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# Temperatures, Firm Size and Exports in Developing Countries\*

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## Abstract

We study how temperature shocks affect exports in developing countries both at the firm- and aggregate-level. While the average effect of temperature rise on exports is negative, small firms are disproportionately harmed compared with others. This feature is robust across sub-samples, specifications and confounding factors. This heterogeneity across firms has aggregate implications. In particular, the overall trade-deterring effect of temperatures would be significantly larger in absence of the largest exporters. Firm size distribution matters for exports under future climate change scenarios, with large firms reducing the costs of predicted temperature rise. We conclude that the existing firm distribution in developing countries may increase the cost of climate change.

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**JEL Codes:** F14 ; F18 ; O13 ; Q56

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**Data availability statement:** Some data used in this article is under confidentiality. In particular, the data employed in this paper are transaction-level customs data. The data was collected by the Trade and Integration Unit of the World Bank Research Department, as part of their efforts to build the Exporter Dynamics Database described in Fernandes, Freund and Pierola (2016). The sources for the data for each country are detailed at <https://www.worldbank.org/en/research/brief/exporter-dynamics-database>

# 1 Introduction

Trade activities in low- and middle-income countries is particularly sensitive to the adverse effects of climate change. First, those countries are more subject to extreme climate events, and climate models predict that this unequal vulnerability will worsen in the coming decades, especially for those located in the tropics (Bathiany et al., 2018; Hoegh-Guldberg et al., 2018). Second, those countries have fewer exporters, a smaller average exporter size, and a lower importance of exports at the top of the firm-size distribution in comparison with high-income countries (Fernandes et al., 2016). As international trade can be a crucial driver of economic development (e.g., World Bank, 2020), it is crucial to understand how climate shocks alter trade in developing countries, and to do so by explicitly accounting for firms' structure.

In this paper, we assess the impact of temperature shocks on several export outcomes using a firm-level perspective. Our first goal is to study how heterogeneous exporters cope differently when facing the same temperature variation. To guide our analysis, we hypothesize that firm size reduces the potentially negative effect of temperature on exports through four main channels. First, the attenuation of climate shocks in the agricultural sector is determined by the ability to irrigate land as well as many other techniques, requiring innovation and investment. As these techniques are not available to all firms (Jones et al., 2019), only the largest firms are expected to have sufficient funds to innovate and acquire these technologies. Second, numerous evidence point that labor productivity is negatively affected by temperatures (Heal and Park, 2016; Somanathan et al., 2021). Since capital to labor ratios tend to be increasing in exporter size (Bernard et al., 2007; Forslid and Okubo, 2011), the largest firms are again expected to be less affected by temperatures. Third, temperature shocks have contrasting effects across skilled and unskilled workers, notably since ventilation and air-conditioning systems allow adaptation (Seppanen et al., 2006). Since these technologies are more likely to be available to skilled workers and as the largest exporters tend to have a lower share of unskilled workers (Bernard et al., 2007), these firms are expected to be less exposed to temperature variations. Fourth, the largest exporters tend to have a high share of imported inputs relative to domestic ones (Amiti et al., 2014), which straightforwardly leads firms' output to be less sensitive to local temperature shocks (e.g., in agriculture see Garcia-Verdu et al., 2019). In all, firm size is thus expected to attenuate the detrimental effect of temperature on economic activity, here firm-exports. The first goal of our paper is to document this heterogeneous firm-level elasticity of exports to temperature.

Our second goal is to highlight the aggregate consequences of the firm-level responses. Assuming temperatures have a negative effect on exports that vanishes for the largest firms, if those firms represent a large share of a country's exports, then the aggregate elasticity of exports to temperatures should be null. On the contrary, if large exporters account for a low share of aggregate exports then this aggregate

elasticity is expected to be significantly negative. The aggregate elasticity of exports to temperatures, which averages firm-level elasticities depending on their share in total exports, will thus vary depending on firm-level elasticities and on firm size distribution. We identify the role of firm size distribution in shaping the aggregate elasticity, and then assess its consequences for a country's exports.

To do this, we take advantage of a database covering exporter-level customs transactions in 10 low- and middle-income countries between 1993 and 2013. These data are a subset from the Export Dynamics Database introduced by [Fernandes et al. \(2016\)](#), available at this level of disaggregation only for those 10 countries and under confidentiality conditions. Sample includes data from Burkina Faso, Bulgaria, Guatemala, Jordan, Mexico, Malawi, Peru, Senegal, Uruguay and Yemen. Within each country, data cover all export transactions at firm-HS6 product - destination country -year dimension. We combine it with weather data providing measures of local temperatures, precipitations and humidity.

Using year-to-year fluctuations in temperatures, as well as firm, country, year, and sector fixed effects as our main identification strategy, temperature variations have a differential effect across exporting firms depending on their size. While the average response of exports is hardly negative, this result hides an important heterogeneity: previously large exporters are significantly and quantitatively less harmed than smaller ones when facing the same temperature shock. A one standard deviation increase in temperature reduces exports for the smallest exporters, by around 4%, but leaves the top firms' exports mainly unchanged. This feature is robust across countries and relies on the within-country distribution of exporters.

Importantly, these results are robust to the use of alternative measures of temperature, exports and firm size proxies. Results also resist to the inclusion of many potential omitted variables, such as additional weather covariates and other macroeconomic determinants of exports. Likewise, controlling for product- and destination-specific shocks of the export flows does not alter our results. Finally, using IV strategy and by instrumenting firms lagged exports with predicted exports from world demand, we establish plausible causality of the role of past exports on the firm-level effect of weather shocks.

To quantify the macroeconomic implications of these firm-level responses, we run a counterfactual exercise measuring the aggregate impact of temperature on export outcomes if all firms in a country had the same size. Keeping the firm-specific response to temperatures constant but excluding the disproportional role of large firms in the aggregate – as supported in [Gabaix \(2011\)](#); [Carvalho and Grassi \(2019\)](#); [Fernandes et al. \(2016\)](#) – would significantly increase the global deterring effect of temperatures. Increasing the role of large exporters in the economy could help reducing the costs of temperature shocks on exports, and sheds light on the economic mechanisms explaining why the tradable sector in some countries is more impacted by temperature shocks than in other countries.

Finally, we quantify the anticipated, marginal impact of *projected* temperatures on aggregate exports, using climate projections (World Bank Climate Change Knowledge Portal) derived from [Mitchell et al.](#)

(2004). Without large exporting firms, the aggregate export growth will be much lower under future climate scenarios. In our sample, the negative marginal effect of temperatures on exports would be at least three times larger without the large exporters.

By documenting evidence on the links between temperature and firm exports, this paper contributes to several strands of the literature. Close to our paper, [Jones and Olken \(2010\)](#) estimate how the annual growth rate of a country's exports in a particular product category is affected by the country's weather. Estimates suggest an overall 2.2% decrease in export growth in poor countries for each degree of temperature rise, and no effect for precipitation. However, the analysis is done at the aggregate level and does not highlight any heterogeneous firm effect, contrary to what we do here. [Karlsson \(2021\)](#) also studies how temperature affects exports but do not highlight any firm size heterogeneity and focuses on the United States. Other related works include [Dallmann \(2019\)](#) which estimates a negative effect of temperature variations on total trade and bilateral trade at the country level. While this level of analysis is very informative, the results may suffer from aggregation bias.<sup>1</sup> The existence of these bias calls for an investigation at a more disaggregated level, as we do in this paper. This is particularly important as the average insignificant effect of temperatures on exports hides a substantial heterogeneity across exports.

By identifying heterogeneous firm effects, our paper also connects to a trade literature documenting heterogeneous impacts of exogenous shocks on firms' trade outcomes and aggregate trade patterns.<sup>2</sup> This work also echoes a general trend in the trade literature, based on heterogeneous firms ([Bernard et al., 2007](#); [Melitz, 2003](#)), emphasizing the non-straightforward links between micro-evidence and aggregate outcomes ([Imbs and Mejean, 2015](#); [Costinot et al., 2020](#); [Gaubert and Itskhoki, 2021](#)).

