The impact of weather shocks on trade diversification

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Abstract

The literature on the link between international trade and climate change addresses mainly the impact of trade on greenhouse gas emissions. However, weather shocks associated with climate change may also affect the pattern and volume of international trade flows. This paper aims to analyze how weather shocks affect the diversification of international trade, using income-level breakdowns. The hypothesis is that international trade is likely to be affected by weather shocks that may impact the comparative advantages of a country and lead to shifts in trade patterns. Preliminary results indicate that an increase in average temperature will increase the variety of products a country exports and the variety of destination countries a country exports to. This finding support the hypothesis of an adaptation capability to climate change of countries by diversifying their exports. When interacting weather and income level, we find that if the average temperature increases at the same level in each group of countries, the groups with lower income will diversify more than the countries with higher income. These findings suggest that we are on the right side of the U-shaped relationship between export concentration and income and that climate reinforce this pattern.

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Keywords: weather shocks, trade diversification.

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1 Introduction

The consequences of climate change on economic and social development of countries have received increasing recognition. The Intergovernmental Panel on Climate Change (IPCC) categorically states that aggregate economic losses accelerate with increasing temperature, but global economic impacts from climate change are currently difficult to estimate. Also, international dimensions such as trade are very important for understanding the risks of climate change at regional scales (IPCC, 2014). In this paper we aim to contribute to the literature on the impact of climate change on economic outcomes, by centering the analysis on the impact of climate shocks on international trade diversification. This focus also allows us to contribute to the literature on the determinants of international trade diversification, in which, to the best of our knowledge, this is the first paper to address the impact of climate on trade diversification.

The literature on the link between international trade and climate change mainly addresses trade impact on greenhouse gas emissions. However, weather shocks associated with climate change[1] may also affect the pattern and volume of international trade flows. Dell et al. (2014) point out that few studies have considered this specific linkage between weather shocks and international trade. In this setting, Jones and Olken (2010), examining the impact of temperature and precipitation on the growth of exports, have demonstrated that higher temperatures in poor countries have led to a negative impact on the growth of exports from manufacturing and agricultural sectors. In fact, higher temperatures could affect the productivity of workers in manufacturing or the land productivity in agriculture. In a different approach, using micro-level data on crop fields into a general equilibrium model, Costinot et al. (2015) study the impact of climate change on agricultural markets, taking into account the ability (or not) of countries to adapt through changes in crops or through changes in international trade. They find that in the agricultural losses caused by climate change, production adjustment play a more important role than international trade adjustment.

In this paper, we analyze the impact of weather on international export diversification. The main hypothesis is that international trade is likely to be affected by weather shocks which may impact the comparative advantages of a country and lead to shifts in trade patterns. Weather shocks could thus reduce exchanges in areas affected by the impact, which could decrease the share of a product on total exports and possibly replace it with other products, depending on the country's adaptation capability. However, the direction in which this impact will act is not quite clear and we could expect three different outcomes.

First, we could expect a neutral effect. Hence, the weather could affect the production in sector A, and the country could adapt its production by moving to sector B. For instance, if

[1] In this paper there is no distinction between the definitions of climate change, climate factors, weather and weather shocks. We are aware that climate refers to a long term fluctuation of temperature (for example 100 years), and weather is the current temperature or precipitation. Nevertheless, since the current weather conditions are a consequence of long term climate change, we consider that the weather is an indirect effect of climate change.

there is a production loss on green tea (HS6=090210), this production could be shifted to mate (HS6=090300), assuming that the country was not producing mate before and that the weather resistance for the two products are different. In this case, countries adapt to climate change by switching the affected production sector, and consequently the country's export basket. Here, the vulnerability to climate change will remain stable. This is a very extreme example, since only a reduction in the production in a sector A and an increase in same dimensions in another sector B will have the same effect. It is important to note that changes in production could also be in several products (and not only two).

Second, the effect of weather on trade diversification could be positive. Weather could affect a sector A, and the country could diversify its production across different sectors B, C, D, resulting in a greater diversification. For example, a production in green tea could be affected by weather and the production could shift to ginger, saffron and thyme (all of them with a different HS6 code). In this scenario, the adaptation to climate change is similar to the first case, but it will reduce not only the vulnerability to climate change, but also the vulnerability to normal risk associated with production concentration (such as international price volatility, the entry of new competitors or corruption).

