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Climate Shocks and Exports

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This paper uses international trade data to examine the effects of climate shocks on economic activity. At the aggregate level, Melissa Dell, Benjamin F. Jones, and Benjamin A. Olken (2008) (hereafter, DJO) have demonstrated that higher temperatures in a given year reduce the growth rate of GDP per capita, but only in poor countries. The analysis of trade data in this paper builds on that finding, with three principal motivations. First, international trade links the fortunes of countries, providing potentially important conduits for geographically limited climatic impacts to have global economic effects. Second, international trade data is the best available source for identifying economic activity worldwide separately by narrowly defined sectors. Examining international trade data, one can thus say more precisely what sectors are affected by climatic changes. Finally, the trade data, collected by the importing country, provides a check on the potentially low-quality national accounts data provided by the home country.

Our analysis employs datasets on national climate, exports to the United States, and exports to the broader world. Using these data, we run panel regressions relating the annual growth rate of a country's exports in a particular product category to the country's weather in that year (i.e., its average temperature and precipitation). We control flexibly for product-year interactions (to capture, for example, price or demand changes in a particular product) and product-country interactions (to capture, for example, the fact that exports of certain products grow faster in some places than others).

Using this approach, we find two main results. First, higher temperatures in poor countries lead to large, negative impacts on the growth of their exports. Depending on the dataset and specification, we find that a poor country being one degree Celsius warmer in a given year reduces the growth of that country's exports by between 2.0 and 5.7 percentage points. We find no effect on rich countries. These results match the qualitative pattern of temperature effects on GDP found in DJO (2008). The magnitudes here are larger than the estimated magnitude of GDP effects in DJO (2008), suggesting a relatively greater sensitivity of national exports.

Second, we examine the industrial breakdown of the impacts of temperature. We find substantial loci of negative impacts on agricultural exports and light manufacturing exports, with little apparent effects on heavy industry or raw materials production. While the negative impact on agricultural exports is consistent with the primary thrust of the climate-economy literature, the negative impact on manufacturing may be more surprising. It is, however, consistent with a long-standing literature emphasizing that factory workers are less productive when it is hot (e.g., Ellsworth Huntington 1915), and the findings of DJO (2008), which also found a negative impact of higher temperatures on industrial output in the national accounts data.

A further advantage of using export data is that it alleviates concerns about data quality in poor countries. In particular, authors have recently questioned the validity of poor country GDP data (e.g., Angus Deaton 2005, Alwyn Young 2009). Since export data (particularly exports to the United States) is recorded by the *importing* country (e.g., the United States), and measured with a high degree of accuracy at the importing ports, export data are likely to be much more reliable than national accounts data, particularly for poor countries. The fact that we find similar impacts in the export data as in the national accounts data in DJO (2008) suggests that the effects we are picking up are, indeed, real effects rather than artifacts of the data.

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I. Data and Methodology

A. *Data*

The historical weather data are taken from the *Terrestrial Air Temperature and Precipitation:* 1900-2006 *Gridded Monthly Time Series*, *Version* 1.01 (Kenji Matsuura and Cort Willmott 2007). This dataset provides worldwide (terrestrial) monthly mean temperature and precipitation data at 0.5 x 0.5 degree resolution (approximately 56km x 56km at the equator). We use geospatial software to aggregate the weather data to the country-year level, weighting by the population distribution within the country. More details about the construction of the weather data can be found in DJO (2008).

The trade data come from two sources. For the US trade data, we use the National Bureau of Economic Research (NBER) US Import Data (Robert C. Feenstra, John Romalis, and Peter K. Schott 2002). For the world trade data, we use the NBER-United Nations Trade Data (Feenstra et al. 2005). We aggregate these data to either the one– or two– Standard International Trade Classification (SITC) digit level. We restrict our attention to those one- or two-digit product-country time series where we observe positive exports in all years of the data from a particular country, though the results are very similar if we do not make this balanced panel restriction (results available on request).

