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In search of factors that explain the impact of climate change on international trade

by

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In search of factors that explain the impact of climate change on international trade.

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Abstract

Climate change impacts international trade. The literature suggests that this relationship is driven by the damage to infrastructure and reduced productivity caused by this global phenomenon. Furthermore, recent research indicates that the impact on energy consumption could explain the real effects of disasters in the United States. Using a sample of 67 countries during the period 1986–2016, we analyze whether the secular increase in global temperatures and the occurrence of drastic climate events (wildfires, floods, extreme temperatures, epidemics, insect infestations, storms, droughts, and landslides) affect countries' energy consumption and labor productivity, which can subsequently impact international trade. By estimating a theory-based gravity model, our results suggest that energy intensity is the channel through which rising temperatures affect international trade. Furthermore, the impact of events on international trade does not seem to be channeled through either energy efficiency or labor productivity. A deeper analysis suggests the key role played by China in this regard. The Chinese government's enormous investment in infrastructure since 1998 to manage these types of disasters seems to be the most reasonable explanation.

Keywords: climate change, energy consumption, productivity, extreme weather events, international trade

JEL classification: C1, F14, F15.

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1. Introduction

The Earth's climate has changed throughout its history. Climate change leads to variations in the average weather conditions in a region over a long period. However, global warming is occurring at a rate not seen in the last 150 years, with many of the warmest years on record occurring in the last 20 years. This is why climate change is one of the biggest concerns worldwide.

The impressive increase in international trade in the last three decades has been considered one of the causes of climate change. However, little attention has been paid to looking for possible effects in the opposite direction. This paper addresses the question of the impact of climate change on international trade. More specifically, this paper aims to dig deeper into this relationship by assessing the relevance of several factors in driving it. We build upon Martínez et al. (2023), who examined the link between climate change, through rising temperatures and extreme weather events, and international trade. Based on the estimation of a gravity model on a sample of 67 countries during the period 1986–2016, these authors found a positive relationship between the rise in temperatures and international trade with respect to domestic trade but a negative association between extreme weather events and international trade (in relation to domestic trade). When disaggregating by country and type of event, remarkable cross-country heterogeneity emerges for both proxies of climate change.

The contribution of this paper is twofold. First, we analyze whether there is a connection between climate change and energy consumption and labor productivity in our sample of countries. Second, once the previous relationship has been determined, the extent to which the aforementioned factors play a role in the impact of climate change on international trade is studied. To do this, we use data on primary energy intensity (primary energy consumption over Gross Domestic Product - GDP) and labor productivity from 67 countries over the period 1986–2016.[1]

To preview our results, we find that climate change affects both energy consumption and labor productivity. However, only the energy channel seems relevant to explaining the effect of temperature on international trade. Regarding the events, the reaction of the Chinese government to manage the disastrous consequences of events seems to explain the sample impact obtained.

The rest of the paper is organized as follows. The next section briefly outlines the relationship found in previous research between climate change and international trade and provides a discussion of the reasons why energy

[1] We tried to use the same sample size as Martínez et al. (2023), except that in this case, the period used is 1986–2016 and we have to restrict the labor productivity analysis to a 1990 start.

consumption and labor productivity may be the channels through which the aforementioned relationship exists. The third section presents the methodology and data sources used. This section explains how we build two types of equations. One of these is the “energy” equation. The other is the “labor productivity” equation. We estimate them using fixed-effects panel data models. In Section 4, we estimate the connection between climate change and primary energy intensity, whereby we explain how rising temperatures boost energy efficiency on average, while extreme weather events reduce it. The fifth section presents the impact of climate change on labor productivity. In that section, we show that an increase in temperatures does not have a general impact on labor productivity, while the impact of events is positive and significant. In addition, a country study is carried out. The sixth section connects the results of Sections 4 and 5 with those related to the impact of climate change on international trade. On average, higher temperatures increase international trade relative to domestic trade. Our results suggest greater energy efficiency (but no impact on labor productivity) in countries as temperatures rise, which is consistent with a bias toward international trade because foreign sales require a more efficient economic system. However, the case of events is more complex. A comprehensive analysis of the case of China gives us the most likely explanation. Finally, Section 7 concludes.

2. Climate Change and International Trade

The first step is to determine the impact of climate change on international trade. To this end, we follow Martínez et al. (2023), who offer an in-depth analysis of the subject by estimating a structural gravity equation. In this research, trade flows by pairs of countries depend on variables accounting for country sizes and multilateral resistances[2] (both controlled by country-year fixed effects); distance and other specific bilateral trade barriers that do not change over time (controlled for country-pair fixed effects); globalization (an interactive dummy for time and international flows); multilateralism and regionalization (by including the respective dummies for the GATT/WTO system and regional trade agreements); and measures of climate change (our variables of interest), such as temperatures and extreme weather events.[3]

Martinez et al. (2023) estimate a structural gravity equation taking into account all the known biases up until now. To this end, they use the PPML (Poisson-Pseudo Maximum Likelihood) estimator (see Santos Silva & Tenreyro,

[2] The exporter-time and importer-time fixed effects also account for any other observable or unobservable country and year-specific factors that affect trade.

[3] However, before describing the conclusions reached by this research, we must be sure that the results obtained in the respective regressions are robust to the loss of part of the sample period, in particular, five years (from 1986 to 1990). This is because one of our key variables explaining labor productivity (internet_users) starts in 1990. In any case, using the sample for the period 1990–2016, the conclusions on climate change and international trade are the same as those presented in the text. Regressions can be provided on request.

2010) with country-year (CYFE) and country-pair fixed effects (CPFE)[4] and take into account intra-national flows (Baier et al., 2019; Beverelli et al., 2018; Esteve-Pérez et al., 2020; Yotov, 2012; Yotov et al., 2016) in line with the most recent development of the gravity model. They also control for a measure of globalization (Bergstrand et al., 2015) by including a vector of dummy variables in the specification that is equal to one for international trade flows and equal to zero for intra-national trade flows for each year "t". In particular, the gravity equation specifications are:

$$X_{ijt} = \exp^{(\beta_1 PTA_{ijt} + \beta_2 (GATT/WTO)_{ijt} + \beta_3 temp_{i(j)t} + \sum_{1987}^{2016} \beta_t Glob_{ijt} + \mu_{ij} + \delta_{it} + \gamma_{jt})} u_{ijt} \quad (1)$$

and

$$X_{ijt} = \exp^{(\beta_1 PTA_{ijt} + \beta_2 (GATT/WTO)_{ijt} + \beta_4 event_{i(j)t} + \sum_{1987}^{2016} \beta_t Glob_{ijt} + \mu_{ij} + \delta_{it} + \gamma_{jt})} u_{ijt} \quad (2),$$

where $Xijt$ are the exports from country "i" to country "j" at time "t", PTA is a dummy for Preferential Trade Agreements, GATT-WTO is a dummy for the GATT/WTO system, Glob measures the globalization and is composed of a

[4] See Baier and Bergstrand (2007), Baldwin and Taglioni (2007), and Gil-Pareja et al. (2008) regarding the inclusion of high dimensional fixed effects in gravity equations.

dummy variable for international trade (which takes the value 1 for international flows and zero for domestic flows, labelled as "int") interacted with year dummies (except 1986, to avoid multicollinearity), "temp" are the average annual temperatures of the countries (implicitly interacted with "int") and "event" is the number of extreme weather events, and their consequences (implicitly interacted with "int"), μij are CPFE and δit and γjt are CYFE for the exporter and importer, respectively.[5] Although, temperatures and events are unilateral variables (only for the origin country or, alternatively, for the destination country), the inclusion of domestic flows converts them as bilateral in nature, and this is why we can identify the respective origin (or destination, but not both) impacts. In any case, the estimated effect of the variables of interest on international flows is always in relation to domestic flows, as it occurs in the aforementioned papers, which include domestic flows in their estimations.[6]

The conclusions of the paper by Martínez et al. (2023) are as follows:

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[5] The dataset for trade, which incorporates both domestic and international manufacturing trade, comes from Thomas Zylkin. This dataset covered the period 1986–2006 for 69 countries and extended through 2016. Martinez et al. (2023) considered 67 countries owing to missing some data for Argentina and Hong Kong. The data for the PTAs and the GATT/WTO system were from the Dynamic Gravity Dataset developed by the United States International Trade Commission. See Section 3 for data sources for proxy indicators of climate change.

[6] See Beverelly et al. (2018).

- The increase in temperatures raises international trade on average compared to domestic trade. On the contrary, extreme weather events reduce international trade relative to domestic trade.
- There is heterogeneity by country in both cases.
- In particular, the outcome of events is mainly driven by a few countries. Specifically, when China and Japan are isolated from the sample, the estimated average parameter completely loses its statistical significance.
- When analyzing by types of events, biological events (epidemics and insect infestation), extreme temperatures, storms, and landslides negatively affect international flows in relation to internal ones.
- The influence of China and Japan on the global result is crucial, especially owing to storms in the case of China (and, to a lesser extent, Japan) and extreme temperatures in the case of Japan.

The previous findings raise an interesting question about the mechanism underlying this relationship. The literature proposes three possible channels for the impact of climate change on international trade. First, a fall in productivity owing to the effect of heat (Gosling et al., 2018; Hancock et al., 2007) affecting workers and probably the maintenance and technology of machines. Second, damage to infrastructure caused by meteorological disasters (Dellink et al., 2017). Finally, a possible positive effect derived from the opening of new maritime routes

(Bekkers et al., 2015). Recently, by analyzing the case of the US in depth, Canova and Pappa (2022)[7] concluded that the real effects (on output, income, and unemployment) of natural disasters are only "those impacting on energy" and that this is independent of the type of disasters. In particular, the authors stated that energy consumption is the key variable that shows a significant decrease for the industrial sector but also affects the residential and transportation sectors.