Third, the effect of weather shocks on trade diversification could be negative. In this case, if a sector is affected by weather shocks, but the country cannot shift or compensate the production loss in another sector, the country will not be able to adapt and it will face vulnerability in two ways: from climate change and from the production concentration.

It is important to note that by giving examples at the 6-digit level of the Harmonized System, we point out that the analysis is very different according to its disaggregation level and we would not expect to see the same results in other levels of disaggregation. In this case, when analyzing production and trade diversification, it is important to analyze the shifts at the lowest level of disaggregation available. For example, if we analyze a switching in production from black tea to green tea in a 4-digit level or in a 2-digit level, where both are categorized within the same Harmonized System chapter, we would not be able to capture the shifting between these two products.

This paper also contributes to the empirical literature on the determinants of export diversification. Indeed, some studies have analyzed the determinants of export diversification but none specifically addresses the impact of climate shocks on the diversification of international trade. Imbs and Wacziarg (2003) analyze various measures of sectoral concentration and find that the relationship between income per capita and sectoral concentration in domestic production follows an U-shaped pattern across a wide variety of data sources. Hence, countries first diversify, in the sense that economic activity is spread more equally across sectors, but there exists a point at which they start specializing again, in a relatively late stage in the development process. Their result join together the different findings and predictions of the linkage between production diversification and growth. In one hand, there is a positive linkage where development leads to diversification, with high trading costs and preference for diversity. On the other hand, there is a negative linkage in the agglomeration economics literature, where positive externalities linked to firms agglomeration (such as firm location close to target markets) suggest a tendency of concentration in the development process.

The findings of Imbs and Wacziarg (2003) lead to the natural question whether the international trade follows the same pattern. Cadot et al. (2011) explores the evolution of export and import diversification along the economic development path. Using a large database with 156 countries over 19 years at the HS6 level of disaggregation. The authors find a U-shaped pattern of export concentration on income per capita, similar to what Imbs and Wacziarg (2003) found for production. In turn, Domingues and Starosta de Waldemar (2015) in a very original approach study the legacy of the Soviet Union on export diversification. In their analysis, they take into account the non-linear relationship between trade diversification and income per capita and also the possible endogeneity of some trade diversification determinants such as institutions. Cadot et al. (2013) does a very comprehensive literature review of the relationship between trade diversification, income and growth. Among the determinants more frequently used to analyze the trade diversification, the authors cite income per capita (mostly in a non-linear relationship), market size, human capital, institutional framework, infrastructure and geographic factors such as distance to markets, landlocked countries and share of rivers and seas. However, to the best of our knowledge there is no previous literature measuring the impact of weather on trade diversification. And as mentioned before, the weather may influence trade diversification in several ways and climate change may leverage this effect.

In order to analyze the impact of weather shocks on export diversification, we use the BACI international trade data covering bilateral trade at the HS6 product-level and the Climate Research Unity database (CRU) of the University East Anglia for climate data, in the 1995-2013 period. For that purpose, we use the Theil index as a measure of export concentration, based on Cadot et al. (2011) and Domingues and Starosta de Waldemar (2015). We also include the variables frequently used in the literature which are considered determinants of trade diversification, such as GDP per capita, population, institutions, infrastructure and human capital. We also control for geographic characteristics such as natural resources endowment and our interest variable, weather. In order to take into account the hypothesis that poor countries are more vulnerable to climate change and their export basket is more concentrated, we break down the estimations by income classification level.

Preliminary results indicate that an increase in average country temperature will increase the export diversification. This finding support the hypothesis of an adaptation capability to climate change of countries by diversifying their exports. When interacting weather and income level, we find that if the average temperature increases at the same level in each group of countries, the groups with lower income will diversify more than the group of countries with higher income. These findings suggest that we are on the right side of the U-shaped relationship between export concentration and income, with climate reinforcing this pattern.

The remainder of the paper is organized as follows. Section 2 introduce the data and provides summary statistics. Section 3 describes the estimation strategy. Section 4 presents the main findings and Section 5 concludes.

