International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Impact of Climate Change on International Trade: An Empirical Estimation

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Abstract: ***The purpose of this article is to examine how climate change affects bilateral trade flows. To achieve this, we employ a theory-based gravity model to analyze bilateral trade data from 10 countries spanning the years 2000 to 2016. We utilize temperature variations and extreme weather occurrences, along with their repercussions, as indicators of climate change. Overall, our findings indicate that international trade flows are less influenced by temperature changes compared to domestic trade flows, whereas the reverse is true for extreme weather events. Notably, there is significant variation among countries and types of events. Specifically, our results indicate that biological events, such as epidemics and insect infestations, along with extreme temperatures, storms, and landslides, negatively impact international trade flows more than domestic ones. Furthermore, the roles of China and Japan are particularly significant in shaping the overall results, with storms affecting China and extreme temperatures impacting Japan. Lastly, our General Equilibrium analyses reveal that insect infestations and extreme temperatures have a more severe adverse effect on welfare compared to other events.***

Keywords: weather events, Temperatures, Domestic and International flows, and Climate change

1. Introduction

Currently, climate change stands as one of the most pressing global issues, gaining significance as time progresses. The socioeconomic ramifications of this phenomenon are extensive and varied, and they will undoubtedly affect the well-being of individuals significantly. This research concentrates on the effects of climate change on international trade, a subject of considerable institutional interest that has not been thoroughly explored in academic studies; conversely, numerous investigations have focused on how international trade impacts climate change. Reports from the World Bank (Brenton & Chemutai, 2021; Onder, 2012; World Bank, 2010), the World Trade Organization, and the United Nations Environmental Program (WTO and UNEP Report, 2009), as well as the OECD (including Dellink et al., 2017; Van Hassel, 2017; and Yamaguchi, 2021), express concerns regarding the interplay between trade and climate change in various publications. However, these analyses tend to be primarily descriptive, qualitative, or based on projections derived from simulations. Building on the work of Grossman and Krueger (1992) and Copeland and Taylor (2003), it is understood that international trade can affect climate change through three primary channels: the 'scale effect' (where an increase in a country's GDP due to trade expansion leads to higher pollutant emissions), the 'composition effect' (where trade liberalization in countries with lower environmental standards may result in a disproportionate focus on pollution-heavy industries), and the 'technique effect' (where trade enables developing nations to access cleaner technologies that reduce pollution and enhance resource efficiency). Antweiler et al. (2001) conclude that the first and third channels are significant, while the second is largely contingent on the specific attributes of the countries involved, such as their capital availability or environmental regulations.

Objective of the study

The objective of this article is to examine how climate change affects International trade patterns.

2. Methodology

We develop a theory-based gravity equation utilizing data from a sample of 10 countries spanning the years 2000 to 2016. Our estimation approach adheres to established best practices in gravity equation estimation (Yotov et al., 2016). This includes the application of panel data techniques to address unobserved bilateral heterogeneity and endogeneity, the incorporation of controls for multilateral resistance terms, and the employment of the Poisson Pseudo Maximum Likelihood (PPML) estimator to tackle econometric challenges associated with heteroscedastic residuals and the occurrence of zero values. The gravity model stands out as one of the most effective econometric instruments in the field of economics, particularly suited for analyzing international trade flows since the influential work of Tinbergen (1962). In its most basic form, the gravity model connects bilateral trade flows to the economic size, specifically the GDP, of both the exporting and importing countries, as well as the geographical distance separating them. Subsequent advancements have incorporated additional factors that influence trade barriers, such as the presence of a shared border, a common language, or whether the countries are islands. This enhanced version is referred to as the 'augmented' gravity model. This econometric approach enables a thorough investigation of the factors influencing bilateral trade flows. Over time, the gravity equation has evolved, incorporating theoretical insights from various scholars. In their seminal work, Anderson and van Wincoop (2003) argue that gravity estimations must consider not only the bilateral trade barriers but also the obstacles that both exporters and importers encounter with third-party partners. These obstacles are referred to as multilateral resistance terms in their framework. In practical applications, particularly in cross-sectional analyses, the inclusion of dummy variables for the countries serving as exporters and importers facilitates the control of these multilateral resistance terms. However, it is important to note that multilateral resistance can fluctuate over time. Consequently, in a panel data context, it becomes necessary to incorporate exporter-time and importer-time dummies into the gravity equation, a method recognized in the literature as country-year fixed effects (CYFE). Furthermore, to account for unobservable constant bilateral heterogeneity and endogeneity, researchers utilize country-pair fixed effects (CPFE; Baier & Berstrand, 2007; Baldwin & Taglioni, 2007; Gil-Pareja et al., 2008). In another significant study, Santos Silva and Tenreyro (2006) highlight that the residuals in the gravity equation often exhibit heteroscedasticity. This issue, combined with the presence of zero values in bilateral trade flows, indicates that traditional estimates based on log-linear specifications of the gravity model may be biased. To address these challenges, the authors recommend using a Poisson Pseudo-Maximum Likelihood (PPML) estimator. Lastly, several researchers (Baier et al., 2019; Bergstrand et al., 2015; Yotov, 2012; Yotov et al., 2016) emphasize the importance of incorporating both international and intranational trade flows to prevent biased estimations and accurately assess the trade creation and diversion effects of trade policies. In our analysis, including intranational trade flows is particularly crucial as it enables us to discern the country-specific impacts of climate change on trade.