The energy system is vulnerable to a wide variety of climate change impacts in terms of production and supply. On the one hand, the increase in temperatures affects because the generation capacity of thermoelectric plants is reduced and the efficiency of the transmission network decreases. However, residential demand seems much more affected by temperature than manufacturing or service demand. According to the study carried out by Chukwuemeka and Nnaemeka (2022), which aimed to investigate the effects of temperature variations on energy demand with a focus on electricity, the demand for cooling processes increases once the temperature exceeds a specific threshold; alternatively users can demand electricity for heating, and their demand grows once the temperature falls below a specified threshold. In this study, the results suggest that residential electricity demand in the G7 countries responds to cold days rather than hot days.

[7] We thank Favio Canova for kindly sending us the paper.

According to a study carried out by Yao (2021, using data on temperatures and night light (night light has a strong linear relationship with electricity consumption), there is a U-shaped relationship between electricity consumption and temperature, with a global turning point of minimum electricity consumption of around 14.6°C (it is higher in urban and more industrial areas). A warming globe could reduce the need for heating in cold seasons and increase the demand for cooling in hot seasons, heterogeneously affecting countries in different geographic locations (van Ruijven et al., 2019). Therefore, when characterizing the relationship between temperature and electricity consumption (derived from primary energy generation), the literature usually assumes a U-shaped curve, with the minimum point being the equilibrium temperature between heating and cooling needs (see also Gupta, 2012; Li et al., 2018).

Conversely, extreme weather events have a wide variety of energy impacts.[8] First, water scarcity (droughts) can cause power supply disruptions by reducing hydroelectric power production and threatening oil and gas extraction and refining, as well as thermoelectric plants that rely on surface water for cooling. Wildfires and extreme winds can damage ground power lines and transmission towers, causing interruptions in the transmission of electricity. Floods and landslides can affect underground power lines and damage roads, railways,

8 See Zamuda et al. (2018).

pipelines, and storage facilities, and near the coast, storms can destroy oil storage tanks, roads, and railways. Additionally, extreme cold events, including ice and snow, can damage power lines and affect fuel supplies.

With these results in mind, we proceed to analyze whether temperatures and extreme weather events influence the intensity of primary energy consumption and labor productivity.

3. Data and Methodology

To perform our analysis, we construct two types of equation. One of these are the "energy" equations. The other are the equations of "labor productivity". Using panel data fixed effects,[9] we estimate the following equations:

- Energy equations

$$lnECI_{it} = \beta_0 + \beta_1 lnGDPpc_{it} + \beta_2 temp_{it} + f_i + u_{it} \tag{3}$$

$$lnECI_{it} = \beta_0 + \beta_1 lnGDPpc_{it} + \beta_2 events_{it} + f_i + u_{it} \tag{4}$$

- Labor productivity equations.

$$lnLproduct_{it} = \beta_0 + \beta_1 \log(\frac{K}{L})_{it} + \beta_2 HCI_{it} + \beta_3 internet\_share_{it} + \beta_4 temp_{it} + f_i + u_{it} \tag{5}$$

[9] The corresponding Hausman test rejects the null that the error term is uncorrelated with the regressors. Therefore, fixed effects is the preferred model.

$$lnLproduct_{it} = \beta_0 + \beta_1 \log(\frac{K}{L})_{it} + \beta_2 HCI_{it} + \beta_2 internet\_share_{it} + \beta_3 events_{it} + f_i + u_{it} \quad (6)$$

where $lnECI_{it}$ is the (logarithm) of the intensity of primary energy consumption (primary energy consumption over GDP) of country "i" in year "t", $lnGDPpc_{it}$ is the (logarithm) of Gross Domestic Product per capita, $lnLproduct_{it}$ is the (logarithm) of labour productivity, $\log(\frac{K}{L})_{it}$ is the capital-labor ratio, HCI_{it} is an index of human capital while $internet\_share_{it}$ is the ratio of Internet users to population, $temp_{it}$ and $events_{it}$ are our measures of climate change, f_i are country fixed effects, and u_{it} is the usual error term. Furthermore, the $events_{it}$ variable is decomposed into the eight types considered: $Wildfire_{ijt}$, $Flood_{ijt}$, Ext_Temp_{ijt}, $Epidemic_{ijt}$, $Insect_{ijt}$, $Storm_{ijt}$, $Drought_{ijt}$ *and* $Landslide_{ijt}$. Therefore, the control variables for our analysis, in addition to our variables of interest, are GDP per capita in equations (3) and (4), and the capital-labor ratio, human capital and the number of Internet users over the population in equations (5) and (6).

Regarding equations (3) and (4), it is important to note that the inclusion of GDP (or, alternatively, population) in an "energy" equation is common in this type of study (Trotter, 2016, and Trotter et al. 2016). It is quite clear that the increase in the production of goods and services implies the increase in energy consumption. In our case, we have controlled for it by including it on the left side of the equation (energy consumption over GDP). In addition, we include GDP per capita as an explanatory variable. Presumably, the economic structure and technological level of countries also influence energy consumption.[10] In principle, as countries get richer, with a greater participation of the service sector (and usually less of the industrial sector) and with more advanced energy saving technologies, consume less energy, *ceteris paribus*.[11]

Relating equations (5) and (6), the explanatory variables used are in line with the Solow´s traditional theory of growth (Solow, 1956), in which increases in labor productivity are the result of capital accumulation and technical change; as well as modern theories of endogenous growth where investment in human capital, innovation, and knowledge are significant factors to economic growth (Arrow, 1962; Uzawa, 1965; Lucas, 1988; or Romer, 1990). Therefore, we include the capital-labor ratio as a proxy for capitalization of the economy, and proxies for human capital and digital capital. The lasts two variables are probably the most relevant for explaining the level and evolution of labor productivity across countries in the period analyzed (Adarov and Stehrer, 2020; Lucas Jr, 2015; Manuelli and Seshadri, 2014) and account for technical change and knowledge. As pointed out by Bye and Fæhn (2022), human capital is a key determinant to

[10] For instance, Liu and Noor (2020) discuss the need for energy efficiency management in ASEAN countries.

[11] Zhou et al. (2021) find, in an analysis of 21 developed countries between 1996 and 2015, that a 1% increase in GDP per capita leads to a reduction of 0.62–0.78% in energy intensity.

knowledge accumulation and structural change by its role on innovative capacity (participation in R&D) and absorptive capacity of new knowledge from abroad.

Regarding the data sources, the intensity of primary energy consumption is from Ritchie et al. (2022), in the database of "Our world in data". From this data source page, we have also obtained the real GDP, population, and internet users for countries. Labor productivity (in real terms) is taken from the World Development Indicators (World Bank), whereas physical capital, number of employees and the human capital index are taken from the Penn World Table (PWT 10.01). Average annual temperature is obtained from the Climate Change Knowledge Portal (World Bank) and extreme weather events are taken from the International Disaster Database (EM-DAT). Our sample covers 67 countries (see tables 3 and 4) for the period 1986-2016 in the case of equations (3) and (4) and for the period 1990-2016 for the equations (5) and (6).

4. The connection between Climate Change and the Intensity of Primary Energy Consumption

The results of the estimations of Equations (3) and (4) are shown in Table 1.[12] The proposed equations explain variations in energy intensity well, obtaining

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[12] In this kind of equations there is some risk of endogeneity relating the variable GDPpc. Instrumental variables (IV) estimations considering human capital as an instrument of GDPpc (coefficient of correlation 0.74) does not change estimations in a significant way. In fact, the

a within-R2 of around 0.45. As expected, primary energy intensity decreases with GDP per capita, showing evidence of higher energy efficiency as countries get richer. The estimated coefficient suggests that a 1% increase in GDP per capita is associated with a reduction of about 0.5% in (primary) energy intensity.[13] As shown, climate change affects energy intensity. On average, one additional degree Celsius reduces the intensity of energy consumption by around 3.2%, while one additional weather event increases it by 0.6%. That is, an increase in temperatures favors energy efficiency on average,[14] while an extreme weather event reduces it.

In Table 3, we present the disaggregated estimations by country and type of event. In Column 1, we show the estimated impact of rising temperatures by country. As shown, there is heterogeneity, and in around half of the countries, we observe a significant impact one way or another.[15] As explained, the literature on this subject finds a U-shaped relationship between electricity (which is generated from primary sources) and temperature, estimating a turning point of around 15

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estimated parameter for our *temperature* variable somewhat increases and that of *events* remains almost the same.

[13] This impact is slightly lower than the range obtained in Zhou et al. (2020).

[14] It make sense to consider if lags in temperatures have any impact on energy efficiency if agents anticipate some mitigation actions. Our estimations show (under request) that the first lag is significant (coefficient of -0.024 and standard deviation of 0.009), the second lag just at 10% level (coefficient of -0.015 and standard deviation of 0.009) and the rest of lags are non-significant. Additionally, one lead of temperatures has a non-significant coefficient.