2 Data and summary statistics

2.1 Diversification/concentration measure

In order to investigate how weather shocks affect the diversification of international trade, we use a country's level of export diversification as our dependent variable. We follow Cadot et al. (2011) and construct the Theil diversification index as:

$$
\begin{aligned}
T_{i,t} &= \frac{1}{n}\sum_{p=1}^{n}\frac{X_{p,i,t}}{B_{i,t}}ln(\frac{X_{p,i,t}}{B_{i,t}}) \\
with\ B_{i,t} &= \frac{\sum_{p=1}^{n} X_{p,i,t}}{n}
\end{aligned}
\tag{1}
$$

where $X_{p,i,t}$ is the export value of each product p in each country i and year t, and n is the number of products exported for each country-year pair.

The Theil index measures the concentration of the economy, hence, the higher the level of the Theil index, the more concentrated is the economy. In this setting, when the Theil index takes a negative sign it means a positive effect on diversification. Based on this index, we construct two different measures of diversification: one in terms of product trade diversification and another in terms of country trade diversification, i.e. the variety of products a country exports and the variety of destination countries a country exports to.

To construct our dependent variables we use the BACI international trade data covering bilateral trade for all countries in the world at the 6-digit product-level for the 1995-2013 period. As mentioned before, when examining trade diversification, it is important to analyze the data at the most disaggregated level possible in order to capture trade shifts that could occur among substitute products within the same sector. It is important to point out that our database does not start before 1995 due to data availability.

2.2 Weather and other explanatory variables

Because our objective is to examine the impact of weather shocks on trade diversification, we require an explanatory variable to capture the climate variability. Hence, we use Climate Research

Unity database (CRU) of the University East Anglia which, among other climate variables, measures the daily mean temperature [expressed in degrees Celsius] averaged by year and by country, and the average precipitation [expressed in mm] for the 1995-2013 period.

Additional explanatory variables of the model are selected based on the determinants of trade diversification the most frequently used in the literature such as GDP per capita, population as a proxy for country size, secondary gross enrollment rate as a proxy for human capital, investment measured by the share of gross capital formation in total output, natural resources endowment measured by the total natural resources rents as a percentage of GDP, infrastructure measured by the number of telephone mainlines per 1000 inhabitants, and institutions. We also include squared GDP per capita in order to provide empirical evidence of the U-shaped relation between domestic production and diversification.

For the institutional dimension, we use the Worldwide Governance Indicators developed by Kaufmann et al. (2010) which present six broad dimensions capturing the perceptions of governance of a large number of survey respondents and expert assessments worldwide with regard to regulatory quality, government effectiveness, control of corruption, rule of law, voice and accountability and political stability.

Additionally, we control for geographic characteristics that could affect trade diversification by using country fixed-effects which aim to capture geographical variables that do not vary across time, for instance, landlocked countries, the share of rivers and seas, and the distance to major markets. For the complete list of variables with their detailed definitions and sources, please see Table A.1 in the Appendix.

2.3 Summary statistics

Table 1 below present the summary statistics for the complete sample. The database covers 164 countries for the 1995-2013 period.

In order to take into account the hypothesis that poor countries are more vulnerable to climate change with a more concentrated export basket, we break down the database by income classification level according to the World Bank classification. For a complete list of countries by income level, based on the World Bank classification, please see Table A.2 in the Appendix.

Table 1: SUMMARY STATISTICS: COMPLETE SAMPLE

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variables					
Product Trade Diversification	3099	2.17	2.34	-2.79	7.91
Country Trade Diversification	3099	-2.71	2.07	-6.57	3.26
Trade diversification determinants					
GDP per capita (USD)	2829	16669	19687	142	136539
Population	3099	3.84e+07	1.36e+08	15334	1.36e+09
Natural Resources (%)	3099	9.48	14.32	0	89.22
Infrastructure (# /1000 inhabitants)	3047	20.15	20.10	0	110.19
Investment (%)	2693	22.87	7.56	-2.42	67.91
Regulatory Quality	2366	.01	1.01	-2.67	2.25
Human Capital (% in official age)	2098	76.83	30.94	5.16	165.58
Weather variables					
Temperature (degrees Celsius)	3099	19.32	7.94	-13.87	29.69
Precipitation (mm)	3099	102.29	79.25	1.65	801.03