We estimate the following gravity equation:

$$X_{ijt} = \exp^{\beta_1 PTA_{ijt}+\beta_2 (GATT/WTO)_{ijt}+\beta_3 temp_{i(j)t}+\Sigma^{2016} \beta_t Glob_{ijt}+\mu_{ij}+\eth_{it}+ jt}$$

$$X_{ijt} = \exp^{\beta_1 PTA_{ijt}+\beta_2 (GATT/WTO)_{ijt}+\beta_4 event_{i(j)t}+\Sigma^{2016} \beta_t Glob_{ijt}+\mu_{ij}+\eth_{it}+ jt}$$

In this context, Xijt represents the exports from country 'i' to country 'j' at time 't'. The variable PTA serves as a dummy indicator for Preferential Trade Agreements, while GATT–WTO functions as a dummy for the GATT/WTO framework. The variable Glob quantifies globalization and is constructed from a dummy for international trade, which is assigned a value of 1 for international transactions and 0 for domestic ones (denoted as int), in conjunction with year dummies (to prevent multicollinearity). The variable temp indicates the average annual temperatures of the countries, implicitly interacting with int, and the event variable counts the number of extreme weather occurrences and their impacts, also implicitly interacting with int. The terms μij represent CPFE, while δit and γjt denote CYFE for the exporter and importer, respectively. The data regarding PTAs and the GATT/WTO system has been sourced from the Dynamic Gravity Dataset (DGD) created by the United States International Trade Commission (USITC; refer to Gurevich & Herman, 2018). This dataset is designed for seamless integration with standard bilateral trade data sources. For our analysis, we utilize a panel dataset compiled by Thomas Zylkin. The strength of this dataset lies in its inclusion of both domestic (intranational) and international trade flows for manufacturing from 2000 to 2006 across 10 countries, which has since been extended to 2016.

Table 1: Trade and climate change. Period 2000–2016.

	(1)	(2)	(3)	(4)
	Nominal trade flows in current	Nominal trade flows in current	Nominal trade flows in current	Nominal trade flows in current
Dependent variable	US dollars	US dollars	US dollars	US dollars
PTA_{ijt}	0.320*** (0.065)	0.122** (0.056)	0.368*** (0.066)	0.122** (0.056)
$GATT/WTO_{ijt}$	1.540*** (0.092)	1.024*** (0.116)	1.620*** (0.086)	1.064*** (0.109)
$temp_{i(j)t}$	0.202*** (0.013)	0.037*** (0.010)		
$event_{i(j)t}$			0.005*** (0.002)	−0.005*** (0.002)