It is important to note that the variance in export growth is extremely large. Moreover, the variance in export growth depends sharply on the country and product, with smaller export volumes tending to be much noisier. For example, the standard deviation of growth of exports to the world for a country-product time series ranges from a minimum of 5.85 percentage points (product 11, "beverages," from Canada) to a maximum of 235 percentage points (product 09, "miscellaneous edible products," from Guatemala). A Breusch-Pagan test rejects homoskedastic export growth for both the US and world trade data at both one- or two-digit levels ($p < 0.0001$ in all cases). The empirical analysis below therefore uses Feasible Generalized Least Squares (FGLS) to adjust for the dramatic heteroskedasticity across the product-country time series in the data.

B. *Empirical Methodology*

The estimating equation follows Dell, Jones, and Olken (2008). To estimate the relationship between weather shocks and growth in international trade, we estimate the following equation, regressing the change in the growth rate of exports of product p from country c on temperature and precipitation in the exporting country:

$$\begin{aligned}(1)\quad \log(EXP_{pct}) - \log(EXP_{pct-1}) &= \alpha_{pc} + \gamma_{pt} \\ &+ \beta_1 TEMP_{ct} + \beta_2 TEMP_{ct} \times POOR_c \\ &+ \beta_3 PRECIP_{ct} + \beta_4 PRECIP_{ct} \\ &\times POOR_c + \epsilon_{pct}\end{aligned}$$

In this specification, the product-country fixed effects, α_{pc}, capture fixed differences in the growth rate of exports of product from country. The product-year fixed effects, γ_{pt}, capture time specific worldwide shocks in trade of product p (for example, they capture changes in prices; they also capture common world time effects such as worldwide recessions). The dummy variable $POOR_c$ captures whether the country is in the bottom or top half of the world per-capita purchasing power parity income distribution in the first year GDP data is available, as in DJO (2008). The coefficient provides the impact of a one degree Celsius temperature increase in year on average exports from wealthy countries, while $\beta_1 + \beta_2$ is the impact of a one degree Celsius temperature increase in year on average exports from poor countries.

Given the substantial heteroskedasticity in export growth rates between products and countries (see discussion above), we estimate equation (1) by FGLS, weighting each product-country time series by the inverse variance of its residuals (see William H. Greene, 2003). Given the large range of variances among series, correcting for heteroskedasticity is important, and analysis without any such corrections produces noisier and less conclusive estimates.[1] Standard

[1] Specifically, if we re-estimate Table 1 without weights, the results at the two-digit level are qualitatively similar to the weighted results but are statistically significant only for the world data. The unweighted results at the one-digit level

TABLE 1: CLIMATIC EFFECTS ON EXPORTS

	Exports to United States		Exports to "world"	
	1 digit	2 digit	1 digit	2 digit
Variables	(1)	(2)	(3)	(4)
Temperature (degrees Celsius)	0.364	0.114	-0.356	−0.192
	(0.421)	(0.465)	(0.289)	(0.326)
Temperature × Poor	−4.173***	−5.812***	−1.637*	−2.216**
	(1.272)	(1.409)	(0.846)	(0.942)
Precipitation (100 mm/year)	0.0830	0.0141	−0.0526	−0.0878
	(0.105)	(0.110)	(0.103)	(0.0882)
Precipitation × Poor	0.0166	0.253	0.105	0.415***
	(0.138)	(0.195)	(0.149)	(0.152)
Observations	19,164	63,990	31,654	123,956
Years	1973–2001	1973–2001	1963–2000	1963–2000
Product categories	10	66	10	70
R^2	0.165	0.188	0.308	0.297
Poor effect	−3.810***	−5.698***	−1.993**	−2.409***
	(1.235)	(1.255)	(0.833)	(0.916)

Notes: Each specification includes country *x* product fixed effects and product *x* year fixed effects. Regressions are Feasible Generalized Least Squares. Standard errors are clustered by exporting country.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

errors are clustered by country to allow for arbitrary serial correlation within countries and to allow for arbitrary correlation across different exports from the same country. To learn more about which products are more and less sensitive to temperature, we also estimate equation (1) product by product.