3 Empirical strategy

Using a OLS estimation, we adopt the following empirical estimation to examine the determinants of trade diversification:

$$\begin{aligned} T_{it} = \alpha_0 + \alpha_1 GDP\_pc_{it} + \alpha_2 GDP\_pc^2_{it} + \alpha_3 Pop_{it} + \alpha_4 NatRes_{it} + \alpha_5 Infra_{it} \\ + \alpha 6 Invest_{it} + \alpha_7 Instit_{it} + \alpha_8 HumCapit + \alpha_9 Wea_{it} + D_i + \varepsilon_{it} \end{aligned} \quad (2)$$

where T_{it} is the Theil diversification index in each country i and year t, GDP_pc_{it} and $GDP\_pc^2_{it}$ are GDP per capita and squared GDP per capita in each country i and year t, Pop_{it} is the population, $NatRes_{it}$ is the natural resources endowment, $Infra_{it}$ is the infrastructure, $Invest_{it}$ is the investment, $Instit_{it}$ is the institutional dimension, $HumCap_{it}$ is human capital, Wea_{it} is our variable of interest (weather), D_i is the country fixed-effects and ε_{it} is the error term (see Table A.3 in the Appendix for the matrix correlation).

As mentioned above, the Theil index measure the concentration of the economy and, therefore, the higher level of the Theil index, the more concentrated is the economy. Hence, when an explanatory variables takes a negative sign it means a positive effect on diversification.

In terms of expected signs for our explanatory variables and how they could influence trade diversification, it is expected that variables such as GDP per capita, population, infrastructure, investment, regulatory quality and human capital would take a negative sign, i.e. they would have a positive impact on trade diversification. The intuition behind these expected signs are quite straightforward since wealthy countries and/or large markets with high levels of investment, good infrastructure and regulatory quality, and well-endowed in skilled labor tend to have more diversified export baskets. With regard to natural resources endowment, the expected relationship is the opposite, with natural resources taking a positive sign and, therefore, negatively affecting trade diversification. Countries which are well-endowed in natural resources usually tend to be less diversified in terms of trade. Also, we expect to find evidence of the U-shaped relation between domestic production and diversification.

Regarding our variables of interest, temperature and precipitation, our intuition is that weather shocks could reduce trade in sectors affected by the impact, reducing the share of a product on total exports and possibly replacing it by substitute products, depending on the country's adaptation capability. However, as mentioned above, the direction in which this impact will act is not quite clear and we could expect three different outcomes, thus, in this case we leave our predictions open.

4 Results

4.1 Baseline results

In Table 2 we present the baseline OLS estimations, using the Theil index for product export diversification as the dependent variable and examining the determinants of trade diversification which are often employed by the literature.

In column (1), we exploit the two most frequently adopted determinants of trade diversification: GDP per capita and country size proxied by population. GDP per capita squared is also included in order to test the U-shaped relationship between trade diversification and income per capita. We can observe that the signs of the explanatory variables are consistent with our hypothesis, and the U-shaped function of GDP per capita and the negative impact of country size on trade concentration are confirmed, both with a 1 % of statistical significance level . In column (2) we add country fixed-effects, which does not change the direction and significance level of the coefficients, but increase the explanation power of the trade diversification variation from 35% to 97%.

From column (3) to column (7), we add each explanatory variable at time. Natural resources endowment has a positive effect on concentration, supporting indirectly the hypothesis of "natural-resource curse", which means that countries with higher natural resources such as oil, ores and metals tend to have a lower economic growth, and tend to be more concentrated. For the institutional variable, regulatory quality, we find also a negative and significant impact on trade concentration just as expected. We also run estimations on other institutional variables, such as the perception on government effectiveness, perception on quality of contracts enforcement (and other society rules), as well as corruption. These variables have the same significance level and sign as the regulatory quality variable presented here.

It is important to take into account that the number of observations is not constant, since there are differences in the data availability regarding the selected explanatory variables. This is the case, for instance, of human capital which is proxied by secondary gross enrollment rate, where only 1613 observations are available, compared to 2829 in the first three estimations. At last, investment and infrastructure are not statistically significant, but the signs are as expected.