[15] The increase in energy efficiency occurs mainly in the coldest countries. With respect to other economic variable (GDPpc) the result along our research is quite coherent with that found by Pretis et al. (2018) who state “warming can increase prosperity in cold places but decrease prosperity in already warm areas”.

degrees Celsius. This means that those countries before the turning point should reduce their energy consumption over time when temperatures rise, and the opposite would be true for countries after the turning point. If we look at the average annual temperatures across countries in our data set, we find that the predictable result is obtained in about 66% of the cases (with a significant estimated impact) for countries before the turning point (this is the case for Bulgaria, Denmark, Germany, Hungary, Norway, Poland, Romania, Sweden, Switzerland, and the US, but not for Bolivia, Jordan, Nigeria, Qatar, and South Africa). Similarly, we obtain the expected result for about 80% of the cases (with a significant estimated impact) for countries after the turning point (this is the case for India, Indonesia, Iran, Malaysia, Malta, Mauritius, Morocco, Myanmar, Senegal, Sri Lanka, Thailand, and Trinidad and Tobago, but not for China, Iceland, Korea, and Nepal).

Results change when we focus on extreme weather events. In the second column of Table 3, we present the overall impact across countries. As can be seen, we found a significant impact (at least at the 5% level) in only 13 countries, and in eight of them, it is positive, in line with the general average. More importantly, when we disaggregate China from the rest of the sample, the corresponding estimated average parameter for the remaining countries completely loses its statistical significance,[16] so the overall result is essentially due to the case of China. Disaggregating by type of event, we see that floods, droughts, and landslides drive the overall impact. As can be seen, weather events do not have a widespread impact across countries, with the exception of China, India, Nepal, and Thailand.

Table 1. Primary energy intensity and climate change for the period 1986–2016: Fixed-effects estimation

	(1)	**(2)**
Dependent variable	**Log of primary energy consumption intensity**	**Log of primary energy consumption intensity**
lnGDPpc	-0.479*** (0.015)	-0.534*** (0.013)
$Temp_{it}$	-0.032*** (0.009)	
$Events_{it}$		0.006*** (0.002)
Constant	5.375*** (0.153)	5.317*** (0.125)
Observations	2028	2046
Within-R2	0.429	0.447

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level

5. The connection between Climate Change and Labor Productivity

The impact of climate change on labor productivity (equations 5 and 6) appears in Table 2. As shown, the proposed equations are adequate and explain more than 65% of the variation in labor productivity within countries. Our three

[16] This is not the case for any of the other regressions with each individual country. Regressions will be provided upon request.

control variables (capitalization, human capital and the proportion of internet users over population) have the expected (positive) sign and are highly significant. In this case, the increase in temperatures does not have a general impact on labor productivity, while the impact of events is positive and significant[17], contrary (a priori) to what was expected.

The disaggregation by country and type of event appears in Table 4. Regarding temperatures, and focusing on the estimated significant parameters at conventional levels, we observe that for some countries the increase in temperatures also increases labor productivity (the cases of China, Indonesia, Malta, Mauritius, Myanmar, Poland and Tanzania) while in others (Bolivia, Brazil, Bulgaria, Iran, Italy, Jordan, Kenya, Kuwait, Macao, Mexico, Qatar, Singapore and Spain) higher temperatures have a negative impact on labor productivity. In general terms (although, with relevant exceptions) in hottest countries productivity growth decreases with temperatures, as it should be expected.

Focusing on events, only a few countries have a significant average impact (at least at 5% level) on labor productivity: China, Jordan, Myanmar, Nigeria, Poland, Romania and Turkey. If we disaggregate China from the rest, the average

[17] An additional event increases productivity around 0.9% on average.

impact decreases dramatically[18], showing again the key role of this country in the results obtained when referring to events. By type of events, floods, extreme temperatures, storms and landslides (positively) impact labor productivity. What is more interesting is that all events (except epidemics) have a significant effect in China. Floods, storms, landslides wildfires and extreme temperatures have a positive effect, while insect infestations and droughts have a negative effect. The rest of the countries do not present any generalized impact. It is important to note that the found negative effect of insect infestation and droughts on labor productivity is perfectly reasonable because these two type of events could directly affect human health. In any case, the positive result of the rest of the events is not intuitive and needs for further explanation.

A characteristic of the analysis in Sections 4 and 5 is that if we ignore China, the average impact of events on energy intensity is null and that of labor productivity is strongly reduced. We have carried out regressions decomposing the events for China, on the one hand, and the rest of the countries, on the other (Table 5). As we can see, the influence of China on the average results obtained is crucial, especially when it comes to storms, floods, and landslides. This result

[18] The impact in the case of China is around 3.44% whereas the average impact for the rest of countries is around 0.36%. Something similar does not occurs with any of the other countries, which leave unaltered the average impact.

is consistent with the one obtained regarding the impact of climate change on international trade (with respect to domestic trade).

Table 2. Labor productivity and climate change. Period 1990-2016. Fixed effects estimation.

	(1)	**(2)**
Dependent variable	**Log of labour productivity**	**Log of labour productivity**
$Log(K/L)_{it}$	0.308^{***} (0.011)	0.317^{***} (0.011)
HCI_{it}	0.255^{***} (0.029)	0.227^{***} (0.029)
$Internet\_share_{it}$	0.044^{**} (0.018)	0.055^{***} (0.018)
$Temp_{it}$	0.001 (0.006)	
$Events_{it}$		0.009^{***} (0.001)
constant	6.270^{***} (0.146)	6.243^{***} (0.106)
Observations	1687	1702
Within-R2	0.673	0.673

Note: *significant at 10% level, ** significant at 5% level, ***significant at 1% level.

Table 3. Impact of the increase in temperatures and extreme events on the intensity of primary energy consumption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Country	**Temperature**	**Events**	**Wildfire**	**Flood**	**Extreme temperatures**	**Epidemic**	**Insect infestation**	**Storm**	**Drought**	**Landslide**
Whole sample	**-0.033*** (0.009)**	**0.006*** (0 .002)**	**NS**	**0.011***(0.003)**	**NS**	**NS**	**NS**	**NS**	**0.028*** (0.014)**	**0.028*** (0 .009)**
Australia	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Austria	NS	NS		NS	NS			NS		NS
Belgium	NS	NS		NS				NS		
Bolivia	-0.280*** (0.107)	0.065*** (0.023)	NS	0.108*** (0.042)	NS	NS		NS	NS	NS
Brazil	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bulgaria	-0.226*** (0.049)	NS	NS	NS	NS			NS	NS	
Cameroon	-0.253* (0.135))	NS		NS		NS			NS	NS
Canada	NS	NS	NS	NS	NS	NS		NS	NS	
Chile	NS	NS	NS	NS	NS	NS		NS		-0.417**(0.196)
China	0.386*** (0.088)	0.025*** (0.005)	NS	0.040*** (0.010)	NS	NS	-0.508** (0.212)	NS	NS	0.073***(0.021)
Colombia	NS	NS	NS	NS		NS	NS	NS	NS	NS
Costa Rica	NS	NS	NS	0.081* (0.042)				NS	NS	NS
Cyprus	NS	NS	NS		NS	NS		NS	NS	
Denmark	-0.093** (0.039)	NS						NS	NS	
Ecuador	NS	NS	NS	NS		NS			NS	NS
Egypt	NS	NS		NS	NS	NS		NS		
Finland	NS	NS		NS				NS		
France	NS	NS	NS	NS	NS	NS		NS	NS	NS
Germany	-0.099**(0.045)	NS		NS	NS	NS		NS		NS
Greece	NS	NS	NS	NS	NS				NS	
Hungary	-0.204**(0.044)	NS		NS	NS			NS	NS	
Iceland	0.232*** (0.054)	-0.156** (0.079)		NS						NS
India	0.665*** (0.225)	0.037*** (0.010)	NS	0.026** (0.013)	NS	NS		0.135** (0.070)	NS	0.068** (0.032)
Indonesia	0.223** (0.107)	NS	NS	0.016* (0.009)		NS	NS	NS	NS	NS
Iran	0.171*** (0.054)	NS	NS	-0.044* (0.022)		NS		NS	NS	NS
Ireland	NS	NS		NS		NS		NS		
Israel	NS	NS	NS	NS	NS	NS		NS	NS	
Italy	NS	NS	NS	NS	NS	NS		NS	NS	NS
Japan	NS	NS	NS	NS	NS	NS		NS		NS
Jordan	-0.110** (0.045)	NS		NS	NS			NS	NS	
Kenya	NS	NS		NS		NS		NS	NS	NS
Korea	0.197*** (0.067)	NS	NS	NS	NS	NS		NS	NS	NS
Kuwait	NS	NS		NS		NS				
Macao										