Finally, our paper is also connected to a large growing literature documenting the effects of climate shocks on economic growth and on other outcomes ([Hsiang, 2010](#); [Dell et al., 2012](#); [Strobl and Valfort, 2013](#); [Dell et al., 2014](#); [Colmer, Forthcoming](#)), at different levels of aggregation ([Burke and Tanutama, 2019](#); [Damania et al., 2020](#); [Kalkuhl and Wenz, 2020](#); [Zhang et al., 2018](#)). None of those studies focus on exporting firms in developing countries as we do here.

Overall, our paper provides an explanation for some results present in the literature. For instance, [Jones and Olken \(2010\)](#) show that poor countries exhibit larger trade deterring effects of climate shocks than others. The lower concentration of exports at the top of the firm-size distribution in these countries could explain this result, provided that large firms are less sensitive to temperature shocks but account for a lower share of total exports in poor countries. This feature could explain the aggregate trade pattern and trade growth under temperature shocks. Our findings also inform debates on the impact of climate on economic development ([Nordhaus, 1993](#); [Greenstone and Jack, 2015](#); [Budolfson et al., 2018](#)), and

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<sup>1</sup>Recent evidence on those potential bias include [Imbs and Mejean \(2015\)](#) for trade or [Damania et al. \(2020\)](#) for economic growth and precipitations.

<sup>2</sup>[Berman et al. \(2012\)](#) document the heterogeneous adjustment of French exporters to exchange rate variations, while [Héricourt and Nedoncelle \(2018\)](#) focus on exchange rate volatility. [Bricongne et al. \(2012\)](#) provide evidence that the 2008-2009 trade collapse had a differential effects across firms. [Asprilla et al. \(2019\)](#) identify the heterogeneous shift in market power across exporters in 12 emerging countries after changes in trade policy.

provide a framework allowing adaptation strategies to be implemented. Firm size distribution and the potential concentration of market shares across exporters could be used as a complementary policy tool to mitigate the impact of climate shifts.

The rest of the paper is organized as follows. The next section presents the data and summary statistics. Section 3 provides the results at the firm level, while Section 4 draws the aggregate implications of the micro-level results. Section 5 discusses the results and concludes.

## 2 Data

In this section, we detail our dataset combining firm-level exports with information on climate conditions and other controls for each country of our sample.

**Firm-level exports.** We use the exporter-level version of the Exporters Dynamics Database (Fernandes et al., 2016). This dataset provides a collection of country-specific exporter-level customs transactions made available to external researchers, under confidentiality conditions. Our data covers the exports, from 1993 to 2013, of a set of 10 developing countries. Sample includes data from Burkina Faso, Bulgaria, Guatemala, Jordan, Mexico, Malawi, Peru, Senegal, Uruguay and Yemen. Within each country, the dataset covers all export transactions at firm-HS6 product - destination country -year dimension. Since the data come from customs agencies, it covers export transactions only, and provides no information on other firm characteristics, in particular firm location, age, ownership, employment, or sales in the domestic market.

Regarding the export structure within each country of the sample, Table 1 displays the average number of exporting firms per year, the average export value in USD by firm, the first and 9th decile of exports per country, and the average number of HS6 products and destinations served by firms. Our sample displays a large heterogeneity across countries in terms of firm size distribution: Mexico has around 100 times more exporters than Malawi or Burkina Faso, and all trade margins are heterogeneous across countries.

- Table 1 here -

Figure 1 digs further into the export structure. Richer countries have more exporters, and within each country, the top 5% of exporters are much larger than the average exports than in “poorer” countries. Firm size distributions are different across countries, in particular, regarding the importance of the top firms.

- Figure 1 here -

**Climate variables.** We gather temperature data from the Climatic Research Unit of the University of East Anglia (CRU version v4.02) (Harris et al., 2014). This dataset is widely used in the literature (Auffhammer et al., 2013) and provides a set of weighted country-year average temperature, precipitation and humidity index<sup>3</sup>. Figure 2 plots the average temperature in each country. We observe a steady within-country increase over time.

- Figure 2 here -

To assess the robustness of our analysis, we will also consider the average minimum and maximum daily temperatures from the same source. Furthermore, in our robustness checks, we follow the literature based on agronomy and convert daily mean temperatures into degree days (DD) (Hsiang, 2016) with thresholds of 32°C and 34°C. Appendix A.2 provides all the details of our approach.

The other weather covariates included in our analysis are precipitations (in millimeters/month) and humidity (number of rainy days per year) from the same source.

**Macroeconomic Controls.** Lastly, we collect a set of macroeconomic variables used as controls in our estimations. These include include population size, growth indicators as well as effective exchange rate and price index, all taken from the World Development Indicators (World Bank, 2016).

**Descriptive Statistics.** Table 2 provides some descriptive statistics of the main sample. Panel A shows the exports characteristics of the firms in our sample, pooling all countries together. On average, firms export the equivalent of 322269 US\$ per year, which represents slightly more than 800 US\$ per unit of exported good. Panel B shows the average characteristics of the origin countries, in terms of weather and other trade determinants. Average temperature in the exporting countries of our sample was 22°C over our period of study, with an average maximum of 29°C for Burkina Faso and Senegal. Panel C provides the characteristics of the destinations served by the exporters of our sample. Destinations were more than 4 times richer than the exporters, and foreign average temperature was almost 2°C lower.

- Table 2 here -

### 3 Firm-level impact of local temperatures

In this section, we first present our empirical strategy, then display the results as well as several robustness checks.

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<sup>3</sup>The CRU CY dataset consists of country averages at a monthly, seasonal and annual frequency, for ten variables. Spatial averages are calculated using area-weighted means. <https://crudata.uea.ac.uk/cru/data/hrg/>

### 3.1 Empirical strategy

To estimate the impact of temperature on exports at the firm-level, as well as its potentially differential effect across firms of different sizes, we choose the following general specification:

$$Exports_{ft} = \alpha Temp_{i(f)t} + \beta FirmSize_{ft-1} + \delta Covariates_{it} + \gamma(Temp_{i(f)t} \times FirmSize_{ft-1}) + \mu(Covariates_{it} \times FirmSize_{ft-1}) + FE + \varepsilon_{ft}, \quad (1)$$

where  $Exports_{ft}$  is the general measure of export outcome for a firm  $f$  in year  $t$ . The variable  $Temp_{i(f)t}$  denotes temperature in country  $i$ , where firm  $f$  operates, in year  $t$ . Our baseline temperature measure is the average yearly temperature (in Celsius).

$FirmSize_{ft-1}$  is a general measure for firm size and is measured at the previous year  $t - 1$  to avoid simultaneity with export outcome in year  $t$ . As the Customs data do not include information about firm output, firm employment or any firm outcome, we rely on the export outcomes to measure firm size. The baseline measure of firm size is the lagged export values (in US\$) at the firm-year level from the Customs data. Total exports can proxy for firm size as exports and firm outcomes are highly correlated (Bernard et al., 2007). We will however test the sensitivity of the results to the use of alternative proxies of firm size.

To measure the differential effect of temperature across firms, we include the interaction term  $Temp_{i(f)t} \times FirmSize_{ft-1}$ . It captures the heterogeneous effect of a same temperature variation on exports across firms of different sizes.<sup>4</sup> In the main estimations including country-year fixed effects (see next paragraphs), the interaction terms are identified from the cross-sectional differences in firm lagged exports.

The model described in equation (1) also includes country-year confounders,  $Covariates_{it}$ , that may explain export outcomes at the firm level. These variables act as alternative variables, potentially omitted, capturing economic and social context in exporting countries: shocks to these variables could have an average effect – captured by the  $\delta$  coefficient – and some heterogeneous effect – captured by  $\mu$ . Controlling for these other time-varying variables allows us to isolate the strict effect of temperature. In practical terms, we first consider weather controls such as the average level of precipitations and humidity (Dallmann, 2019). Second, we include economic controls such as exporting countries' GDP, real effective exchange rate, and effective average tariffs (faced by the exporter). Our approach is thus consistent with gravity equations at both the aggregate and the firm levels (Head and Mayer, 2014).