Table 2: TRADE DIVERSIFICATION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GDP_pc_{it}	-13.500 ***	-4.160 ***	-4.520***	-3.220 ***	-2.110**	-3.210 ***	-3.130 ***
	(0.512)	(0.505)	(0.510)	(0.572)	(0.670)	(0.594)	(0.586)
$GDP\_pc_{it}^2$	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
$Population_{it}$	-0.0005***	-0.0002**	-0.0002**	-0.000*	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$NatutalResources_{it}$			0.007***	0.008***	0.005**	0.007***	0.007***
			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$RegulatoryQuality_{it}$				-0.170***	-0.155**	-0.144**	-0.139**
				(0.048)	(0.055)	(0.050)	(0.050)
$HumanCapital_{it}$					-0.006***		
					(0.001)		
$Investment_{it}$						-0.001	-0.001
						(0.002)	(0.002)
$Infrastructure_{it}$							-0.004
							(0.002)
Country FE	No	Yes	Yes	Yes	Yes	Yes	Yes
N	2829	2829	2829	2231	1613	2085	2071
R^2	0.357	0.972	0.972	0.976	0.982	0.975	0.975

GDP_pc_{it}, $GDP\_pc_{it}^2$ and $Population_{it}$ are divided by 100000.
Robust standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.001.

4.2 Weather and trade diversification

Table 3 reports the results including our climate variables: average temperature and precipitation. The four columns presented differ on the explanatory variables adopted, considering the trade-off between adding more determinants or having more observations. In all cases, the determinants of trade diversification are robust in magnitude and significance, except for population which is mainly affected by adding human capital. Concerning our variable of interest, average temperature has a negative and significant impact on trade concentration, which means a positive impact on trade diversification. This finding support the hypothesis on an adaptation capability to climate change of countries by diversifying their exports. Precipitation is not significant, suggesting that other measures such as precipitation excess or inundation events could be more appropriated in this case.

In order to test the hypothesis that poorer countries are more vulnerable to climate change and more impacted by weather shocks, we add in Table 4 dummies for income classification defined by the World Bank (see the list of countries in Table A.2 in Appendix).

The trade diversification determinants presented are selected favoring the number of ob-

Table 3: TRADE DIVERSIFICATION AND WEATHER

	(1)	(2)	(3)	(4)
GDP_pc_{it}	-3.880***	-3.640 ***	-2.870 ***	-1.960**
	(0.506)	(0.498)	(0.600)	(0.694)
$GDP\_pc^2_{it}$	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
$Population_{it}$	-0.0002**	-0.0002*	-0.0002	0.000
	(0.0001)	(0.000)	(0.0001)	(0.0001)
$NaturalResources_{it}$	0.007***	0.007***	0.007***	0.006**
	(0.002)	(0.002)	(0.002)	(0.002)
$Infrastructure_{it}$	-0.006**	-0.007***	-0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
$avg\_temperature_{it}$	-0.087***	-0.083***	-0.055**	-0.028
	(0.019)	(0.019)	(0.020)	(0.020)
$avg\_precipitation\_it$	-0.001	-0.001	0.000	0.000
	(0.000)	(0.000)	(0.001)	(0.001)
$Investment_{it}$		-0.002	-0.001	-0.001
		(0.002)	(0.002)	(0.002)
$RegulatoryQuality_{it}$			-0.137**	-0.152**
			(0.050)	(0.055)
$HumanCapital_{it}$				-0.006***
				(0.001)
Country FE	Yes	Yes	Yes	
N	2799	2614	2071	1548
R^2	0.972	0.972	0.975	0.981

The dependent variable is *product* trade diversification.
GDP_pc_{it}, $GDP\_pc^2_{it}$ and $Population_{it}$ are divided by 100000.
Robust standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.001

servations and similar results are found when adding all the explanatory variables at once. In column (1) to column (4), the dependent variable is the product trade diversification and column (5) to column (8) present the same estimations with country export diversification as the dependent variable. We show results for income classification 2 to 5, using income classification 1 as the reference variable [2].

Results show that comparing the income group 1 (OECD countries), the lower income groups are likely to have a higher export concentration, with a high statistical significance level. Between all the income groups, countries belonging to the income group 3 (upper middle income) have the highest impact on concentration. Note that this result is not surprising, since as we can see in Table A.2, group 3 is composed by countries such as former Soviet states, oil producers and islands, which are very likely to be more concentrated. The remainder variables hold their sign and significance level.