Year Data

$Glob_{ij2000}$	0.603*** (0.030)	0.668*** (0.033)
$Glob_{ij2001}$	0.581*** (0.029)	0.634*** (0.030)
$Glob_{ij2002}$	0.531*** (0.030)	0.601*** (0.034)
$Glob_{ij2003}$	0.577*** (0.031)	0.629*** (0.033)
$Glob_{ij2004}$	0.624*** (0.032)	0.670*** (0.034)
$Glob_{ij2005}$	0.642*** (0.033)	0.691*** (0.036)
$Glob_{ij2006}$	0.671*** (0.033)	0.739*** (0.036)
$Glob_{ij2007}$	0.794*** (0.039)	0.855*** (0.040)
$Glob_{ij2008}$	0.822*** (0.039)	0.869*** (0.040)
$Glob_{ij2009}$	0.736*** (0.042)	0.785*** (0.042)
$Glob_{ij2010}$	0.819*** (0.044)	0.853*** (0.043)
$Glob_{ij2011}$	0.824*** (0.045)	0.873*** (0.043)
$Glob_{ij2012}$	0.818*** (0.047)	0.869*** (0.045)
$Glob_{ij2013}$	0.847*** (0.048)	0.907*** (0.048)
$Glob_{ij2014}$	0.804*** (0.048)	0.876*** (0.046)
$Glob_{ij2015}$	0.786*** (0.054)	0.865*** (0.050)
$Glob_{ij2016}$	0.745*** (0.056)	0.821*** (0.052)

Table 1 (Continued)

	(1)	(2)	(3)	(4)
	Nominal trade flows in current	Nominal trade flows in current	Nominal trade flows in current	Nominal trade flows in current
Dependent variable	US dollars	US dollars	US dollars	US dollars
Constant	10.946*** (0.095)	11.776*** (0.108)	11.410*** (0.083)	11.835*** (0.103)
Observations	136,153	136,153	136,153	136,153
Country pair FE	Yes	Yes	Yes	Yes
Importer-year and Exporter year FE	Yes	Yes	Yes	Yes
Intra-national trade	Yes	Yes	Yes	Yes
Pseudo R^2	0.99	0.99	0.99	0.99

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

An event has been identified that demonstrates a distinct influence from this country compared to the average of other nations. Notably, when analyzing Storms, the exclusion of China results in the general average parameter losing its significance, while the specific impact of this event on China rises to approximately 3%. Such events, particularly cyclones, tornadoes, and convective hail, have a considerable adverse effect on China, likely jeopardizing critical infrastructure associated with international trade. A similar situation is observed in Japan concerning our Extreme Temperature variable, which shows a negative impact of about 18%. The omission of Japan from the analysis renders the general average nearly insignificant at the 10% level. We tentatively suggest that the differing behavior of labor productivity across various trade types may explain this phenomenon. Like China, the impact of Storms in Japan is significant, estimated at around 2.4%, and this also affects the general average, which is reduced by half. Additionally, Landslides have a relatively negative effect on Japan's international trade, while other events appear to have no significant impact on the country.

General Equilibrium

we run a General Equilibrium analysis that closely follows the implementation in Baier et al. The starting point (see, for instance, Costinot & Rodríguez-Clare, 2014) is a theoretical model for international trade flows based on an Armingon–CES model with a single sector being labor (L) the only factor of production of the (standard) type:

$$Xij= \sum(Aiw\text{-}\Theta ri\text{-}\Theta Ei)/(KA_K\, W_K\text{-}\Theta r_{ki}\text{-}e)$$

where *i* is origin, *j* destination, *X* are trade flows (domestic, when *i* coincides with *j*, and inter- national, if it is not the case), *A* is technology level, *w* is production cost (wages), *τ* are iceberg trade costs, *Θ* is the elasticity of substitution across (differentiated) goods, which is also assumed to be trade elasticity and *E* is total expenditure.

Table 2: General Equilibrium. Welfare effect (% change) of events.