Table 3. Impact of the increase in temperatures and extreme events on the intensity of primary energy consumption (cont.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Country	**Temperature**	**Events**	**Wildfire**	**Flood**	**Extreme**	**Epidemic**	**Insect infestation**	**Storm**	**Drought**	**Landslide**
Malawi	NS	NS		NS		NS			NS	
Malaysia	0.447***(0.140)	0.054***	NS	0.084*** (0.029)		NS		NS	NS	NS
Malta	0.532*** (0.076)									
Mauritius	0.540*** (0.083)	NS		NS		NS		NS		
Mexico	NS	NS	NS	NS	NS	NS		NS	NS	NS
Morocco	0.179** (0.074)	NS		NS	NS		NS	NS	NS	
Myanmar	0.299** (0.135)	0.079***		0.091* (0.047)		NS		NS		NS
Nepal	0.596*** (0.007)	0.088***	0.194* (0.117)	0.289*** (0.043)	NS	NS		-0.476***	NS	0.098** (0.049)
Netherlands	NS	NS		NS	NS	NS		NS		
Niger	NS	NS		NS		NS	NS	NS	NS	
Nigeria	-0.630*** (0.096)	-0.020* (0.011)		-0.104*** (0.028)	NS	NS	NS	NS		0.270*** (0.099)
Norway	-0.085** (0.043)	0.105* (0.062)		NS				NS		
Panama	NS	NS	NS	NS		NS		NS	NS	
Philippines	NS	NS	NS	NS		NS	NS	NS	NS	NS
Poland	-0.185*** (0.042)	-0.138***	NS	NS	-0.204*** (0.054)			NS		
Portugal	NS	NS	NS	NS	NS			NS	NS	
Qatar	-0.764*** (0.056)									
Romania	-0.156** (0.076)	-0.059***		-0.064** (0.026)	-0.114* (0.065)	NS		NS	NS	NS
Senegal	0.258*** (0.009)	NS		NS		NS	NS	NS	NS	
Singapore	NS	NS				NS				
South Africa	-0.180** (0.081)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spain	NS	NS	NS	NS	NS	NS		NS	NS	NS
Sri Lanka	0.419*** (0.142)	0.050** (0.024)		NS		NS		NS	NS	NS
Sweden	-0.093** (0.039)	NS			NS	NS		NS		
Switzerland	-0.162*** (0.058)	0.144** (0.064)		NS	NS	NS		NS		NS
Tanzania	NS	NS	NS	NS		NS	NS	NS	NS	NS
Thailand	0.173** (0.098)	0.058***	NS	0.049** (0.021)	0.345** (0.140)	0.245*** (0.094)		NS	0.174** (0.073)	NS
Trinidad and Tobago	0.463*** (0.113)	NS		NS				NS	0.402** (0.188)	NS
Tunisia	NS	NS		NS					NS	
Turkey	NS	NS	NS	NS	NS	NS		NS		NS
United Kingdom	NS	NS		NS	NS	NS		NS		
United States	-0.132*** (0 .072)	NS	NS	NS	NS	NS		NS	NS	NS
Uruguay	NS	NS		NS	NS			NS	NS	

Note: NS: non-significant, *significant at 10% level, ** significant at 5% level, ***significant at 1% level

Table 4. Impact of rising temperatures and extreme events on labor productivity.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Country	**Temperature**	**Events**	**Wildfire**	**Flood**	**Extreme**	**Epidemic**	**Insect infestation**	**Storm**	**Drought**	**Landslide**
Whole sample	0.001 (0.006)	0.009*** (0 .001)	NS	0.010***(0.002)	0.025***(0.007))	NS	NS	0.009*** (0.002)	NS	0.017*** (0.006)
Australia	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Austria	NS	NS		NS	NS			NS		NS
Belgium	NS	NS		NS	NS			NS		
Bolivia	-0.128** (0.077)	NS	NS	NS	NS	NS		NS	NS	NS
Brazil	-0.316*** (0.079)	NS	NS	-0.021* (0.012)	NS	NS	NS	NS	NS	NS
Bulgaria	-0.055** (0.033)	NS	NS	NS	NS			NS	NS	
Cameroon	NS	NS		NS		NS			NS	NS
Canada	NS	NS	NS	NS	NS	NS		NS		
Chile	NS	NS	NS	NS	NS	-0.196* (0.114)		NS		
China	0.558*** (0.058)	0.034*** (0.003)	0.140** (0.068)	0.052*** (0.006)	0.085*** (0.030)	NS	-0.483*** (0.121)	0.034*** (0.007)	-0.091*** (0.027)	0.094***(0.012)
Colombia	NS	NS	NS	NS		NS	NS	NS	NS	NS
Costa Rica	NS	NS	NS	NS				NS	NS	NS
Cyprus	NS	NS	NS		NS	NS		NS	NS	
Denmark	NS	NS						NS	NS	
Ecuador	NS	NS	NS	NS		NS			NS	NS
Egypt	NS	NS		NS	NS	NS		NS		
Finland	NS	NS		NS						
France	NS	NS	NS	NS	NS	NS		NS	NS	NS
Germany	NS	NS		NS	NS	NS		NS		NS
Greece	-0.070* (0.040)	0.024* (0.014)	NS	NS	NS					
Hungary	NS	0.036* (0.022)		NS	NS			NS	NS	
Iceland	NS	NS								NS
India	NS	NS	0.146* (0.085)	0.012** (0.006)		NS	NS	NS	NS	NS
Indonesia	0.336** (0.159)	0.011* (0.006)	NS	0.015* (0.088)	NS	NS		NS	NS	NS
Iran	-0.098** (0.037)	0.021* (0.012)	NS	NS		NS		NS	NS	NS
Ireland	NS	NS		NS		NS		NS		
Israel	NS	NS	NS	NS		NS		NS	NS	
Italy	-0.139** (0.048))	NS	NS	-0.031* (0.018)	NS	NS		NS	NS	NS
Japan	NS	NS	NS	NS	NS	NS		NS		NS
Jordan	-0.155*** (0.034)	0.066** (0.029)		0.169* (0.089)	0.182* (0.093)			NS	NS	
Kenya	-0.210** (0.086)	NS		NS		NS			NS	NS
Korea	NS	NS	NS	NS	NS	NS		NS	NS	NS
Kuwait	-0.091** (0.038)	NS		NS		NS				
Macao	-0.163**(0.060)	NS				NS		NS		

Table 4. Impact of rising temperatures and extreme events on labor productivity.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Country	**Temperature**	**Events**	**Wildfire**	**Flood**	**Extreme**	**Epidemic**	**Insect**	**Storm**	**Drought**	**Landslide**
Malawi	NS	NS		NS		-0.048* (0.027)			NS	
Malaysia	NS	NS	NS	NS		NS		NS	NS	NS
Malta	0.098** (0.049)									
Mauritius	0.203*** (0.057)	NS		NS		NS		NS)		
Mexico	-0.224*** (0.078)	NS	NS	NS	NS	NS		NS	NS	NS
Morocco	0.085* (0.048)	NS		NS	NS		NS	NS	NS	
Myanmar	0.558** (0.088)	0.117*** (0.021)		0.105** (0.053)		NS		0.247*** (0.058)		0.426*** (0.073)
Nepal	0.096* (0.050)	NS	NS	NS	NS	NS		NS	NS	NS
Netherlands	NS	NS		NS	NS	NS		NS		
Niger	NS	NS		NS		NS	NS	NS	NS	
Nigeria	NS	-0.018*** (0.007)		-0.063** (0.022)	NS	NS	NS	0.148** (0.066)		NS
Norway	NS	NS		NS				NS		
Panama	NS	NS	NS	NS		NS		NS	NS	
Philippines	NS	NS	NS	NS		NS	NS	NS	NS	NS
Poland	0.100*** (0.031)	0.075*** (0.018)	-0.220* (0.113)	0.070* (0.039)	0.077** (0.034)			0.063* (0.033)		
Portugal	NS	NS	NS	NS	NS			NS	NS	
Qatar	-0.308*** (0.096)									
Romania	NS	0.020** (0.010)		0.045** (0.016)	NS	NS		NS	-0.242** (0.112)	-0.285** (0.139)
Senegal	NS	NS		NS		NS	NS	NS	NS	
Singapore	-0.268***(0.091)	NS				NS				
South Africa	NS	NS	NS	NS	NS	NS		NS	NS	NS
Spain	-0.324*** (0.053)	NS	0.136*** (0.042)	-0.094*** (0.030)	NS	0.240*** (0.071)		NS	NS	0.379*** (0.114)
Sri Lanka	NS	NS		NS		NS		NS	NS	NS
Sweden	0.054* (0.032)	NS			NS	NS		NS		
Switzerland	NS	NS			NS					
Tanzania	0.279** (0.113)	NS	NS	NS		NS	NS	NS	NS	NS
Thailand	NS	NS	NS	NS	NS	NS		NS	NS	NS
Trinidad and	NS	NS		NS				NS	NS	NS
Tunisia	NS	NS		NS						
Turkey	NS	0.024** (0.011)	NS	NS	NS	NS		NS		NS
United Kingdom	NS	NS		NS	NS	NS		NS		
United States	NS	NS	NS	NS	NS	NS		NS	NS	NS
Uruguay	NS	NS		NS	NS			NS	NS	

Note: NS: non-significant, *significant at 10% level, ** significant at 5% level, ***significant at 1% level.

Table 5. Energy intensity, labor productivity, and types of events

	(1)	(2)
Dependent variable	**Log of primary energy consumption intensity**	**Log of labor productivity**
Wildfire-no-China$_{ijt}$	0.006	0.009
	(0.011)	(0.007)
Wildfire-China$_{ijt}$	0.028	0.149**
	(0.103)	(0.068)
Flood-no-China$_{ijt}$	0.006*	0.005**
	(0.003)	(0.002)
Flood-China$_{ijt}$	0.041***	0.054***
	(0.010)	(0.006)
Ext_Temp-no-China$_{ijt}$	-0.019	0.022***
	(0.012)	(0.007)
Ext_Temp -China$_{ijt}$	0.053	0.085***
	(0.050)	(0.029)
Epidemic-no-China$_{ijt}$	-0.004	-0.007
	(0.007)	(0.004)
Epidemic-China$_{ijt}$	-0.076	-0.056
	(0.059)	(0.037)
Insect-no-China$_{ijt}$	-0.003	-0.012
	(0.037)	(0.030)
Insect-China$_{ijt}$	-0.509**	-0.486***
	(0.511)	(0.121)
Storm-no-China$_{ijt}$	-0.004	0.001
	(0.004)	(0.003)
Storm-China$_{ijt}$	0.018	0.034***
	(0.011)	(0.007)
Drought-no-China$_{ijt}$	0.035**	0.003
	(0.016)	(0.010)
Drought-China$_{ijt}$	-0.059	-0.092***
	(0.044)	(0.027)
Landslide-no-China$_{ijt}$	0.026**	0.005
	(0.010)	(0.006)
Landslide-China$_{ijt}$	0.073***	0.095***
	(0.021)	(0.012)
Observations	2046	1702

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level

Standard errors are clustered by country.
Control variables in both equations have been excluded for simplicity.