To absorb unobserved heterogeneity, a set of fixed effects  $FE$  is included in equation (1). First, we include a firm fixed effect. The identifying variation is thus the change in export outcomes for a given firm (in a given country, as no firm changes of exporting country) across years. This fixed effect absorbs firm-specific time-invariant characteristics affecting exports. For instance, it could control for a firm's

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<sup>4</sup>Following Freund and Pierola (2020), we expect the differences in firms' size to capture most of the cross-firms' heterogeneity.



specialization across products, its management strategy, the average (over time) skills of its labor force, whether it is a multinational firm, *etc.* As no firm changes of origin country, this firm FE controls for the origin country as well, and absorbs for instance initial differences between climates across countries.<sup>5</sup>

Our sample is slightly affected by this inclusion as we have to drop firms that appear only 1 year in the sample. Second, we include a (HS2) sector-country-year fixed effect, for unobserved heterogeneity across sector-countries in the sample. This fixed effect controls for all pre-existing differences in the specialization of countries across types of products and industries, as well as for differences in the level of development across countries. It also absorbs the differences across countries in average temperatures and other aggregate covariates. Further, this fixed effect holds constant the total exports of the HS2 sector from each country-year period. As a result, the identifying variation in our exercise is across firms all belonging to the same sector-country and thus face the same temperature shocks.

Finally,  $\varepsilon_{ft}$  is a random error term capturing all omitted factors, which we allow to be heteroskedastic and correlated across HS2 sectors and years. In all our regressions we report the standard errors clustered at the HS2 sector-country-year level<sup>6</sup>.

**Trade margins, dependent variables and estimators.** At the intensive margin, the export outcome is the level of exports at the firm level,  $X_{ft}$ . When estimating this equation, we use a linear estimator and a log specification for exports. We thus focus only on positive export flows at the firm level. Our preferred measure of exports is the exported values (in US\$). At the extensive margin, the export outcomes are the number of HS6 products and the number of destinations served by a firm, following [Arkolakis et al. \(2010\)](#).

## 3.2 Results

We start by providing results for the intensive margin and then for the extensive one. We then turn to several robustness checks, focusing on potential omitted variables and product- and destination- specific shocks.

**Baseline results: intensive margin.** Table 3 presents the benchmark estimation of equation (1) at the intensive margin. The dependent variable is the log of exports.

- Table 3 here -

Column 1 shows that an increase in temperature does not decrease exports on average, independently of firms' characteristics and export trend of the other firms. This specification provides the average,

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<sup>5</sup>Results then account for the fact a shock to average temperature in a very hot country like Burkina Faso may impact exports very differently than the same shock, but for a more moderate temperature country like Mexico.

<sup>6</sup>Our preferred cluster level would be at the country-year level, as it is exactly the level of the temperature shock. However, in our sample, the number of clusters in this dimension would be too small ( $N = 26$  in our baseline regressions), thus affecting the inference quality ([Cameron et al., 2008](#)).

firm-level exports response to temperature, controlling for aggregate, country-wide trade determinants GDP and lagged firm export outcome. Since we have included a firm fixed effect, identification comes from exports variations across years for a given firm. On average, in our sample, firm-level exports are hardly deterred by local temperature shocks. Past exports also determine increased exports, as well as GDP. Regarding additional weather covariates, higher precipitations are negatively correlated to exports while humidity exhibits a positive impact.

The insignificant average effect of temperatures hides a strong heterogeneity across firms. Columns 2 and 3 condition the impact of temperature on the total lagged exports at the firm level. We find a positive and significant coefficient associated to the interaction between temperature and lagged exports. The impact of temperatures for firms with a low level of past exports is highly negative (around -0.10) and significant. This means that the impact of temperature is highly negative for firm with low past exports, but is dampened for firms with large past exports. Column 4 introduces a country-sector-year fixed effect, absorbing the unconditional effect of temperature shocks, and controlling for all country-wide shocks. Armed with this fixed effect, we again estimate a positive coefficient to the interaction term, with a point estimate close to that of columns 2 and 3. Temperature shocks decreases exports, but this effect is decreasing with firm size. The point estimate is stable, around 0.010, which is then confirmed in column 5 allowing other weather shocks to have some differential effects across firms.

Regarding the sole effects of weather shock, figure 3 plots the country-by-country expected response of firms belonging to the bottom 5%, bottom 10%, top 10% and top 5%. A one standard deviation increase in temperature (around 0.3 in the data) reduces exports for the smallest firms, by around 4%, but leaves the top firms' exports mainly unchanged. This feature is robust across countries and relies on the within-country distribution of firms.

- Figure 3 here -

The results at the intensive margin provide an important description of the link between temperature and firm dynamics. Overall, the average response of exports to temperature is insignificant, but large firms are less impacted by these shocks than smaller ones.

**Baseline results: extensive margin.** Table 4 replicates the analysis for the extensive margin of trade, still at the firm-level. We estimate the impact of temperature shocks on the number of HS6 products exported to any destinations (columns 1, 2 and 3), and on the number of destinations served (columns 4 to 6). We follow [Arkolakis et al. \(2010\)](#) and consider that, on top of the intensive margin, exporters choose presence at export destination and product scope. In theory, these two measures capture the extensive margin of trade as expanding product scope and serving additional markets requires the payment of additional fixed costs. The inability to cover for these costs leads some firms to exit foreign market and/or reduce their product scope, which can be seen as firm selection.

- Table 4 here -

Results displayed in Table 4 suggest that temperature deters both measures of the extensive margin of trade (columns 1 and 4). We can also see that, as for the intensive margin, firm size dampens this negative effect. The interaction terms coefficients are significant in columns 2, 3, 5 and 6 when using demanding fixed effects.

Hence, on average, temperature shocks deter exports at both trade margins: intensive and extensive. This effect, in both cases, is dampened by firms' size. This is the core result of our paper. We further note that the dampening effect of firms' size appears to be quantitatively more important at the intensive margin (compared to the unconditional effect). As a result, most of the differential adjustment to a rise in temperature appears to be occurring at the intensive margin. For this reason, we mainly focus our robustness checks on this dimension.

### 3.3 Robustness analysis

In this section, we assess the robustness of our results to variables' measures, omitted variables as well as product and destination shocks.

#### 3.3.1 Sensitivity to key variables

We now check the sensitivity of our results to the measures of the following variables: exports value, firm size, temperatures. To do this, we estimate the following equation:

$$\begin{aligned} Exports_{ft} = & \beta FirmSize_{ft-1} + \gamma(Temp_{i(f)t} \times FirmSize_{ft-1}) \\ & + \mu(Covariates_{it} \times FirmSize_{ft-1}) + FE_f + FE_{ist} + \varepsilon_{ft}, \end{aligned} \quad (2)$$

where we alternatively replace the measures of  $Exports_{ft}$ ,  $FirmSize_{ft-1}$ ,  $Temp_{i(f)t}$  and of the weather covariates included in  $Covariates_{it}$ . The key part of our robustness exercise is to challenge the significance and magnitude of the coefficient  $\gamma$ . To save space we follow [Simonsohn et al. \(2020\)](#) and provide a "specification curve" of the coefficients of interest. We obtain a set of estimates (N=120) displayed in Figure 4. The top panel shows the estimated  $\gamma$  while the bottom panel shows the characteristics of the corresponding estimation.

- Figure 4 here -

First, we run a sectoral decomposition between agricultural and manufacturing products of our baseline result (focusing on total exports). The dampening effect of firm size on the impact of temperature holds for both types of products, and also regarding export volumes. Second, results are not sensitive to our measure of temperature. Indeed, using average minimum and maximum daily temperatures, as

well as degree-days, does not affect the sign and significance of our main coefficients of interest.<sup>7</sup> Third, results do not depend on the choice of proxy for firm size. In Figure 4, we use alternatively the two-year lagged exports, the lagged number of products (in  $t - 1$  or  $t - 2$ ) or the lagged number of destinations (in  $t - 1$  or  $t - 2$ ). The interaction coefficients are significant, positive and close in point estimates.

This exercise confirms a robust pattern: firm size dampens the negative effect of temperature on firm level exports. This pattern is robust to several measures of export outcomes, temperature and firm size. We estimate a significant and meaningful differential effect across firms.

### 3.3.2 Omitted Variables

Although the fixed effects included in our specification capture potentially omitted variables, some covariates, not included in our model so far, could explain the differential effect of temperature across firms. For this reason, we now add a cumulative measure of temperature, some indexes of countries' governance, and two variables related to credit access. Table 5 presents the results of this robustness exercise.