II. Results

A. *Overall results*

The results from estimating equation (1) are shown in Table 1. Column 1 shows results using one-digit SITC data on exports to the United States (i.e., an observation is the export growth from country *c* to the United States between time *t* and $t-1$ for a single one-digit SITC category). Column 2 presents the same results but using data at the more disaggregated two-digit SITC level. Columns 3 and 4 repeat the same specifications but consider exports from country to all countries in the world trade data (i.e., to the substantial but ultimately limited set of countries that report in the Feenstra et al. 2005 data), rather than just exports to the United States.

The results show large, negative effects of higher temperatures on exports from poor countries, and no effects on exports from rich countries. Focusing on the bottom row of the table, which reports the total impact of temperature on poor country exports ($\beta_1 + \beta_2$), we see that a one degree Celsius temperature increase reduces the export growth rate from poor countries to the United States by between 3.8 percentage points (1 digit SITC data) and 5.7 percentage points (2 digit SITC data). These effects are statistically significant at the one percent level. Looking at all exports to the world, we also find very large effects—one degree Celsius reduces the export growth rate by between 2.0 percentage points (1 digit, statistically significant at 5 percent) and 2.4 percentage points (2 digit, statistically significant at 1 percent). The first row of the table shows that we find no impact of temperature shocks on exports from rich countries. We also find little impact of average precipitation on exports—the only exception is column 4, which suggests that greater average precipitation in poor countries leads to more exports in the world data, though this impact is smaller than the impact of temperature and is not robust to specification.

are inconclusive (negative and insignificant in the world data and positive and insignificant in the US data).

TABLE 2: CLIMATIC EFFECTS ON EXPORTS TO THE UNITED STATES BY 2-DIGIT PRODUCT CATEGORY

SITC code	Product category description	Coefficient	SE	T–stat	P–value
Panel A: Negative and Statistically Significant Products					
88	Photo equipment, watches, and clocks	−17.93	2.00	−8.98	< 0.001
02	Dairy products and eggs	−12.35	2.13	−5.81	< 0.001
61	Leather	−12.81	2.83	−4.53	< 0.001
85	Footwear	−19.31	4.28	−4.52	< 0.001
04	Cereals and preparations	−12.24	2.99	−4.09	< 0.001
63	Wood manufactures (excl. furniture)	−14.19	3.91	−3.63	< 0.001
89	Misc manufactured goods[a]	−10.33	2.88	−3.58	< 0.001
77	Electric machinery and appliances[a]	−10.19	3.03	−3.37	0.001
62	Rubber manufactures[a]	−10.79	3.21	−3.36	0.001
81	Plumbing, heating, and light fixtures	−17.84	6.30	−2.83	0.005
74	General industrial machinery[a]	−14.79	5.24	−2.82	0.005
65	Textile yarn and fabrics	−9.44	3.39	−2.79	0.005
08	Feeding stuff for animals	−14.26	5.56	−2.56	0.010
75	Office machines	−13.59	5.48	−2.48	0.013
71	Power generating equipment	−17.32	7.28	−2.38	0.017
69	Metal manufactures[a]	−6.65	2.85	−2.34	0.020
95	War firearms	−19.71	9.24	−2.13	0.033
83	Travel goods	−11.19	5.44	−2.06	0.040
11	Beverages	−8.97	4.43	−2.02	0.043
34	Gas	−22.20	11.22	−1.98	0.048
Panel B: Positive and Statistically Significant Products					
53	Dyes	20.57	10.25	2.01	0.045
21	Hides	37.66	11.24	3.35	0.001

Notes: Regressions are Feasible Generalized Least Squares, run product by product. Each specification includes country and year fixed effects. Standard errors are clustered by exporting country.

[a] Not elsewhere specified.

The patterns we see here—very large impacts of temperature on poor countries and no impact on rich countries—mirror precisely the effects seen in Dell, Jones, and Olken (2008). This is particularly remarkable given that the data in this paper—exports—is measured predominantly by the *importing country* (i.e., reported by the United States in the case of the exports to the United States data, and primarily by Organization for Economic Co-operation and Development countries for exports to the world), whereas the GDP data examined in DJO (2008) came from the poor country itself. Given recent criticisms of national accounts data (e.g., Deaton 2005), the fact that these impacts are showing up in export data measured by the importing country suggests that these are very much real impacts and are not just an artifact of the way GDP data are put together.