6. Connecting Previous Results with the Impact of Climate Change on International Trade

It is now interesting to see whether energy intensity and labor productivity have an impact on international trade, as well as the connection between these variables and climate change in that relationship. To see this, we are going to estimate the structural gravity model described in Equations (1) and (2), with the inclusion, on the one hand, of the energy intensity variable and, on the other, of labor productivity. In Table 6, we present the results obtained. In Columns 1 and 2, we present the results without including the aforementioned factors,[19] while in Columns 3 to 6, we present the results including energy intensity (Columns 3 and 4) and labor productivity (Columns 5 and 6). As can be seen, energy intensity presents a negative and highly significant coefficient, which implies that international trade increases with respect to domestic trade at a higher level of energy efficiency (with an elasticity of around 0.75). More importantly, by introducing this variable into the gravity equation, our "temp" variable completely loses its statistical significance, which means that, on average, the impact of temperatures on international trade comes from this channel. Removing the "temp" variable from the gravity equation, the estimated coefficient is -0.765 (not shown). Thus, if we focus on the estimation in Column 1 of Table 1, we see

[19] Extracted from Martinez et al. (2023).

that an additional degree of temperature will imply an increase of 2.44% [(-0.032) * (-0.765)] of international trade flows with respect to intra-national trade ones. Regarding events, we observe a slight decrease in the impact, which is now significant at the 10% level (although very close to 5%). Likewise, part of the effect of these phenomena on international trade comes from this channel but to a much lesser extent than temperatures. Making a parallelism with the previous case, an additional event would decrease international trade in relation to domestic trade by around 0.46% [0.006*(-0.765)].

Next, we introduce labor productivity into the gravity equation. As shown, the respective coefficients are not significant at conventional levels, leaving the impacts of our “temp” and “events” variables unchanged. This implies that this factor has no effect on “relative” bilateral trade flows. That is, although events influence labor productivity, there should be no relevant effect between those tasks devoted to domestic trade in relation to those devoted to international trade.

At this point, it is interesting to note how the respective coefficients by country of the variables that measure climate change are altered when introducing the energy intensity variable. The results are presented in Table 7. In general, the interpretation of the change in the coefficients is as follows. If the coefficient was positive and is reduced once we include the energy intensity variable, this implies that the impact of temperatures comes (totally or partially) from this channel, and this is because temperatures imply an increase in energy efficiency (see Table 3). The same happens if the coefficient is negative and becomes more negative. The opposite situation should imply that temperatures decrease energy efficiency. As can be seen, the changes in the coefficients are quite generalized. However, we are going to focus on the three most relevant cases in this analysis: Germany, the Netherlands, and the United Kingdom (UK). The differential impact on these countries (especially Germany) drives the overall result.[20] The case of Germany seems clear. In this country, an increase in average temperature considerably improves energy efficiency (Column 1 of Table 3), and from here (it seems wholly), international trade increases with respect to domestic trade.

The other cases are different. The change in the respective positive coefficients of the Netherlands (partly reduced) and the UK (fully) is not due to an improvement in their energy efficiency (again, Column 1 of Table 3) resulting from the increase in temperatures. Therefore, the only sensible alternative is for this change to be driven mainly by variations in the energy efficiency of the partners. Unfortunately, this methodology does not allow us to distinguish the impact of our variables of interest when countries act as exporters or importers.

[20] Regressions provided under request.

However, we can estimate the impact of the energy intensity of trading partners when a specific country acts as an exporter, on the one hand, and as an importer, on the other. If we look at Table 3, we realize that there are two very important partners of both countries with improvements in energy efficiency because of the increase in temperatures: Germany and the US. Therefore, we have regressed the bilateral trade flows of the Netherlands and the UK (each separately) when they act as exporters and importers, and we have disaggregated the energy intensity of Germany and the US from that of the other partners. The results are shown in Table 8. As can be seen, both German and US energy intensity impact Dutch trade, albeit in different directions: An improvement in US energy efficiency increases exports for the Netherlands, while an improvement in energy efficiency in Germany reduces imports for the Netherlands. Considering the estimated coefficients, an increase of one degree Celsius in the US and Germany will imply an increase of 9.43% [(-0.132) * (-0.715)] of the exports of the Netherlands and a decrease of 6.30% [(-0.099) * (0.636)] of imports to the Netherlands, respectively. In any case, the estimations in Table 7 tell us that the balance has to be positive. For its part, UK trade is affected by an increase in US energy efficiency: An increase of, on average, one degree Celsius in the US will imply a 10.89% increase in UK exports, with no impact on imports.

Focusing on the events (Columns 3 and 4 in Table 3), we can see that there are no significant changes in the estimated parameters (albeit with some exceptions) with slight reductions across the board (as expected) in relevant countries, such as (of course) China, Germany, Japan, France, or Italy. As shown in Table 9, China remains the crucial country in determining the sample estimated coefficient. In any case, the impact of events on international trade (which, as has been said, is mainly driven by the case of China) can be explained only to limited extent by the energy intensity channel.

When referring to the impact of labor productivity, we observe (Table 7) that this variable does not play an explanatory role in the impact on relative trade flows (international versus domestic). When conducting the analysis by country (not shown),[21] there is no relevant change in the respective estimated coefficients.

As we have seen, energy efficiency nor labour productivity are the channels (or vey partially) through which disasters impact trade. Additionally, we have seen that in the sample's impact, China is the key and specially relating the phenomena of Storms – Floods - Landslides. The answer probably lies in the Chinese government's reaction to the occurrence of this type of disaster, especially after the Yangtze River floods in 1998 (Wei et al. 2022, or Jia, et al. 2022). The

[21] Regressions will be provided upon request.

large investments in infrastructure to manage the risk of floods have generated quite relevant economic development in the area (which accounts for close to 30% of China's GDP). This fact has probably implied a high impact on labour productivity, but in tasks more oriented to domestic goods and services (infrastructure construction, urbanization of areas, etc.), which explain why this type of event positively affects domestic sales with respect to intra-national ones.

Table 6. Trade and climate change: Inclusion of energy intensity and labor productivity

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**
PTA_{ijt}	0.122**	0.122**	0.142**	0.143**	0.051	0.051
	(0.056)	(0.056)	(0.056)	(0.056)	(0.053)	(0.053)
$GATT/WTO_{ijt}$	1.024***	1.064***	1.260***	1.293***	0.913***	0.942***
	(0.116)	(0.109)	(0.116)	(0.111)	(0.125)	(0.124)
$temp_{i(j)t}$	0.037***		0.015		0.037***	
	(0.010)		(0.009)		(0.010)	
$event_{i(j)t}$		-0.005***		-0.004*		-0.005**
		(0.002)		(0.002)		(0.002)
$lnEnergy\_Intensity_{i(j)t}$			-0.728***	-0.732***		
			(0.151)	(0.149)		
$lnLabour\_Productivity_{i(j)t}$					-0.087	-0.074
					(0.130)	(0.129)
$Glob_{ij1987}$	0.024***	0.029***	0.019**	0.022***	-	-
	(0.008)	(0.007)	(0.008)	(0.007)	-	-
$Glob_{ij1988}$	0.088***	0.121***	0.080***	0.097***	-	-
	(0.010)	(0.010)	(0.011)	(0.010)	-	-
$Glob_{ij1989}$	0.126***	0.162***	0.103***	0.119***	-	-
	(0.016)	(0.015)	(0.017)	(0.016)	-	-
$Glob_{ij1990}$	0.193***	0.254***	0.169***	0.202***	-	-
	(0.019)	(0.019)	(0.020)	(0.019)	-	-
$Glob_{ij1991}$	0.228***	0.267***	0.188***	0.212***	-	-
	(0.018)	(0.019)	(0.019)	(0.019)	-	-
$Glob_{ij1992}$	0.244***	0.285***	0.200***	0.222***	0.011	0.015*
	(0.018)	(0.019)	(0.020)	(0.021)	(0.009)	(0.009)
$Glob_{ij1993}$	0.277***	0.306***	0.217***	0.236***	0.038**	0.029*
	(0.020)	(0.021)	(0.023)	(0.024)	(0.018)	(0.017)
$Glob_{ij1994}$	0.323***	0.370***	0.268***	0.290***	0.087***	0.098***
	(0.023)	(0.023)	(0.026)	(0.027)	(0.019)	(0.019)
$Glob_{ij1995}$	0.411***	0.447***	0.345***	0.362***	0.179***	0.177***
	(0.024)	(0.024)	(0.030)	(0.032)	(0.026)	(0.026)

Table 6. Trade and Climate change: Inclusion of energy intensity and labor productivity (cont.)

