwto	-0.02	-0.02	-0.02
	(0.02)	(0.02)	(0.02)
Constant	-6.98***	-7.08***	-7.04***
	(0.86)	(0.86)	(0.86)
Observations	45,487	45,487	45,487
R-squared	0.27	0.29	0.28
Dyads	17,518	17,518	17,518

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

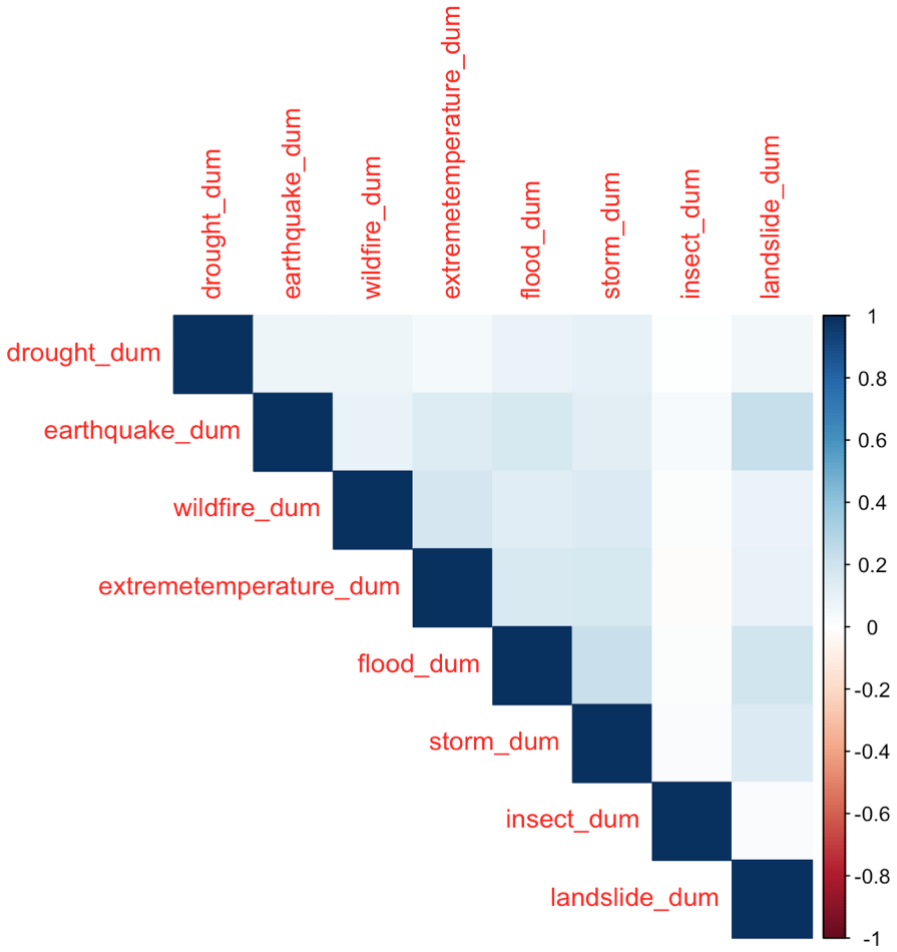

Figure 6: Natural Disaster Correlations

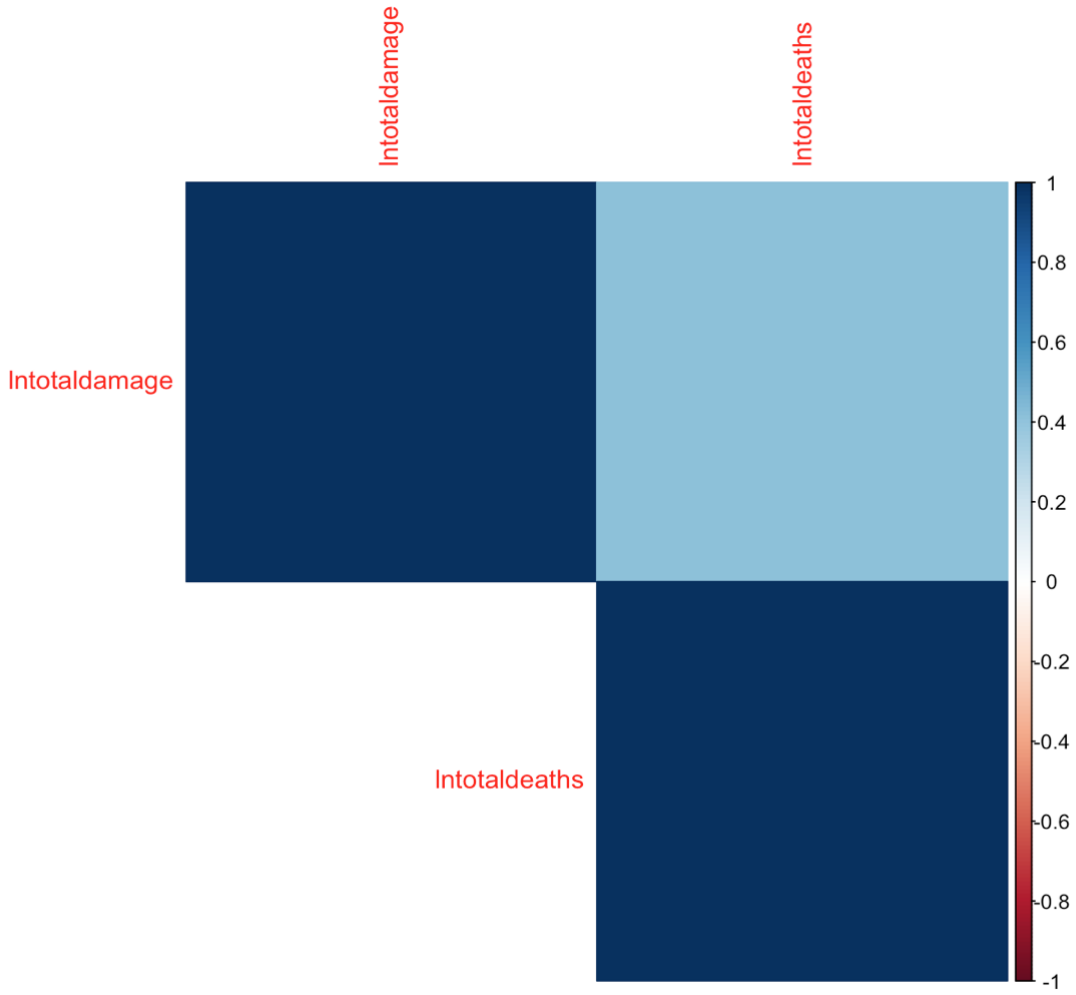

Figure 7: Deaths and Damages Correlations