It is interesting to note that the magnitudes estimated here are two to three times larger than the estimated impacts of temperature on the growth rate of GDP in DJO (2008), which were on the order of one to two percentage points per degree Celsius. This extra sensitivity is consistent with trade models in which domestic consumption is relatively steady, so that volatility in domestic production translates into greater volatility in net exports.[2]

B. *Heterogeneity by Product*

Table 2 reports the results of estimating equation (1) separately for each two-digit SITC category of exports to the United States. Each coefficient is the total effect on poor countries (i.e $\beta_1 + \beta_2$ from equation (1)), and the listed p-values are from the test of no effect in poor countries, i.e., the test that $\beta_1 + \beta_2 = 0$.

[2] For example, consider a model with homothetic preferences (such as Heckscher-Ohlin-Vanek) where a country's domestic consumption of each good scales linearly with its income. Then shocks to the domestic production of a subset of goods will cause domestic consumption of each good to change only to the extent that aggregate national income changes. The net exports of any particular good will thus see greater volatility than domestic output.

To conserve space, we report coefficients only for products where the effect of temperature is statistically significant at the 5 percent level. Panel A shows SITC codes where the estimated temperate effect is negative and statistically significant; panel B shows those SITC codes where the effect is positive and statistically significant.

The first finding that emerges from Table 2 is that there are many more SITC products that are negative and statistically significant than positive and statistically significant. Were there no true relationship, then by random chance one would expect 2.5 percent of the categories (1.65 out of 66) to be negative and statistically significant at the 5 percent level and a similar amount to be positive and statistically significant. In fact, we find negative and statistically significant impacts of temperature on exports for 20 out of the 66 categories, consistent with the very large negative effects shown in Table 1. By contrast, we find positive and statistically significant effects for only two of the 66 categories, or exactly what one would expect from random chance.

Examining the negative and statistically significant categories, we find that the negative impacts of temperature seem to fall into two broad categories: agricultural products (e.g., cereals, dairy products and eggs, leather, feed stuff for animals) and light manufacturing (e.g., photo equipment, footwear, misc manufactured goods, electrical machinery, rubber manufactures, office machines, firearms, travel goods, plumbing, wood manufactures, metal manufactures). Heavy industry (e.g., chemicals, paper, cement, iron and steel, cars and trucks) and raw materials (mining, petroleum, wood and pulp) seem generally unaffected. The explanation for agriculture seems clear (plants and animals may not thrive as well when it is too hot) and is consistent with negative effects on agriculture in poor countries reported elsewhere (e.g., DJO 2008, Raymond Guiteras 2009). The negative impacts on manufacturing are perhaps more surprising and suggest that factory workers may be less productive when conditions inside the factory become too hot. This is consistent with the large literature on worker productivity and temperature dating back to Huntington (1915). It is worth noting, however, that DJO (2008) also find negative impacts of temperature on industrial GDP growth in poor countries when examining national accounts data, so the findings in this paper confirm the findings there.

III. Conclusions

This paper has examined the impacts of temperature shocks on exports. We find substantial impacts of higher temperatures on poor countries exports, with no effects on richer countries' exports. Specifically, we find that an additional one degree Celsius reduces the growth rate of a poor country's exports by between 2.0 and 5.7 percentage points. We find that the impacts are concentrated in exports of agricultural products and light manufactures.

The findings of this paper have several implications. First, the findings here are remarkably similar (though greater in magnitude) to the findings that higher temperatures negatively impact growth of GDP in poor countries, but not in rich countries, reported in Dell, Jones, and Olken (2008). The fact that similar results are found in independent data lends credibility to these estimates. Second, the impact on exports suggests that—even though we estimate no direct impacts of higher temperatures on rich countries—rich countries may nonetheless be affected since their imports will decline. Climate change may therefore decrease welfare in rich countries not by affecting production directly, but by raising prices and reducing quantities of goods imported from poorer countries. Analyzing the welfare consequences for rich countries is one trajectory for further work.

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