$Glob_{ij1996}$	0.447***	0.454***	0.361***	0.367***	0.215***	0.185***
	(0.025)	(0.025)	(0.032)	(0.032)	(0.029)	(0.028)
$Glob_{ij1997}$	0.509***	0.560***	0.425***	0.454***	0.290***	0.303***
	(0.028)	(0.029)	(0.035)	(0.036)	(0.033)	(0.033)
$Glob_{ij1998}$	0.554***	0.617***	0.463***	0.497***	0.337***	0.361***
	(0.027)	(0.029)	(0.035)	(0.038)	(0.034)	(0.035)
$Glob_{ij1999}$	0.539***	0.594***	0.430***	0.458***	0.324***	0.339***
	(0.029)	(0.031)	(0.040)	(0.032)	(0.038)	(0.039)
$Glob_{ij2000}$	0.603***	0.668***	0.473***	0.508***	0.388***	0.413***
	(0.030)	(0.033)	(0.043)	(0.047)	(0.042)	(0.043)
$Glob_{ij2001}$	0.581***	0.634***	0.424***	0.452***	0.369***	0.383***
	(0.029)	(0.030)	(0.046)	(0.030)	(0.038)	(0.038)
$Glob_{ij2002}$	0.531***	0.601***	0.366***	0.405***	0.319***	0.352***
	(0.030)	(0.034)	(0.048)	(0.053)	(0.039)	(0.041)
$Glob_{ij2003}$	0.577***	0.629***	0.406***	0.432***	0.368***	0.379***
	(0.031)	(0.033)	(0.051)	(0.053)	(0.043)	(0.043)
$Glob_{ij2004}$	0.624***	0.670***	0.443***	0.465***	0.418***	0.424***
	(0.032)	(0.034)	(0.053)	(0.055)	(0.045)	(0.045)
$Glob_{ij2005}$	0.642***	0.691***	0.446***	0.470***	0.438***	0.446***
	(0.033)	(0.036)	(0.056)	(0.059)	(0.047)	(0.047)
$Glob_{ij2006}$	0.671***	0.739***	0.460***	0.495***	0.469***	0.498***
	(0.033)	(0.036)	(0.059)	(0.062)	(0.049)	(0.049)
$Glob_{ij2007}$	0.794***	0.855***	0.561***	0.590***	0.596***	0.616***
	(0.039)	(0.040)	(0.064)	(0.066)	(0.059)	(0.058)
$Glob_{ij2008}$	0.822***	0.869***	0.574***	0.596***	0.625***	0.631***
	(0.039)	(0.040)	(0.066)	(0.067)	(0.059)	(0.058)
$Glob_{ij2009}$	0.736***	0.785***	0.477***	0.500***	0.538***	0.547***
	(0.042)	(0.042)	(0.068)	(0.069)	(0.059)	(0.057)
$Glob_{ij2010}$	0.819***	0.853***	0.551***	0.566***	0.624***	0.617***
	(0.044)	(0.043)	(0.069)	(0.070)	(0.065)	(0.064)
$Glob_{ij2011}$	0.824***	0.873***	0.542***	0.563***	0.633***	0.640***
	(0.045)	(0.043)	(0.075)	(0.075)	(0.068)	(0.066)
$Glob_{ij2012}$	0.818***	0.869***	0.524***	0.549***	0.629***	0.639***
	(0.047)	(0.045)	(0.077)	(0.077)	(0.069)	(0.068)
$Glob_{ij2013}$	0.847***	0.907***	0.543***	0.576***	0.660***	0.679***
	(0.048)	(0.048)	(0.079)	(0.079)	(0.071)	(0.070)
$Glob_{ij2014}$	0.804***	0.876***	0.487***	0.521***	0.619***	0.648***
	(0.048)	(0.046)	(0.082)	(0.082)	(0.076)	(0.073)
$Glob_{ij2015}$	0.786***	0.865***	0.460***	0.499***	0.606***	0.643***
	(0.054)	(0.050)	(0.086)	(0.085)	(0.082)	(0.079)
$Glob_{ij2016}$	0.745***	0.821***	0.418***	0.455***	0.567***	0.601***
	(0.056)	(0.052)	(0.088)	(0.084)	(0.085)	(0.082)
Constant	11.776***	11.835***	11.733***	11.742***	12.212***	12.261***
	(0.108)	(0.103)	(0.104)	(0.100)	(0.298)	(0.286)
Observations	136,153	136,153	134,163	134,163	112,616	112,616
Country-pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Importer-year and Exporter-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Intranational trade	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R2	0.99	0.99	0.99	0.99	0.99	0.99

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level
Standard errors are clustered by country pair.

Table 7. Trade and climate change: Inclusion of energy intensity.

		Including energy intensity		Including energy intensity
	(1)	(2)	(3)	(4)
Country	Coefficient of temperatures (temp)	Coefficient of temperatures (temp)	Coefficient of events (event)	Coefficient of events (event)
Australia	-0.030 (0.028)	-0.053** (0.027)	-0.005 (0.004)	-0.004 (0.004)
Austria	0.107*** (0.018)	0.081*** (0.017)	0.005 (0.004)	0.006 (0.004)
Belgium	-0.097*** (0.018)	-0.118*** (0.018)	0.005 (0.009)	0.006 (0.009)
Bolivia	0.187** (0.075)	0.194** (0.084)	0.020** (0.009)	0.022** (0.010)
Brazil	0.095*** (0.030)	0.117*** (0.032)	0.003 (0.002)	0.005*** (0.002)
Bulgaria	0.348*** (0.050)	0.247*** (0.047)	0.022*** (0.006)	0.017*** (0.005)
Cameroon	0.053 (0.195)	0.031 (0.194)	0.023* (0.014)	0.024* (0.014)
Canada	0.021 (0.016)	0.003 (0.015)	0.002 (0.003)	0.003 (0.003)
Chile	0.107** (0.043)	0.120*** (0.044)	0.004 (0.003)	0.006* (0.004)
China	0.025 (0.018)	0.012 (0.018)	-0.010***(0.003)	-0.009***(0.003)
Colombia	0.104* (0.058)	0.101* (0.061)	0.003 (0.006)	0.003 (0.006)
Costa Rica	0.202* (0.121)	0.195 (0.125)	-0.002 (0.006)	-0.002 (0.006)
Cyprus	0.382*** (0.090)	0.360*** (0.089)	-0.005 (0.007)	-0.004 (0.007)
Denmark	-0.002 (0.014)	-0.000585	-0.014***(0.003)	-0.014***(0.004)
Ecuador	0.003 (0.050)	0.006 (0.049)	-0.002 (0.005)	-0.000 (0.006)
Egypt	0.246*** (0.071)	0.221*** (0.072)	0.004 (0.005)	0.004 (0.005)
Finland	-0.042** (0.020)	-0.067*** (0.019)	-0.016**(0.007)	-0.015**(0.007)
France	0.013 (0.018)	-0.005 (0.017)	-0.008**(0.003)	-0.006**(0.003)
Germany	0.058*** (0.019)	0.020 (0.017)	-0.007***(0.002)	-0.006***(0.002)
Greece	-0.063 (0.049)	-0.073 (0.048)	-0.00004	-0.007 (0.005)
Hungary	0.491*** (0.043)	0.413*** (0.039)	0.004 (0.011)	0.001 (0.010)
Iceland	0.092 (0.081)	0.147* (0.086)	0.001 (0.006)	0.002 (0.006)
India	0.287*** (0.077)	0.292*** (0.076)	-0.003 (0.005)	-0.001 (0.005)
Indonesia	-0.232*** (0.064)	-0.218*** (0.061)	-0.011 (0.006)	-0.006 (0.005)
Iran	-0.301*** (0.114)	-0.283*** (0.108)	0.016 (0.011)	0.021 (0.013)
Ireland	0.034 (0.027)	-0.029 (0.030)	-0.004 (0.006)	-0.004 (0.007)
Israel	0.200*** (0.056)	0.207*** (0.057)	0.003 (0.006)	0.005 (0.006)
Italy	-0.048** (0.023)	-0.059** (0.022)	-0.013***(0.003)	-0.011***(0.003)
Japan	-0.164*** (0.031)	-0.149*** (0.030)	-0.020***(0.004)	-0.017***(0.004)
Jordan	-0.027 (0.057)	-0.077 (0.055)	0.001 (0.008)	0.005 (0.009)
Kenya	-0.004 (0.054)	-0.021 (0.054)	0.013 (0.009)	0.014 (0.010)
Korea	-0.016 (0.031)	-0.002 (0.029)	-0.000028	-0.004 (0.003)
Kuwait	-0.199*** (0.074)	-0.254*** (0.079)	-0.003 (0.007)	-0.003 (0.008)
Macao	0.277 (0.211)	0.590** (0.239)	-0.031 (0.027)	-0.026 (0.027)
Malawi	0.759*** (0.294)	0.779*** (0.301)	0.043 (0.034)	0.045 (0.034)
Malaysia	-0.193** (0.086)	-0.169** (0.079)	-0.003 (0.007)	-0.001 (0.007)
Malta	0.024 (0.080)	0.078 (0.100)	0.002 (0.008)	0.004 (0.008)

Table 7. Trade and climate change: Inclusion of energy intensity (cont.)