Event	Average impact (%)	Highest impact (%)	Lowest impact (%)
$Wildfire_{ijt}$	0.23	0.67	0.02
$Flood_{ijt}$	0.00	0.00	0.00
Ext_Temp_{ijt}	−0.40	−1.15	−0.04
$Epidemic_{ijt}$	0.56	6.93	−0.08
$Insect_{ijt}$	−1.56	−4.36	−0.17
$Storm_{ijt}$	−0.07	−0.22	−0.01
$Drought_{ijt}$	0.01	0.03	0.00
$Landslide_{ijt}$	−0.14	−0.39	−0.01

some interesting conclusions stand out. *First*, Insect infestation and Extreme temperatures lead to the greatest reduction in average welfare, especially the first one. *Second*, Landslides and Storms also reduce welfare, but to a much lesser extent. In all these four cases, the reduction in welfare is generalized. *Third*, Floods and Droughts have null (or almost null) impacts on welfare. It is important to bear in mind that these events did not present significant estimated parameters *Fourth*, Wildfires, with a positive and significant estimated parameter (which implies that the costs of domestic trade increase with respect to international ones) have a positive (and generalized) effect on welfare. *Finally*, Epidemics, al- though with a positive average welfare effect, have a mixed welfare impact (although in most cases it is positive). In the latter case, two comments are in order. On the one hand, although the estimated average parameter (partial equilibrium) is almost identical to that of Extreme Temperatures, the consequences on welfare are very different. On the other hand, and connected with the previous point, the different evolution of nominal wages and prices across countries is what matters for welfare.

Table 3: Trade and climate change. Period 2000–2016.

Country	Coefficient of temperatures (temp)	Coefficient of events (event)
Australia	−0.030 (0.028)	−0.005 (0.004)
Austria	0.107*** (0.018)	0.005 (0.004)
Brazil	0.095*** (0.030)	0.003 (0.002)
China	0.025 (0.018)	−0.010***(0.003)
Denmark	−0.002 (0.014)	−0.014*** (0.003)
France	0.013 (0.018)	−0.008** (0.003)
India	0.287*** (0.077)	−0.003 (0.005)
Indonesia	−0.232*** (0.064)	−0.011 (0.006)
Italy	−0.048** (0.023)	−0.013*** (0.003)
Japan	−0.164*** (0.031)	−0.020*** (0.004)
Malaysia	−0.193** (0.086)	−0.003 (0.007)
Singapore	−0.323*** (0.110)	−0.021** (0.010)
United Kingdom	0.055*** (0.015)	0.002 (0.003)
United States	0.031 (0.023)	−0.002 (0.002)
Uruguay	0.015 (0.059)	−0.012*** (0.005)

*Note: Full estimates are available from the authors upon request. Standard errors are clustered by country pair. *Significant at 10% level, **Significant at 5% level, ***Significant at 1% level.*

where *i* is origin, *j* destination, *X* are trade flows (domestic, when *i* coincides with *j*, and inter- national, if it is not the case), *A* is technology level, *w* is production cost (wages), *τ* are iceberg trade costs, *Θ* is the elasticity of substitution across (differentiated) goods, which is also assumed to be

Paper ID: SR25424095413 DOI: https://dx.doi.org/10.21275/SR25424095413

trade elasticity and E is total expenditure. It is the case that $E_j \equiv \sum X_{ij}$. In the model, trade unbalances (D, assumed exogenous) are introduced additively to expenditure,

$$E_j \equiv w_j L_j + D_j.$$

3. Conclusion

This article examines the effects of climate change on international trade flows using a robust econometric approach. We have developed a theory-consistent gravity model based on annual data from 10 countries spanning the years 2000 to 2016. The primary variables of focus include temperature variations and extreme weather occurrences, such as wildfires, floods, severe temperatures, epidemics, insect infestations, storms, droughts, and landslides. Our findings indicate that rising temperatures increase the trade costs associated with domestic flows compared to international ones, whereas extreme weather events have the opposite effect. However, a country-specific analysis reveals significant variability among nations and across different extreme events. Notably, the estimated impact of these events is heavily influenced by China and Japan. In China, storms are the critical factor, while in Japan, extreme temperatures play a significant role. Overall, extreme weather events tend to adversely affect welfare, although there are notable exceptions.

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