- Table 5 here -

Column 1 includes temperatures in  $t$ ,  $t - 1$  and in  $t - 2$  in the specification and shows that our main coefficient does not capture the differential effect of previous temperature shocks. Column 2 controls for the differential effect of tariffs dynamics, without affecting the estimated interaction coefficient. In columns 3 and 4, we use the data from Dahlberg et al. (2018) to test the impact of changes in the quality of governance in exporting countries. Column 3 estimates the differential trade effects of temperature controlling for changes in the "Voice and Accountability" measure, while in column 4 we control for the government effectiveness and for political stability. The sample size is affected but we still estimate a positive and significant coefficient of temperature and firm size, confirming our benchmark estimation. Notice that the point estimate is slightly higher here. Finally, temperature shocks could be correlated to changes in the economic environment of firms, and thus access to credit. Changes in domestic credit (as a share of GDP) in column 5 and changes in the number of banks in column 6 indeed have a differential effect across firms, but it does not alter our main conclusion: temperature shocks have a differential impact across firms, in favor of larger firms.

### 3.3.3 Causal impact of lagged exports: IV results

Our main specification implies that exports are dynamically related to weather outcomes. This threatens identification, in particular the interaction between weather shocks and firm size. To overcome this issue, we rely on an IV-2SLS strategy to identify the mitigating role of firm size.

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<sup>7</sup>The degree-days index was computed using 32°C and 34°C thresholds, as detailed in Appendix A.2.

We rely on an imputed measure of expected exports at the firm-year level. We hypothesize that firm-level exports are determined by (i) the total (import) demand in each destination weighted by (ii) the lagged exposure of the firm to each destination demand shock. In formal terms, we define the expected exports as follows:

$$ExpectedExports_{fit} = \sum_j \frac{X_{fjt-1}}{X_{ft-1}} \times M_{jt}$$

in which the first right-hand term captures the exposure of firm  $f$  to demand shocks in destination  $j$  and the second term is the total import demand in country  $j$  (not arising for country  $i$  to exclude endogeneity).

We instrument the lagged firm exports by the lagged expected firm exports in equation 1 and results are presented in Table 6. The table displays the (first-stage) F-stats, confirming the statistical validity of the IV strategy. All statistics are above the critical values, confirming that the expected exports are strong predictors of observed exports.

- Table 6 here -

Estimated coefficients are almost equivalent to OLS benchmark estimates but precision is much smaller. Despite this loss in efficiency, most interactions coefficients of interest remain significant. Our results can thus plausibly be considered as causal.

### 3.3.4 Product-specific and destination-specific shocks

Export patterns at the firm level are also determined by product-specific shocks such as changes in tastes, and by destinations-specific shifts such as varying GDP. Here we test the robustness of our results when accounting for such possible shocks. Suppose for instance that weather shocks in country  $c_1$  and  $c_2$  are correlated, and that  $c_2$  imports goods from  $c_1$ . Following these weather shocks, part of our main result could come from changes in  $c_2$  imports that, in turn, affect exports in  $c_1$ . Cross-country correlation of weather shocks is thus a potential challenge in our case. To neutralize these issues, we estimate the following specification, using export information at the firm-destination-product level:

$$\begin{aligned} Exports_{fjpt} = & \alpha Temp_{i(f)t} + \beta Exports_{ft-1} + \delta Covariates_{it} + \nu Shocks_{jt} \\ & + \gamma(Temp_{i(f)t} \times Exports_{ft-1}) + \mu(Covariates_{it} \times Exports_{ft-1}) \\ & + \eta(Shocks_{jt} \times Exports_{ft-1}) + FE + \varepsilon_{ft} \end{aligned} \quad (3)$$

where  $j$  denotes the destination market,  $p$  denotes the HS6 product category.  $Shock_{jt}$  captures destination-specific aggregate shocks that may have both an average effect on exports and a differential effect across exporting firms. We include a set of fixed effects to account for unobserved heterogeneity, combining firm-, product-, sector- and destination- effects. Both these combinations of product- and destination-

specific fixed effects and the inclusion of destination-year macroeconomic control variables allows us to absorb competing mechanisms, and we cluster the standard errors at the origin- HS2 sector-year level. Results are displayed in Table 7.

- Table 7 here -

Column 1 shows that temperatures in home country do not deter the average exports at the intensive margin once accounting for destination temperatures and GDP. Column 2 introduces additional trade determinants, which do not allow to estimate a significant impact of temperatures on exports.

Column 3 however supports this average null effect hides heterogeneity across local firms: larger firms are less negatively affected by temperature shocks at home, even when controlling for home and foreign aggregate shifts in GDP and trade determinants.

Columns 4 to 6 further support that the differential effect of local temperature shocks holds when taking into account the potential differential effect of foreign temperatures and foreign macroeconomic shocks (and by including demanding fixed effects). The interaction term is only slightly affected, without any change on its significance. The coefficient is stable across specification, which reinforces confidence in the estimation and in the model we estimate.

Overall, whereas cross-country correlation of weather shocks could explain our results, we show that this is not the case. This confirms the differential effect previously estimated at the firm-year dimension.

### 3.4 Additional results

Appendix B displays additional supporting results discussed here.

**Alternative estimators.** Table B.1 shows the results when using a pseudo-Poisson maximum likelihood (PPML) estimator on the rectangular dataset (i.e. over firms and years, not across destinations and products), to account at least for both trade margins simultaneously, for heteroskedasticity and for zero-trade flows. We obtain coefficients very close to the baseline ones, in sign and in magnitudes.

Table B.2 shows results when using a dynamic panel specification (Arellano and Bond, 1991) and accounting for the potential Nickell bias (Nickell, 1981). As our specification includes the lagged exports as a right-hand side variable, this raises potential exogeneity issues. Results – using firm and year fixed effects – confirm the differential effect of firm size on the elasticity.

**Sub-samples.** Table B.3 replicates our baseline estimates differentiating agricultural and manufacturing exports, without emphasizing robust differences in estimates across the two sub-samples. Table B.4 displays the results when focusing on alternative sub-samples, by continent. Results appear to be consistent across continents.

Results are also robust to (i) excluding data from Mexico, which represents a very large share of the observations, see Table B.5, and (ii) to excluding very small trade flows (bottom 5% of exports within each country, potentially adding noise) from the sample, see Table B.6.

**Additional firm characteristics.** Table B.7 shows results when including lagged exports and other firm characteristics in the same specification. Table B.7 allows temperatures to have a differential effect across firms along their experience on the export market, their continuous experience in exporting (i.e. controlling for consecutive years), their number of products and destinations served. Lagged export is the main variable that allows to capture the differential effect. The major part of the cross-firm variance in the heterogeneous reaction to temperatures is accounted for by lagged exports.

**Non-linearities along firm size.** Figure B.1 checks where, in the distribution, the differential effect of temperature across firms comes from. Whereas our baseline interaction coefficient provides an average measure of the effect of firm size on the elasticity, we allow this elasticity to vary non-linearly, along firm size distribution. We estimate the following model:

$$\begin{aligned}
 Exports_{ft} = & \alpha Temp_{i(f)t} + \delta Covariates_{it} + \sum_{d=1}^{10} \beta_d \mathbb{1}[Decile_{ft-1} = d] \\
 & + \sum_{d=1}^{10} \gamma_d (\mathbb{1}[Decile_{ft-1} = d] \times Temp_{i(f)t}) + FE + \varepsilon_{ft}
 \end{aligned} \tag{4}$$

where  $\mathbb{1}[Decile_{ft-1} = d]$  is a set of dummy variables for each decile  $d$  in the lagged exports distribution. Figure B.1 plots the estimates of all  $\gamma_d$  for  $d = \{1, \dots, 9\}$ , as the last decile is the reference group. Compared to the top firms, export growth is dampened by 50% for the median firm, and by 80% for firms in first decile. The differential effect of temperature across firms however appears to be linear along firm size. The interaction coefficient in our estimation is thus a good approximation of the differential effect across firms.

**Non-linearities in temperature.** Temperatures may have a non-linear effect on economic outcomes (Burke et al., 2015; Deschênes and Greenstone, 2011). Table B.8 accounts for this feature by controlling for squared temperatures. Controlling for squared temperatures and squared terms of other weather covariates does not alter our main coefficient.