		Including energy intensity		Including energy intensity
	(1)	(2)	(3)	(4)
Country	**Coefficient of temperatures (temp)**	**Coefficient of temperatures (temp)**	**Coefficient of events (event)**	**Coefficient of events (event)**
Mauritius	-0.170** (0.082)	-0.062 (0.077)	0.003 (0.005)	0.008 (0.005)
Mexico	0.378*** (0.094)	0.372*** (0.098)	0.013*** (0.003)	0.013*** (0.003)
Morocco	0.510** (0.203)	0.551*** (0.208)	-0.000112	-0.013 (0.009)
Myanmar	0.424 (0.300)	0.422 (0.304)	0.027 (0.027)	0.030 (0.029)
Netherlands	0.081*** (0.020)	0.051*** (0.019)	-0.002 (0.004)	-0.002 (0.004)
Niger	-0.117 (0.150)	-0.053 (0.146)	-0.027**(0.013)	-0.022**0.012)
Nigeria	0.030 (0.051)	-0.034 (0.049)	-0.006 (0.012)	-0.003 (0.012)
Norway	0.045 (0.031)	0.002 (0.029)	-0.013**(0.006)	-0.000072
Panama	0.223*** (0.087)	0.187** (0.009)	-0.012 (0.007)	-0.010 (0.008)
Philippines	0.126** (0.060)	0.111* (0.063)	0.003 (0.004)	0.002 (0.004)
Poland	0.307*** (0.026)	0.237*** (0.026)	0.023*** (0.008)	0.017*** (0.006)
Portugal	0.047 (0.037)	0.073* (0.041)	-0.005 (0.005)	-0.000 (0.005)
Qatar	0.417*** (0.156)	0.231* (0.122)	0.002 (0.007)	0.002 (0.007)
Romania	0.292*** (0.050)	0.226*** (0.047)	0.074** (0.037)	0.052** (0.031)
Senegal	0.087 (0.104)	0.117 (0.104)	0.030** (0.014)	0.033** (0.014)
Singapore	-0.323*** (0.110)	-0.326*** (0.106)	-0.021**(0.010)	-0.020**(0.009)
South Africa	0.049 (0.039)	-0.004 (0.039)	-0.002 (0.006)	-0.001 (0.005)
Spain	0.157*** (0.022)	0.149*** (0.023)	-0.003 (0.003)	-0.001 (0.003)
Sri Lanka	-0.105 (0.074)	-0.078 (0.069)	-0.00006	-0.007 (0.006)
Sweden	-0.012 (0.012)	-0.048*** (0.013)	-0.010***(0.004)	-0.009**(0.004)
Switzerland	0.202*** (0.037)	0.149*** (0.036)	-0.009 (0.007)	-0.007 (0.007)
Tanzania	0.045 (0.072)	0.019 (0.072)	0.015 (0.013)	0.016 (0.013)
Thailand	0.031 (0.047)	0.118** (0.049)	0.002 (0.004)	0.009** (0.004)
Trinidad and Tobago	0.101 (0.179)	0.157 (0.170)	0.005 (0.007)	0.007 (0.007)
Tunisia	0.202*** (0.055)	0.194*** (0.057)	-0.004 (0.008)	-0.002 (0.008)
Turkey	0.195*** (0.034)	0.209*** (0.037)	-0.002 (0.003)	-0.001 (0.003)
United Kingdom	0.055*** (0.015)	0.017 (0.015)	0.002 (0.003)	0.003 (0.003)
United States	0.031 (0.023)	0.012 (0.023)	-0.002 (0.002)	-0.001 (0.002)
Uruguay	-0.015 (0.059)	0.021 (0.054)	-0.012***(0.005)	-0.009**(0.00)

*significant at 10% level, **significant at 5% level, ***significant at 1% level
For the sake of brevity, the estimations for dummies capturing PTAs, GATT/WTO, and globalization are not shown.
Standard errors are clustered by country pair.

Table 8. Impact of energy efficiency of partners on exports and imports of the Netherlands and the UK

	(1)	(2)	(3)	(4)
Dependent variable	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**
	Netherlands as exporter	*Netherlands as importer*	*UK as exporter*	*UK as importer*
PTA_{ijt}	0.554***	0.466*	0.367***	0.235
	(0.145)	(0.275)	(0.200)	(0.164)
$GATT/WTO_{ijt}$	1.243***	1.879***	1.468***	2.280***
	(0.182)	(0.118)	(0.197)	(0.178)
$temp_{i(j)t}$	0.003	0.019	0.010	0.008
	(0.016)	(0.016)	(0.023)	(0.031)
$lnEnergy\_Intensity_{i(j)t}$ - GER	-0.111	0.636***	0.130	-0.429
	(0.189)	(0.294)	(0.221)	(0.410)
$lnEnergy\_Intensity_{i(j)t}$ - USA	-0.715***	0.164	-0.825***	0.031
	(0.268)	(0.422)	(0.319)	(0.591)
$lnEnergy\_Intensity_{i(j)t}$ - Rest	-0.314	0.560	-0.398	-0.843
	(0.237)	(0.359)	(0.251)	(0.597)
Constant	6.658***	5.552***	6.602***	6.414***
	(0.269)	(0.266)	(0.259)	(0.440)
Observations	1,994	1,994	1,994	1,994
Country-pair FE	Yes	Yes	Yes	Yes
Exporter-year	No	Yes	No	No
Importer-year	Yes	No	Yes	Yes
Intranational trade	Yes	Yes	Yes	Yes
Pseudo R2	0.99	0.99	0.99	0.99

Note: The coefficients of the dummy variables for globalization are dropped for the sake of brevity. This is equivalent to including the exporter-year and the importer-year in the import and export equations, respectively.

Therefore, our view is that the explanation is based on the management of these events since 1998 through very large investments in infrastructure (domestic trade) by the Chinese government. But, how it should be viewed? In our opinion, the way forward is to see whether there has been any change in the impact of weather events on international trade before and after this year. For this reason, we have divided the entire sample into the periods 1986–1998 and 1999–2016. The results are shown in Table 9. As can be seen, in the case of China, the coefficient for the first period of the sample is far from significant, while the coefficient for the second period is highly significant. In the case of the rest of the countries in the sample, the coefficient is not significant in both periods. Obviously, the total impact is the result of a weighted average of the partial impacts. For this reason, we have disaggregated by type of event.[22] Focusing on storms and landslides, we can see that in the first period, neither coefficient is significant at the conventional level (storms at 10%), but both coefficients are negative and highly significant in the second period. Furthermore, they are responsible for the sign and significance of the entire impact, as is quite clear when we group the events into two types: storms and landslides, and the rest (Column 3). Therefore, these results suggest that something different happened in the Chinese economy compared to these types of events after 1998, as stated.

[22] Floods have been removed from the estimation because in the trade equation the respective variable has a very high correlation with storms and multicollinearity problems would arise.

In fact, by looking at Figures 1 to 6, we can realize some very relevant facts that relate these phenomena in the time interval of our sample period. In 1986, China experienced seven serious storm-related events, two floods, and no landslides. In 2016, 13 severe storms occurred in China, 12 floods and three landslides. This year, China was the country most affected by these phenomena worldwide.

7. Conclusions

In this paper, we investigated the causes of the relationship between climate change and international trade obtained from previous research. To do this, we estimated the impact of temperatures and disasters related to climate change both on the intensity of energy consumption and on labor productivity. Regarding the first variable, we tried to measure the effect on energy infrastructure (energy efficiency). In the case of the second variable, we measured labor efficiency. We made estimations on a sample of 67 countries during the period 1986 – 2016.

On the one hand, our results suggest that energy intensity is the channel through which rising temperatures affect international trade (increasing it relative to domestic trade), with Germany (jointly, although indirectly, with the US) being the main actor in this process. On the other hand, neither energy intensity nor labor productivity seems to play a relevant role in the impact of events on international trade. In this sense, we identify the key role of China in the average result obtained, especially with regard to the storm–flood–landslide phenomena The counterintuitive result obtained on the impact of these events on labor productivity (also determined by China) gave us a clue: something happened in the Chinese economy related to these events. After the corresponding analysis, we conclude that the enormous investment in infrastructure of the Chinese government from 1998 to manage the floods seems to be the most reasonable explanation.

Table 9. Trade and Climate change in the period 1986–2016: The events and the case of China

	(1)	(2)	(3)	(4)
Dependent variable	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**	**Nominal trade flows in current US dollars**
Event_CHN	-0.009*** (0.003)			
Event_CHN_1986-1998$_{i(j)t}$		-0.021 (0.015)		
Wildfire-China$_{ijt}$			0.221*** (0.053)	
Ext_Temp -China$_{ijt}$			-	
Epidemic-China$_{ijt}$			-0.363*** (0.131)	-0.036 (0.050)
Insect-China$_{ijt}$			-0.900** (0.445)	
Drought-China$_{ijt}$			-0.121*** (0.038)	
Storm-China$_{ijt}$			-0.046* (0.025)	-0.033* (0.019)
Landslide-China$_{ijt}$			-0.020 (0.050)	
Event_CHN_1999-2016$_{i(j)t}$		-0.009*** (0.003)		
Wildfire-China$_{ijt}$			0.002 (0.012)	
Ext_Temp -China$_{ijt}$			-0.054*** (0.021)	
Epidemic-China$_{ijt}$			-0.022 (0.021)	-0.011 (0.010)
Insect-China$_{ijt}$			-0.529** (0.113)	
Drought-China$_{ijt}$			0.041* (0.023)	
Storm-China$_{ijt}$			-0.025*** (0.006)	-0.021*** (0.006)
Landslide-China$_{ijt}$			-0.024*** (0.009)	
Event_no_CHN	-0.000 (0.001)			
Event_no_CHN_1986-1998$_{i(j)t}$		0.002 (0.003)	0.002 (0.003)	0.002 (0.003)
Event_no_CHN_1999-2016$_{i(j)t}$		-0.002 (0.003)	-0.002 (0.003)	-0.002 (0.002)
lnEnergy_Intensity$_{i(j)t}$	-0.732*** (0.149)	-0.742*** (0.151)	-0.727*** (0.148)	-0.727*** (0.148)
Observations	134,163	134,163	134,163	134,163
Country-pair FE	Yes	Yes	Yes	Yes
Importer-year and Exporter-year FE	Yes	Yes	Yes	Yes
Intranational trade	Yes	Yes	Yes	Yes
Pseudo R2	0.99	0.99	0.99	0.99

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.
For the sake of brevity, the dummy estimations capturing PTAs, GATT/WTO, and globalization are not shown.