Interaction terms between income classification and average temperature are added in column (2). Precipitation interaction terms were highly correlated to temperature interactions resulting in a collinearity, so we only display here the results on temperature interactions. This es-

[2] The variable records the value of 1 if the country is part of the group of high-income OECD countries, 2 if it is a non-OECD high income country,3 if it is a upper middle income country, 4 if it is a lower middle income country and, 5 if it is a low income country

timation allows us to better measure the vulnerability of climate change concerning export concentration between different income groups. Here again, the reference group is income group 1. As showed in the estimation results, since the coefficient of the interaction terms are negative, significant and higher for lower income groups, we can conclude that the impact on export concentration is higher the higher the income level group. Hence, if the average temperature increases at the same level in each country group, the groups with lower income will diversify more than the countries with higher income. These results are not intuitive and gives raise to various alternative explanations.

First, maybe the selected income groups are not the best classification, and we could have defined as Jones and Olken (2010) for example, poor countries as the countries in the bottom half of the world per capita purchasing power parity income distribution in the first year of GDP data availability, but we could think of other alternative measures taking into account the income distribution. Second, these findings suggest that we are on the right side of the U-shaped relationship between export concentration and income and that climate reinforces this pattern. Third, some poorer countries may be more concentrated and with a higher sectoral share in agriculture. More concentrated countries have a higher potential to be diversified and agricultural sector may be more prone to diversification. In this setting, the same analysis done in a HS4 or HS2 aggregation level, could turn out into an opposite result. We would like to continue this analysis and answer to these hypothesis.

Column (3) and (4) present the same type of analysis, but here instead of having the World Bank income classification, we have a dummy "south" assuming the value 1 for all the non-OECD countries. The results are comparable to estimations in column (1) and (2), non-OECD countries (south=1) have a higher impact on export diversification than OECD countries (south=0). In column (5) to (8) the same analysis is done with export country partner diversification as the dependent variable. We can observe the same line of results as for product export diversification.

5 Conclusion

In this paper, we analyze the impact of weather on international trade diversification. Our main hypothesis is that international trade is likely to be affected by weather shocks which may lead to shifts in trade patterns. Therefore, weather shocks could reduce trade in areas affected by the impact, which could decrease the share of a product on total exports and possibly replace it by other products, depending on the country's adaptation capability.

Using the BACI international trade data covering bilateral trade at the HS6 product-level we construct the Theil index as a measure of export concentration. We consider all the usual determinants of trade diversification, taking into account the non-linear relationship of GDP per capita. Country fixed-effects allow us to control for heterogeneous unobserved factors. Our interest variables are average temperature and precipitation from the Climate Research Unity database (CRU) of the University East Anglia for climate data. Panel data in the 1995-2013 period and with 164 countries contribute to the statistical power of our results.

We find that average temperature has a positive and significant impact on export diversification. This finding support the hypothesis of an adaptation capability to climate change of countries by diversifying their exports. When interacting weather and country income level, we find that if the average temperature increases at the same level in each group of countries, the groups with lower income will diversify more than the countries with higher income. These results are not intuitive and give raise to various alternative explanations.

First, maybe the selected income groups are not the best classification, and we could have defined alternatives measures taking into account the income distribution. Second, these findings suggest that we are on the right side of the U-shaped relationship between export concentration and income, with climate reinforcing this pattern. Third, some poorer countries may be more concentrated and with a higher sectoral share in agriculture. More concentrated countries have a higher potential to be diversified and the agricultural sector may be more prone to diversification. In this setting, the same analysis done in a HS4 or HS2 aggregation level, could turn out into an opposite result. We would like to continue this analysis and answer to these hypothesis. The results are the same if we use export country partner diversification as the dependent variable. Precipitation is not significant in any set of estimations, suggesting that another measure such as precipitation excess or inundation events could be more appropriated.

In this article, we contribute to the climate change and trade literature and to the trade diversification literature, since there is few literature addressing the impact of weather shocks on trade diversification. Further robustness checks and the treatment of possible endogeneity in the trade diversification determinants should be carried out in order to enrich the causality hypothesis of our analysis.