**Clustering level.** Tables B.9, B.10, and B.11 show results when clustering the standard errors at the country-HS2 sector level, HS2 sector-year level, and firm respectively, without affecting inference.

## 4 Aggregate Implications

In this section, we develop the aggregate implications of the micro-level results presented previously. We build on the approach developed by [Di Giovanni et al. \(2018\)](#), and adapted to a trade environment by [Héricourt and Nedoncelle \(2018\)](#) or [Erbahar \(2019\)](#).

In section 3, we identified the heterogeneous firm-specific elasticity of exports to temperatures  $\Delta X_{fit}$ : larger firms exhibit a closer-to-0 response to an increase in temperature. Hence, aggregate country-wide exports should be deterred to the extent that exports are realized by numerous smaller firms, which are particularly harmed by temperatures shocks. We empirically investigate this intuition here by performing a set of counterfactual exercises relative to the structure of exports and to climate scenarios. This allows us to quantify the crucial role of firm distribution for exports in developing economies facing climate shocks.

### 4.1 The dampening effect of firm size: aggregate consequences

Consider a country  $i$  made of many exporting firms  $f$ . In this country, the aggregate elasticity of exports  $\Delta X$  to temperatures at year  $t$  can be written as the weighted sum of firm-specific elasticity to temperatures:

$$\Delta X_{it} = \sum_{f \in i} \omega_{ft-1} \times \Delta X_{fit}, \quad (5)$$

where  $\omega_{ft-1}$  is the market share of firm  $f$  in the aggregate exports at year  $t - 1$ . Equation (5) thus decomposes the aggregate impact of temperatures on exports into two forces: market concentration  $\omega_{ft-1}$  and firm-specific elasticity  $\Delta X_{fit}$ .

Now, to assess the role played by firm-size distribution in country  $i$ , we compute a first counterfactual aggregate exports response, denoted  $\Delta X'_{it}$ , in which every firm accounts for the same share of total exports. It reads:

$$\Delta X'_{it} = \sum_{f \in i} \omega_{it-1} \times \Delta \hat{X}_{fit}. \quad (6)$$

In equation (6), the term  $\omega_{it-1}$  is a country-year specific market share equal to  $1/n_{it-1}$ , where  $n_{it-1}$  is the total number of exporting firms in country  $i$  in  $t - 1$ . The specification of  $\omega_{it-1}$  thus assumes a uniform distribution of exports across firms in the economy. This allows us to quantify the role played by larger firms in the aggregate marginal export response to temperature variation.

Figure 5 displays the results with variables aggregated at the country-year level. In red color is plotted the ratio between exports as predicted by the model and exports from the counterfactual using uniform market shares.

- Figure 5 here -



For every country-year but one, we observe a ratio below 1 and mostly below 0.5. Exports under uniform market shares would be much lower compared to the effective, observed distribution of firms. On average, counterfactual observations lie around a ratio of 0.4, implying a massive temperature-led export loss.

This implies that firm size distribution accounts for almost 60% of the aggregate adaptation to higher temperature in our sample. The negative impact of temperature on exports, at the country level, would be significantly larger if all firms in the economy had the same weight. This result thus highlights the crucial role played by firm size distribution in shaping the aggregate marginal export response to a temperature shocks.

To further assess the role of firm-size distribution, we compute a second counterfactual aggregate exports response, denoted  $\Delta X''_{it}$ , in which we increase the role of large firms. Precisely, we consider:

$$\Delta X''_{it} = \sum_{f \in i} \frac{X_{ft-1}^2}{\sum_f (X_{ft-1}^2)} \times \Delta \hat{X}_{fit}. \quad (7)$$

This “concentrated” pattern aggregates firms’ reaction using (relative) squared firm-specific shares, i.e. increasing the relative role of large firms in the aggregate. The ratio between these counterfactual exports and the predicted, model-implied exports are plotted in green color in Figure 5. We find – in line with intuition – that increasing the relative size of the largest firms dampens the negative impact of temperature shocks. If large firms would have been even larger (i.e. accounting for a larger share of total countrywide exports), exports would have been higher than observed, still conditional on each firm’s response to temperatures. The results from this quantitative exercise support that firm size distribution is crucial and determines the aggregate costs of current temperature shocks.

**Robustness checks.** Figure C.1 in Appendix C shows the results using the decile-specific response (Figure B.1) of firms instead of the interaction term from the baseline regression (Table 3). We obtain a close picture. Excluding the differential role played by firms in deciles 9 and 10 (which drive most of the null effect across firms in average) further emphasizes the aggregate importance of these firms in shaping the aggregate trade outcomes. We obtain similar differences between the model and the counterfactual export variations.

## 4.2 Firm size and adaptation to climate change

We further build on the method developed in section 4.1 to quantify the anticipated, marginal impact of *projected* temperatures on aggregate exports. We collect data from Mitchell et al. (2004) and obtain for each country of the sample the projected temperatures for the 2020-2040, 2040-2060, 2060-2080 and 2080-2100 periods, under 4 climate scenarios.

We proceed in several steps. First, the firm-specific (conditional on its size) response to future temperature shifts in period  $t + n$ ,  $\Delta \hat{X}_{fit+n}$ , is computed. Second, these micro-level marginal effects are aggregated using the three alternative weighting schemes (already presented) allowing us to identify the role of firm size distribution. Consider the following general form:

$$\Delta X'_{it+n} = \Omega \times \Delta \hat{X}_{fit+n}. \quad (8)$$

We again study three specific forms corresponding to different patterns for  $\Omega$ :

- The “observed” pattern aggregates firms’ reaction using their effective and observed share in the data:  $\Omega = \sum_{f \in i} \omega_{fit-1}$  ;
- The “constant” pattern aggregates firms’ reaction using a constant share across firms:  $\Omega = \sum_{f \in i} \omega_{it-1}$  ;
- The “concentrated” pattern aggregates firms’ reaction using (relative) squared firm-specific shares, i.e. increasing the relative role of large firms in the aggregate:  $\Omega = \sum_{f \in i} (\omega_{ft-1})^2$ , where  $(\omega_{ft-1})^2 = X_{ft-1}^2 / \sum_f (X_{ft-1}^2)$ .

Figure 6 plots the aggregate export patterns (relative to the last observed exports in data) under the alternative weighting schemes and the alternative climate scenarios. For a given weighting scheme, we plot the range of the estimated trade growth across the 4 climate scenarios we consider, i.e. RCP 2.6 (the most optimistic), RCP 4.5, RCP 6.0 and RCP 8.5 (the most pessimistic).

- Figure 6 here -

First, in any of the counterfactual presented here, aggregate exports in the developing economies of our sample are predicted to be lowered by climate change. The negative impact ranges from 1% (RCP 2.6, concentrated shares, period 2020-2040) to 12% (RCP 8.5, constant shares, period 2080-2100), and the case of constant market shares is systematically dominated by other counterfactual.

Second, the more concentrated the market is, the less variance there is in the distribution of the negative impacts of the different climate scenarios. Indeed, when comparing the concentrated shares counterfactual to the observed and constant shares ones, the predicted aggregate exports under RCP8.5 are systematically closer to those predicted under RCP2.6. This highlights the role of market concentration in adapting to different climate scenarios.

Third, in most cases, export growth with higher firm concentration and a pessimistic scenario (triangle shape on the graph) could dominate export growth under an optimistic climate change scenario (square shape on the graph) but with lower firm concentration. As a result, *ceteris paribus*, firm size distribution may act as an engine for trade growth even with large temperature shifts.

We find only two cases where the effect of climate scenarios dominate the one of market shares. This is for periods 2060-2080 and 2080-2100, where aggregate exports under RCP2.6 and observed shares would be less damaged by temperatures than aggregate exports under RCP8.5 and concentrated shares.

In all, this shows that firm size distribution and the potential concentration of market shares across exporters could plausibly help against the adverse effect of climate shocks, complementing for instance other policies favoring mitigation in temperatures increase. The main limit of the exercise is that it ignores the potential response of firms to the weather shocks. Yet, results support that beyond the individual response of firms, the within-country distribution of exporters is a key determinant of the aggregate impact of future weather shocks.

## 5 Concluding remarks

In this paper, we analyze the impact of temperature shocks on firm-level exports in 10 developing countries. For this purpose, we combined weather data with various information on exporting firms. Our main identification strategy uses year-to-year fluctuations in temperatures, as well as country, year and sector fixed-effect.