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FIGURES

STORMS 1986/2016

FIGURE 1

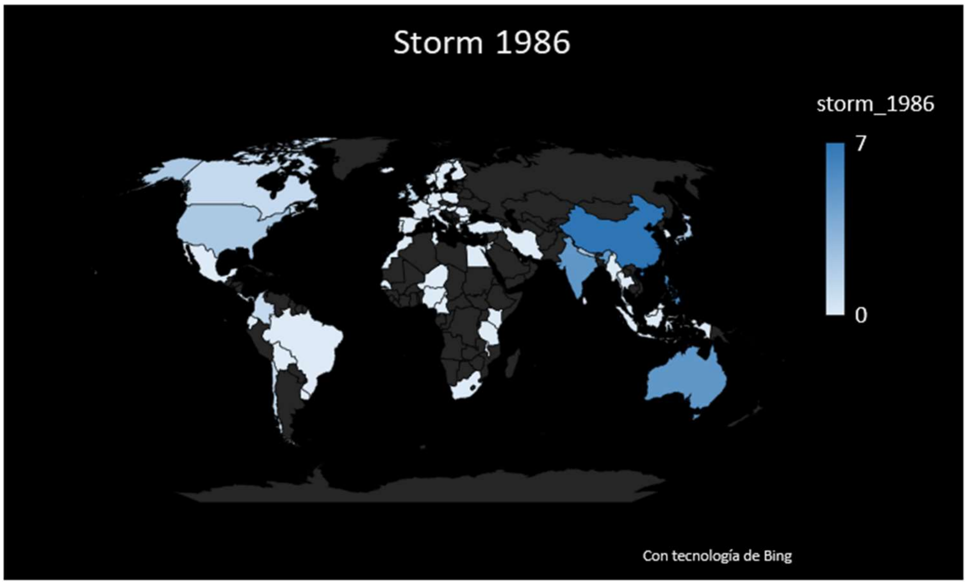
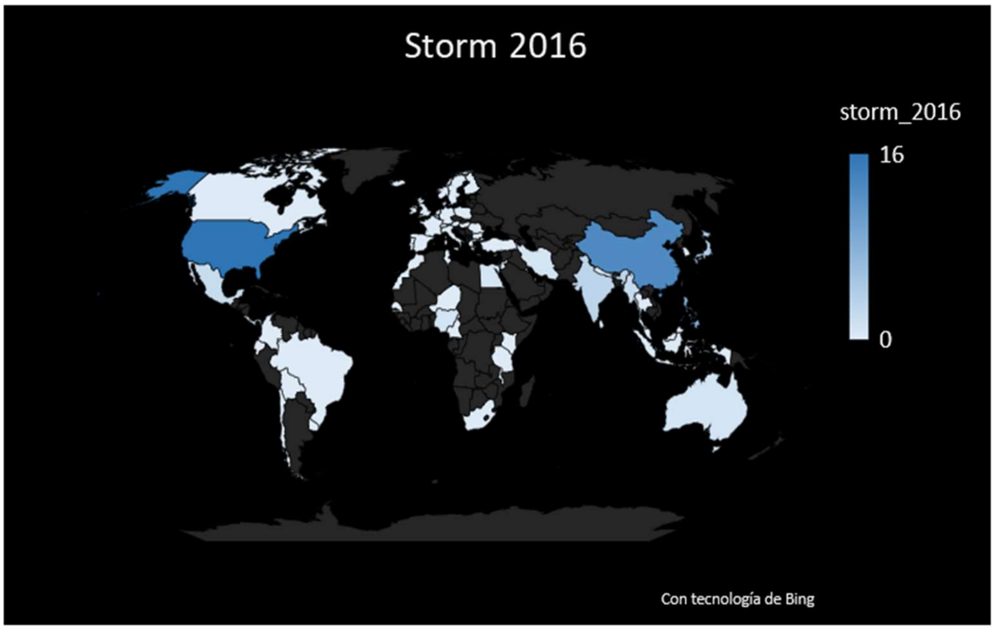


FIGURE 2



FLOODS 1986/2016

FIGURE 3

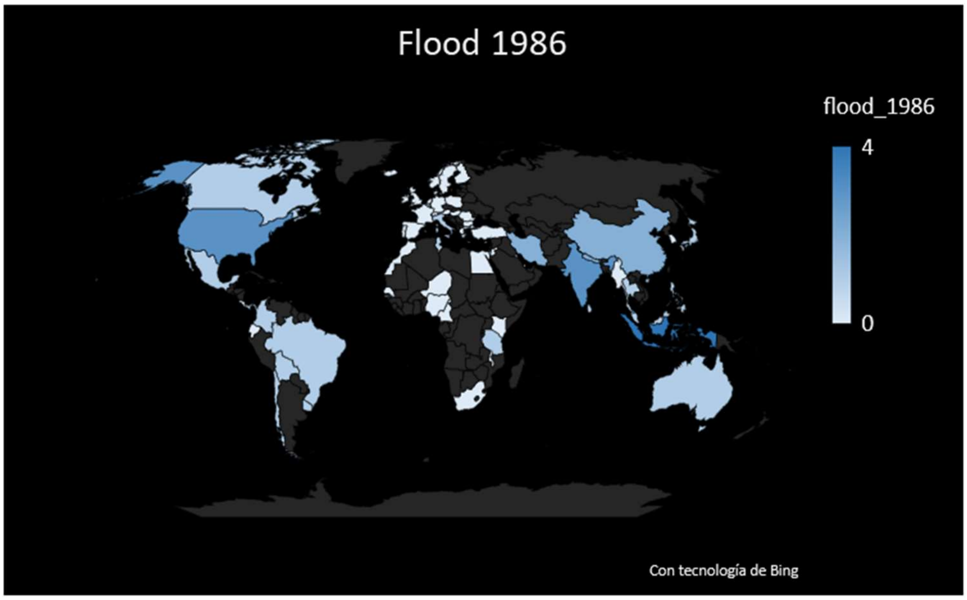
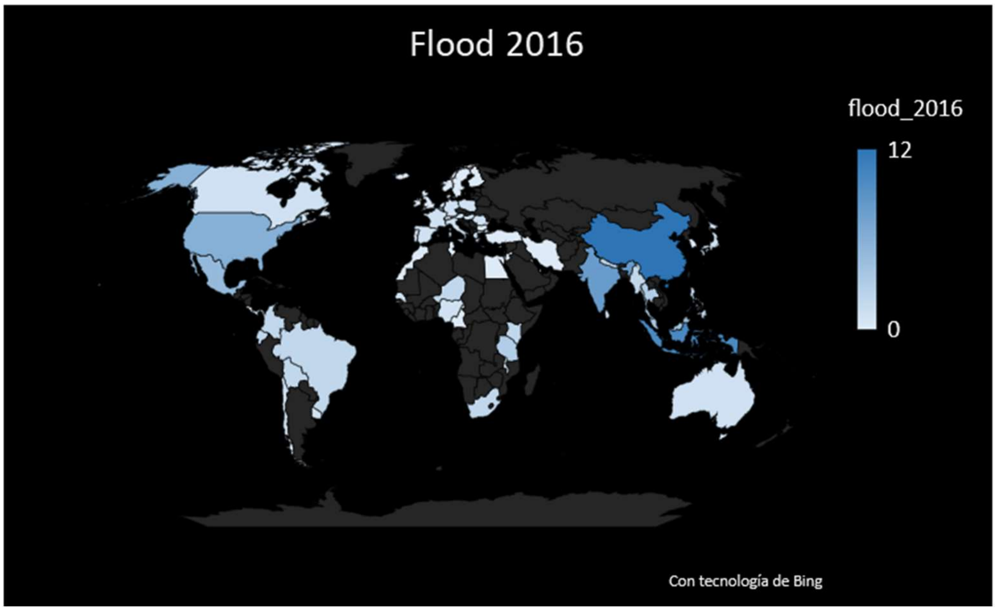


FIGURE 4



LANDSLIDES 1986/2016

FIGURE 5

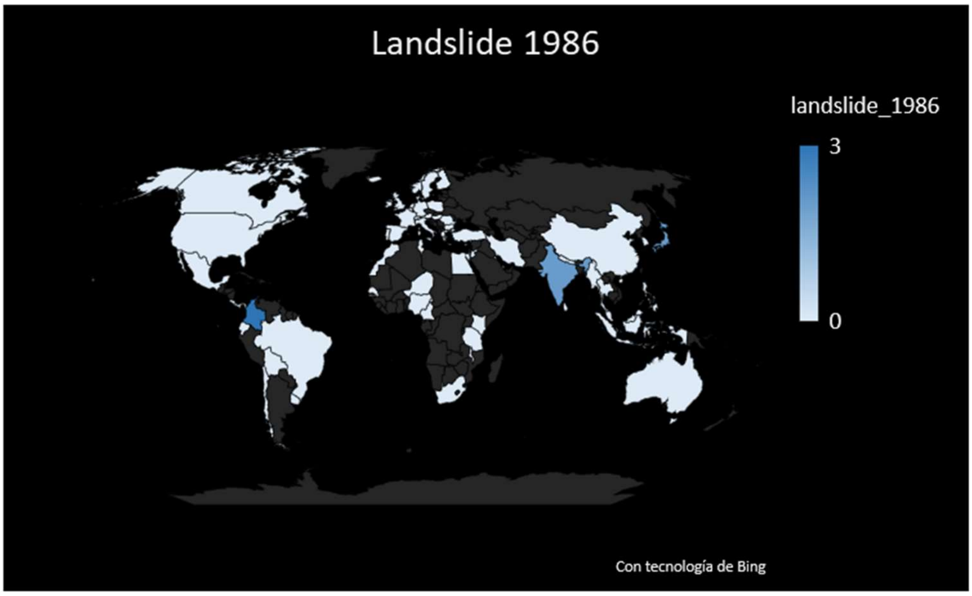


FIGURE 6