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Table 4: TRADE DIVERSIFICATION AND WEATHER: INCOME HETEROGENEITY

	(1) $Tproduct_{it}$	(2) $Tproduct_{it}$	(3) $Tproduct_{it}$	(4) $Tproduct_{it}$	(5) $Tcountry_{it}$	(6) $Tcountry_{it}$	(7) $Tcountry_{it}$	(8) $Tcountry_{it}$
GDP_pc_{it}	-3.878***	-4.047***	-3.878***	-3.928***	-6.214***	-6.320***	-6.214***	-6.254***
	(0.506)	(0.508)	(0.506)	(0.504)	(0.494)	(0.499)	(0.494)	(0.491)
$GDP\_pc^2_{it}$	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Population_{it}$	-0.000**	-0.000**	-0.000**	-0.000**	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$NaturalResources_{it}$	0.007***	0.007***	0.007***	0.007***	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$Infrastructure_{it}$	-0.006**	-0.005**	-0.006**	-0.005**	-0.006***	-0.005***	-0.006***	-0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$avg\_temperature_{it}$	-0.087***	0.033	-0.087***	0.032	-0.078***	0.017*	-0.078***	0.015
	(0.019)	(0.023)	(0.019)	(0.023)	(0.017)	(0.010)	(0.017)	(0.010)
$precipitation_{it}$	-0.001	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	0.001
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
income=2	3.822***	10.539***			2.786***	9.706***		
	(0.303)	(1.331)			(0.374)	(1.254)		
income=3	6.651***	8.510***			5.553***	7.256***		
	(0.265)	(1.167)			(0.259)	(0.869)		
income=4	1.786***	9.388***			1.012**	7.257***		
	(0.412)	(1.326)			(0.337)	(1.182)		
income=5	4.434***	10.827***			3.605***	7.175***		
	(0.244)	(2.199)			(0.257)	(1.961)		
$avg\_tmpX(inc=2)_{it}$		-0.127**				-0.113**		
		(0.051)				(0.046)		
$avg\_tmpX(inc=3)_{it}$		-0.098**				-0.085**		
		(0.044)				(0.030)		
$avg\_tmpX(inc=4)_{it}$		-0.226***				-0.166***		
		(0.048)				(0.041)		
$avg\_tmpX(inc=5)_{it}$		-0.273***				-0.188**		
		(0.078)				(0.068)		
south=1			7.712***	10.710***			7.830***	8.410***
			(0.420)	(0.663)			(0.364)	(0.589)
$avg\_tmpX(south=1)_{it}$				-0.162***				-0.126***
				(0.033)				(0.023)
$avg\_preX(south=1)_{it}$				-0.000				-0.001
				(0.001)				(0.001)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2799	2799	2799	2799	2799	2799	2799	2799
R^2	0.972	0.973	0.972	0.972	0.966	0.966	0.966	0.966

GDP_pc_{it}, $GDP\_pc^2_{it}$ and $Population_{it}$ are divided by 100000.
Robust standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.001
income=1=high income OECD, income=2=high income non OECD, income=3=upper middle income, income=4=lower middle income and income=5=low income. South=1=income>1.

Table A.1: DEFINITION OF EXPLANATORY VARIABLES AND DATA SOURCES

Variable	**Definition**	**Source**
$Theil$	Constructed by the authors using the BACI international trade data	CEPII
$GDPpc$	GDP per capita, PPP (constant 2011 USD)	World Development Indicators
$Population$	Population as a proxy for country size	World Development Indicators
$NaturalResources$	Total natural resources rents (percentage of GDP)	World Development Indicators
$Infrastructure$	Nb of telephone mainlines per 1000 inhabitants	World Development Indicators
$Investment$	Share of gross capital formation in total output	World Development Indicators
$RegulatoryQuality$	Perception of the ability of the government to formulate and implement sound policies and regulations to promote private sector development.	Worldwide Governance Indicators
$HumanCapital$	Secondary gross enrollment ratio	World Development Indicators
$avg\_temperature$	Daily mean temperature averaged by year and by country, expressed in degrees Celsius	Climate Research Unity database (CRU) - University East Anglia
$avg\_precipitation$	Precipitation averaged by year and by country, expressed in mm	Climate Research Unity database (CRU) - University East Anglia