We find a differential effect of temperature rise across exporting firms depending on their size. While the average response of exports to temperature is negative, this result hides a large heterogeneity across exporters: large exporters are significantly and quantitatively less harmed than smaller ones when facing a same temperature shock. A one standard deviation increase in temperature reduces exports for the smallest firms, by around 4%, but leaves the top firms' exports mainly unchanged. This feature is robust across countries and relies on the within-country distribution of firms.

These micro-level results have macroeconomic implications that are critical for economic development. For this reason, in the second part of this paper, we investigate how the impact of temperature estimated at the firm-level influences aggregate exporting outcomes. In absence of large exporting firms, the aggregate trade deterring effect of temperature would be significantly larger overall. This counterfactual exercise shows the importance of exports' concentration at the top of the firm size distribution to cope with the rise of temperature in developing countries. Using projected temperatures over the next 80 years also confirms this result, as expanding the role of large firms in the economy reduces the costs of future climate shifts on aggregate exports. This is the second important result of this paper.

Given the importance of future climate trends, firm size distribution in low- and middle-income countries, characterized by a lower share of large exporters, could increase the aggregate cost of climate shocks on trade. While increasing firm concentration could help mitigating the adverse effect of temperature, such a shift in firm size distribution may affect other aggregate outcomes. Indeed, whereas trade deepening already favored inequalities in developing countries ([Pavcnik, 2017](#)), firm concentration has

affected markups (De Loecker and Eeckhout, 2018), labor share (Autor et al., 2020), investment (Gutiérrez and Philippon, 2017), among others, in advanced economies. These dynamics may also be at play in developing countries.<sup>8</sup> Future research could thus also account for the potential trade-offs in such a policy in an integrated aggregate framework. We believe this kind of analysis to be an important research avenue, in particular in a climate change context, making these questions even more challenging.

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<sup>8</sup>See in particular De Loecker and Eeckhout (2018) for a discussion on the regional differences in market power shifts.

## Bibliography

- AMITI, M., O. ITSKHOKI, AND J. KONINGS (2014): "Importers, exporters, and exchange rate disconnect," *American Economic Review*, 104, 1942–78.
- ARELLANO, M. AND S. BOND (1991): "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *The Review of Economic Studies*, 58, 277–297.
- ARKOLAKIS, C., S. GANAPATI, AND M.-A. MUENDLER (2010): "The Extensive Margin of Exporting Products: A Firm-level Analysis," NBER Working Papers 16641, National Bureau of Economic Research, Inc.
- ASPRILLA, A., N. BERMAN, O. CADOT, AND M. JAUD (2019): "Trade Policy and Market Power: Firm-level Evidence," *International Economic Review*, 60, 1647–1673.
- AUFFHAMMER, M., S. M. HSIANG, W. SCHLENKER, AND A. SOBEL (2013): "Using Weather Data and Climate Model Output in Economic Analyses of Climate Change," *Review of Environmental Economics and Policy*, 7, 181–198.
- AUTOR, D., D. DORN, L. F. KATZ, C. PATTERSON, AND J. VAN REENEN (2020): "The Fall of the Labor Share and the Rise of Superstar Firms\*," *The Quarterly Journal of Economics*, 135, 645–709.
- BATHIANY, S., V. DAKOS, M. SCHEFFER, AND T. M. LENTON (2018): "Climate models predict increasing temperature variability in poor countries," *Science advances*, 4, eaar5809.
- BERMAN, N., P. MARTIN, AND T. MAYER (2012): "How do different exporters react to exchange rate changes?" *The Quarterly Journal of Economics*, 127, 437–492.
- BERNARD, A. B., J. B. JENSEN, S. J. REDDING, AND P. K. SCHOTT (2007): "Firms in international trade," *Journal of Economic perspectives*, 21, 105–130.
- BRICONGNE, J.-C., L. FONTAGNÉ, G. GAULIER, D. TAGLIONI, AND V. VICARD (2012): "Firms and the global crisis: French exports in the turmoil," *Journal of international Economics*, 87, 134–146.
- BUDOLFSON, M., F. DENNIG, M. FLEURBAEY, N. SCOVRONICK, A. SIEBERT, D. SPEARS, AND F. WAGNER (2018): "Optimal Climate Policy and the Future of World Economic Development," *The World Bank Economic Review*, 33, 21–40.
- BURKE, M., S. M. HSIANG, AND E. MIGUEL (2015): "Global non-linear effect of temperature on economic production," *Nature*, 527, 235–239.
- BURKE, M. AND V. TANUTAMA (2019): "Climatic constraints on aggregate economic output," Tech. rep., National Bureau of Economic Research.

- CAMERON, A. C., J. B. GELBACH, AND D. L. MILLER (2008): “Bootstrap-Based Improvements for Inference with Clustered Errors,” *Review of Economics and Statistics*, 90, 414–427.
- CARVALHO, V. M. AND B. GRASSI (2019): “Large firm dynamics and the business cycle,” *American Economic Review*, 109, 1375–1425.
- COLMER, J. (Forthcoming): “Temperature, Labor Reallocation, and Industrial Production: Evidence from India,” *American Economic Journal: Applied Economics*.
- COSTINOT, A., A. RODRÍGUEZ-CLARE, AND I. WERNING (2020): “Micro to macro: Optimal trade policy with firm heterogeneity,” *Econometrica*, 88, 2739–2776.
- DAHLBERG, S., S. HOLMBERG, B. ROTHSTEIN, N. ALVARADO PACHON, AND R. SVENSSON (2018): “The quality of government basic dataset, version Jan18,” *University of Gothenburg: The Quality of Government Institute*, <http://www.qog.pol.gu.se/doi/10>.
- DALLMANN, I. (2019): “Weather variations and international trade,” *Environmental and resource economics*, 72, 155–206.
- DAMANIA, R., S. DESBUREAUX, AND E. ZAVERI (2020): “Does rainfall matter for economic growth? Evidence from global sub-national data (1990–2014),” *Journal of Environmental Economics and Management*, 102, 102335.
- DE LOECKER, J. AND J. EECKHOUT (2018): “Global Market Power,” Tech. rep., NBER.
- DELL, M., B. F. JONES, AND B. A. OLKEN (2012): “Temperature shocks and economic growth: Evidence from the last half century,” *American Economic Journal: Macroeconomics*, 4, 66–95.
- (2014): “What Do We Learn from the Weather? The New Climate-Economy Literature,” *Journal of Economic Literature*, 52, 740–98.
- DESCHÊNES, O. AND M. GREENSTONE (2011): “Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US,” *American Economic Journal: Applied Economics*, 3, 152–85.
- DI GIOVANNI, J., A. A. LEVCHENKO, AND I. MEJEAN (2018): “The micro origins of international business-cycle comovement,” *American Economic Review*, 108, 82–108.
- ERBAHAR, A. (2019): “Two worlds apart? Export demand shocks and domestic sales,” *Review of World Economics*, 1–30.
- FERNANDES, A. M., C. FREUND, AND M. D. PIEROLA (2016): “Exporter behavior, country size and stage of development: Evidence from the exporter dynamics database,” *Journal of Development Economics*, 119, 121–137.