Table A.2: List of countries in the sample by income level(based on the World Bank classification)

income = 1 High income: OECD	income = 2 High income: other	income = 3 Upper middle income	income = 4 Lower middle income	income = 5 Low income
Australia	Chile	Albania	Armenia	Afghanistan
Austria	Czech Republic	Algeria	Bhutan	Bangladesh
Belgium	Estonia	American Samoa	Bolivia	Benin
Canada	Poland	Angola	Cabo Verde	Burkina Faso
Denmark	Slovak Rep.	Argentina	Cameroon	Burundi
Finland	Antigua	Azerbaijan	Congo, Rep.	Cambodia
France	Aruba	Belarus	Cote d'Ivoire	C. African Rep.
Germany	Bahamas	Belize	Djibouti	Chad
Greece	Bahrain	Bosnia and Herz.	Egypt	Comoros
Iceland	Barbados	Brazil	El Salvador	Congo, RD
Ireland	Bermuda	Bulgaria	Georgia	Eritrea
Israel	Brunei	China	Ghana	Ethiopia
Italy	Cayman Islands	Colombia	Guatemala	Gambia
Japan	Croatia	Costa Rica	Guyana	Guinea
South Korea	Cyprus	Cuba	Honduras	Guinea-Bissau
Netherlands	Eq. Guinea	Dominica	India	Haiti
New Zealand	Fr. Polynesia	Dominican Rep.	Indonesia	Kenya
Norway	Greenland	Ecuador	Kiribati	Korea, DR
Portugal	Guam	Fiji	Kyrgyzstan	Liberia
Slovenia	Hong Kong	Gabon	Lao	Madagascar
Spain	Kuwait	Grenada	Mauritania	Malawi
Sweden	Latvia	Hungary	Micronesia	Mali
Switzerland	Lithuania	Iran	Moldova	Mozambique
UK	Macao	Iraq	Mongolia	Myanmar
USA	Malta	Jamaica	Morocco	Nepal
	New Caledonia	Jordan	Nicaragua	NIger
	N. Mariana Is.	Kazakhstan	Nigeria	Rwanda
	Oman	Lebanon	Pakistan	Sierra Leone
	Qatar	Libya	P. New Guinea	Somalia
	Russia	Malaysia	Paraguay	Tajikistan
	San Marino	Maldives	Philippines	Tanzania
	Saudi Arabia	Marshall Is.	Samoa	Togo
	Singapore	Mauritius	Senegal	Uganda
	St. Kitts & Nevis	Mexico	Solomon Is.	Zimbabwe
	Tri. and Tobago	Palau	Sri Lanka	
	Turks & Caicos	Panama	Sudan	
	UAE	Peru	Syria	
	Uruguay	Romania	S. T. & Principe	
		Seychelles	Timor-Leste	
		South Africa	Ukraine	
		St. Lucia	Uzbekistan	
		St. Vinc. & Gren.	Vanuatu	
		Suriname	Vietnam	
		Thailand	Yemen	
		Tonga	Zambia	
		Tunisia		
		Turkey		
		Turkmenistan		
		Tuvalu		
		Venezuela		

Table A.3: CORRELATION MATRIX

	T_{it}	$T_{it}country$	GDP_pc_{it}	Pop_{it}	$NatRes_{it}$	$Infra_{it}$	$Invest_{it}$	$RegQual_{it}$	$HumCap_{it}$	avg_temp_{it}	avg_precip_{it}
T_{it}	1.0000										
$T_{it}country$	0.9390	1.0000									
GDP_pc_{it}	-0.3023	-0.3659	1.0000								
Pop_{it}	-0.2855	-0.2742	-0.0868	1.0000							
$NatRes_{it}$	0.5487	0.4370	0.0733	-0.0364	1.0000						
$Infra_{it}$	-0.5892	-0.6059	0.6405	-0.0557	-0.3544	1.0000					
$Invest_{it}$	-0.0269	-0.0196	-0.0106	0.2333	0.0369	-0.0127	1.0000				
$RegQual_{it}$	-0.6241	-0.6484	0.6480	-0.0800	-0.4197	0.7969	-0.0118	1.0000			
$HumanCapital_{it}$	-0.5328	-0.5994	0.6073	-0.0637	-0.2237	0.7459	0.0415	0.6804	1.0000		
avg_temp_{it}	0.4963	0.5129	-0.2644	0.0099	0.2375	-0.5709	-0.1270	-0.4767	-0.5896	1.0000	
avg_precip_{it}	0.0790	0.1113	-0.0741	-0.0047	-0.1233	-0.0769	-0.1148	-0.0250	-0.1093	0.3765	1.0000