- FORSOLID, R. AND T. OKUBO (2011): "Are Capital Intensive Firms the Biggest Exporters?" Discussion papers 11014, Research Institute of Economy, Trade and Industry (RIETI).
- FREUND, C. AND M. D. PIEROLA (2020): "The origins and dynamics of export superstars," *The World Bank Economic Review*, 34, 28–47.
- GABAIX, X. (2011): "The granular origins of aggregate fluctuations," *Econometrica*, 79, 733–772.
- GARCIA-VERDU, R., A. MEYER-CIRKEL, A. SASAHARA, AND H. WEISFELD (2019): "Importing Inputs for Climate Change Mitigation: The Case of Agricultural Productivity," IMF Working Papers 19/26, International Monetary Fund.
- GAUBERT, C. AND O. ITSKHOKI (2021): "Granular comparative advantage," *Journal of Political Economy*, 129, 871–939.
- GREENSTONE, M. AND B. K. JACK (2015): "Envirodevonomics: A research agenda for an emerging field," *Journal of Economic Literature*, 53, 5–42.
- GUTIÉRREZ, G. AND T. PHILIPPON (2017): "Declining Competition and Investment in the U.S," NBER Working Papers 23583, National Bureau of Economic Research, Inc.
- HARRIS, I., P. JONES, T. OSBORN, AND D. LISTER (2014): "Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset," *International Journal of Climatology*, 34, 623–642.
- HEAD, K. AND T. MAYER (2014): "Gravity equations: Workhorse, toolkit, and cookbook," in *Handbook of international economics*, Elsevier, vol. 4, 131–195.
- HEAL, G. AND J. PARK (2016): "Reflections—temperature stress and the direct impact of climate change: a review of an emerging literature," *Review of Environmental Economics and Policy*, 10, 347–362.
- HÉRICOURT, J. AND C. NEDONCELLE (2018): "Multi-destination firms and the impact of exchange-rate risk on trade," *Journal of Comparative Economics*, 46, 1178–1193.
- HOEGH-GULDBERG, O., D. JACOB, M. BINDI, S. BROWN, I. CAMILLONI, A. DIEDHIU, R. DJALANTE, K. EBI, F. ENGELBRECHT, J. GUIOT, ET AL. (2018): "Impacts of 1.5 C global warming on natural and human systems," *Global warming of 1.5°C. An IPCC Special Report*.
- HSIANG, S. (2016): "Climate Econometrics," *Annual Review of Resource Economics*, 8, 43–75.
- HSIANG, S. M. (2010): "Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America," *Proceedings of the National Academy of sciences*, 107, 15367–15372.
- IMBS, J. AND I. MEJEAN (2015): "Elasticity optimism," *American Economic Journal: Macroeconomics*, 7, 43–83.

- JONES, B. F. AND B. A. OLKEN (2010): "Climate shocks and exports," *American Economic Review*, 100, 454–59.
- JONES, M., F. KONDYLISS, J. A. LOESER, AND J. MAGRUDER (2019): "Factor Market Failures and the Adoption of Irrigation in Rwanda," *World Bank Policy Research Working Paper*.
- KALKUHL, M. AND L. WENZ (2020): "The impact of climate conditions on economic production. Evidence from a global panel of regions," *Journal of Environmental Economics and Management*, 102360.
- KARLSSON, J. (2021): "Temperature and Exports: Evidence from the United States," *Environmental and Resource Economics*, 1–27.
- MELITZ, M. J. (2003): "The impact of trade on intra-industry reallocations and aggregate industry productivity," *Econometrica*, 71, 1695–1725.
- MITCHELL, T. D., T. R. CARTER, P. D. JONES, M. HULME, M. NEW, ET AL. (2004): "A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901–2000) and 16 scenarios (2001–2100)," *Tyndall centre for climate change research working paper*, 55, 25.
- NICKELL, S. (1981): "Biases in Dynamic Models with Fixed Effects," *Econometrica*, 49, 1417.
- NORDHAUS, W. D. (1993): "Climate and Economic Development: Climates Past and Climate Change Future," *The World Bank Economic Review*, 7, 355–376.
- PAVCNIK, N. (2017): "The impact of trade on inequality in developing countries," Tech. rep., National Bureau of Economic Research.
- SCHLENKER, W. AND M. J. ROBERTS (2009): "Nonlinear temperature effects indicate severe damages to US crop yields under climate change," *Proceedings of the National Academy of sciences*, 106, 15594–15598.
- SEPPANEN, O., W. J. FISK, AND Q. LEI (2006): "Effect of temperature on task performance in office environment," .
- SIMONSOHN, U., J. P. SIMMONS, AND L. D. NELSON (2020): "Specification curve analysis," *Nature Human Behaviour*.
- SOMANATHAN, E., R. SOMANATHAN, A. SUDARSHAN, AND M. TEWARI (2021): "The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing," *Journal of Political Economy*, 129, 1797–1827.
- STROBL, E. AND M.-A. VALFORT (2013): "The Effect of Weather-Induced Internal Migration on Local Labor Markets. Evidence from Uganda," *The World Bank Economic Review*, 29, 385–412.
- WORLD BANK (2016): *World Development Indicators 2016*, Washington, DC.



—— (2020): *World Development Report 2020*, no. 32437 in World Bank Publications, The World Bank.

ZHANG, P., O. DESCHENES, K. MENG, AND J. ZHANG (2018): “Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants,” *Journal of Environmental Economics and Management*, 88, 1–17.

# Tables

Table 1: Statistics about firm-level exports, by country

Country	Start	End	Nb. Exporters	Mean Exports	P10	P90	# Prod.	# Dest.
Bulgaria	2002	2006	7,147	117,746	1,596	177,317	24	8.2
Burkina Faso	2006	2012	223	227,989	1,835	251,635	16	6.8
Guatemala	2006	2013	2,801	238,014	1,644	306,505	28	6.3
Jordan	2004	2012	1,305	264,925	2,817	318,483	13	11
Malawi	2007	2012	223	361,878	1,937	613,498	9.1	6.2
Mexico	2001	2012	19,585	424,722	1,819	420,005	23	7.9
Peru	1997	2013	3,501	225,876	1,699	321,227	19	9.7
Senegal	2001	2012	394	120,028	1,793	166,408	23	11
Uruguay	2002	2012	993	425,240	2,560	709,500	8.9	13
Yemen	2009	2012	313	220,370	2,215	385,685	17	7.7

Table 2: Descriptive statistics of the sample

## Panel A: Firm-Product-Destination-Year Variables

variable	mean	sd	min	max	N
Exports (value)	322269.25	2.22e+06	1,000.00	9.92e+07	2.47e+06
Exports (volume)	220385.41	5.93e+06	0.00	2.04e+09	1.11e+06
Unit Value	833.51	61,829.91	0.00	3.80e+07	1.11e+06

## Panel B: Origin Country-Year Variables

variable	mean	sd	min	max	N
Temp.	22.56	5.38	10.70	29.20	117.00
Preci.	1,019.89	665.39	63.60	3,449.00	117.00
Humidity	94.03	42.27	21.20	201.20	117.00
GDP pc.	3,126.49	3,135.63	193.07	15,171.58	117.00

## Panel C: Destination Country-Year Variables

variable	mean	sd	min	max	N
Dest. Temp.	19.33	7.76	0.40	29.30	2,575.00
Dest. Prec.	1,145.59	833.71	21.80	4,915.10	2,621.00
Dest. GDP pc.	13,076.38	20,343.22	102.60	185721.79	2,956.00

Table 3: Results: Intensive Margin - Temperatures in levels

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Temperatures	-0.027 (0.018)	-0.104*** (0.034)	-0.173*** (0.034)		
GDP	1.953*** (0.150)	1.979*** (0.150)	2.398*** (0.188)		
Humidity	2.440*** (0.336)	2.457*** (0.335)	2.482*** (0.334)		
Preci.	-1.541*** (0.173)	-1.541*** (0.172)	-1.575*** (0.172)		
Exports ( $t - 1$ )	0.298*** (0.010)	0.172*** (0.052)	1.075*** (0.162)	0.810*** (0.163)	-0.915*** (0.176)
Temperatures $\times$ Exports ( $t - 1$ )		0.006** (0.002)	0.011*** (0.003)	0.007*** (0.003)	0.015*** (0.003)
GDP $\times$ Exports ( $t - 1$ )			-0.039*** (0.006)	-0.027*** (0.006)	0.017*** (0.006)
Preci. $\times$ Exports ( $t - 1$ )					-0.255*** (0.032)
Humidity $\times$ Exports ( $t - 1$ )					0.484*** (0.051)
Observations	176912	176912	176912	145500	145500
$R^2$	0.874	0.874	0.875	0.913	0.914
Firm FE	x	x	x	x	x
Country FE					
Sector-Year FE	x	x	x		
Country-Year FE					
Country-Sector-Year FE				x	x
Cluster	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables (excare in logs).

Table 4: Extensive margin

	Dep. Variable: Nb. Products			Nb. Dest		
	(1)	(2)	(3)	(4)	(5)	(6)
Mean Temp.	-0.052*** (0.010)	-0.141*** (0.012)		-0.050*** (0.007)	-0.126*** (0.010)	
GDP	0.320*** (0.050)	0.187*** (0.052)		0.233*** (0.036)	0.078* (0.040)	
Precipitations	-0.364*** (0.077)	1.427*** (0.170)		-0.297*** (0.057)	1.792*** (0.132)	
Humidity	0.489*** (0.141)	-2.416*** (0.274)		0.353*** (0.106)	-3.249*** (0.211)	
Exports ( $t - 1$ )	0.076*** (0.003)	-0.335*** (0.066)	-0.360*** (0.067)	0.073*** (0.003)	-0.396*** (0.057)	-0.399*** (0.055)
Mean Temp. $\times$ Exports ( $t - 1$ )		0.007*** (0.001)	0.006*** (0.001)		0.007*** (0.001)	0.006*** (0.001)
Precipitations $\times$ Exports ( $t - 1$ )		-0.141*** (0.014)	-0.124*** (0.014)		-0.163*** (0.010)	-0.148*** (0.010)
Humidity $\times$ Exports ( $t - 1$ )		0.228*** (0.022)	0.214*** (0.022)		0.280*** (0.016)	0.264*** (0.016)
GDP $\times$ Exports ( $t - 1$ )		0.008*** (0.002)	0.008*** (0.002)		0.008*** (0.002)	0.007*** (0.002)
Observations	176912	176912	176024	176912	176912	176024
$R^2$	0.847	0.847	0.855	0.850	0.852	0.859
Firm FE	x	x	x	x	x	x
Year FE						
Sector-Year FE	x	x		x	x	
Country-Year FE						
Country-Sector-Year FE			x			x
Cluster	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table 5: Omitted variables

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Exports ( $t - 1$ )	1.364*** (0.220)	-1.587*** (0.242)	-1.473*** (0.379)	-1.913** (0.765)	-0.192 (0.258)	-0.702*** (0.187)
Temperatures $\times$ Exports ( $t - 1$ )	0.047*** (0.010)	0.018*** (0.003)	0.049*** (0.007)	0.081*** (0.012)	0.028*** (0.004)	0.026*** (0.003)
Temp. ( $t - 1$ ) $\times$ Exports ( $t - 1$ )	0.013 (0.009)					
Temp. ( $t - 2$ ) $\times$ Exports ( $t - 1$ )	-0.051*** (0.013)					
GDP $\times$ Exports ( $t - 1$ )	-0.049*** (0.008)	0.034*** (0.007)	0.022* (0.011)	-0.021 (0.017)	-0.016* (0.009)	0.028*** (0.007)
Preci. $\times$ Exports ( $t - 1$ )		-0.375*** (0.042)	-0.559*** (0.107)	-0.644*** (0.165)	-0.513*** (0.061)	-0.632*** (0.073)
Humidity $\times$ Exports ( $t - 1$ )		0.685*** (0.068)	0.928*** (0.147)	1.255*** (0.303)	0.871*** (0.100)	1.028*** (0.108)
Tariffs $\times$ Exports ( $t - 1$ )		0.045*** (0.012)				
Voice/Accountability $\times$ Exports ( $t - 1$ )			0.080*** (0.015)			
Government Eff. $\times$ Exports ( $t - 1$ )				0.005 (0.009)		
Nb. Banks $\times$ Exports ( $t - 1$ )					-0.090*** (0.012)	
Domestic Credit $\times$ Exports ( $t - 1$ )						-0.175*** (0.029)
Observations	123403	140218	137605	113322	107958	176024
$R^2$	0.891	0.914	0.883	0.879	0.895	0.883
Firm FE	x	x	x	x	x	x
Country-Sector-Year FE	x	x	x	x	x	x
Cluster	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables (except Voice and Accountability and Gov. Effectiveness) are in logs.

Table 6: IV results

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )			
	(1)	(2)	(3)	(4)
Exports ( $t - 1$ )	0.392*** (0.034)	0.130 (0.206)	2.944*** (0.515)	-2.694*** (0.354)
Temperatures	0.086*** (0.024)	-0.084 (0.135)	-0.269* (0.159)	
GDP	2.977*** (0.200)	2.996*** (0.202)	4.421*** (0.371)	
Humidity	2.329*** (0.330)	2.364*** (0.333)	2.372*** (0.333)	
Preci.	-1.390*** (0.176)	-1.400*** (0.176)	-1.448*** (0.179)	
Temperatures $\times$ Exports ( $t - 1$ )		0.013 (0.010)	0.027** (0.012)	0.006*** (0.002)
GDP $\times$ Exports ( $t - 1$ )			0.121*** (0.022)	0.110*** (0.012)
Preci. $\times$ Exports ( $t - 1$ )				-0.171*** (0.018)
Humidity $\times$ Exports ( $t - 1$ )				0.296*** (0.034)
Observations	117583	117583	117583	117583
$R^2$	0.086	0.085	0.088	0.050
Cragg-Donald Wald F statistic	809.349	198.119	154.318	156.613
Kleibergen-Paap rk Wald F statistic	2109.531	955.308	576.598	437.901
Firm FE	x	x	x	x
Sector-Year FE	x	x	x	x
Cluster	cntr-sec-yr	cntr-sec-yr	cntr-sec-yr	cntr-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table 7: Destination- and Product Specific Shocks

	Dep. Variable: Exports, ( $\ln X_{fjpt}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Temperatures	-0.002 (0.017)	-0.000 (0.020)	-0.076** (0.035)	-0.211*** (0.029)	-0.058 (0.051)	
GDP	0.381*** (0.060)	0.055 (0.113)	0.113 (0.114)	-0.069 (0.124)	0.068 (0.291)	
Exports ( $f, t - 1$ )	0.195*** (0.007)	0.199*** (0.008)	0.094** (0.039)	-1.205*** (0.125)	-0.774*** (0.251)	-0.691** (0.278)
Dest. GDP	0.415*** (0.028)	0.386*** (0.030)	0.386*** (0.030)			
Dest. Temp.	-0.029*** (0.009)	-0.051*** (0.013)	-0.050*** (0.012)			
REER		-0.560*** (0.155)	-0.514*** (0.156)	-0.196 (0.157)	-0.149 (0.404)	
Preci.		-0.187** (0.091)	-0.192** (0.091)	0.922*** (0.281)	0.598 (0.537)	
Humidity		-0.042 (0.174)	-0.026 (0.173)	-3.284*** (0.464)	-2.118** (0.890)	
Dest. Precip.		0.117** (0.051)	0.115** (0.051)			
Dest. Humidity		-0.067 (0.107)	-0.063 (0.106)			
Dest. REER		-0.032*** (0.009)	-0.032*** (0.009)			
Temperatures $\times$ Exports ( $f, t - 1$ )			0.005*** (0.002)	0.012*** (0.002)	0.007*** (0.003)	0.006** (0.003)
GDP $\times$ Exports ( $f, t - 1$ )				0.029*** (0.004)	0.002 (0.007)	-0.000 (0.008)
REER $\times$ Exports ( $f, t - 1$ )				-0.022*** (0.005)	-0.005 (0.008)	-0.003 (0.008)
Preci. $\times$ Exports ( $f, t - 1$ )				-0.078*** (0.019)	-0.064* (0.035)	-0.066* (0.039)
Humidity $\times$ Exports ( $f, t - 1$ )				0.225*** (0.031)	0.174*** (0.056)	0.177*** (0.062)
Dest. Temp. $\times$ Exports ( $f, t - 1$ )					0.002 (0.002)	0.002 (0.002)
Dest. GDP $\times$ Exports ( $f, t - 1$ )					0.013*** (0.005)	0.011** (0.005)
Dest. Precip. $\times$ Exports ( $f, t - 1$ )					0.022 (0.021)	-0.001 (0.022)
Dest. Humidity $\times$ Exports ( $f, t - 1$ )					-0.025 (0.027)	0.016 (0.028)
Observations	431682	332367	332367	667011	272267	251066
$R^2$	0.857	0.854	0.854	0.865	0.910	0.912
Firm FE	x	x				
Home-Destination FE	x	x				
Product-Year FE	x	x				
Firm-Product-Destination FE			x	x	x	x
Year FE			x	x		
Destination-Product-Year FE					x	
Home-Destination-Product-Year FE						x

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs. home sector year cluster

# Figures

Figure 1: Exports structure

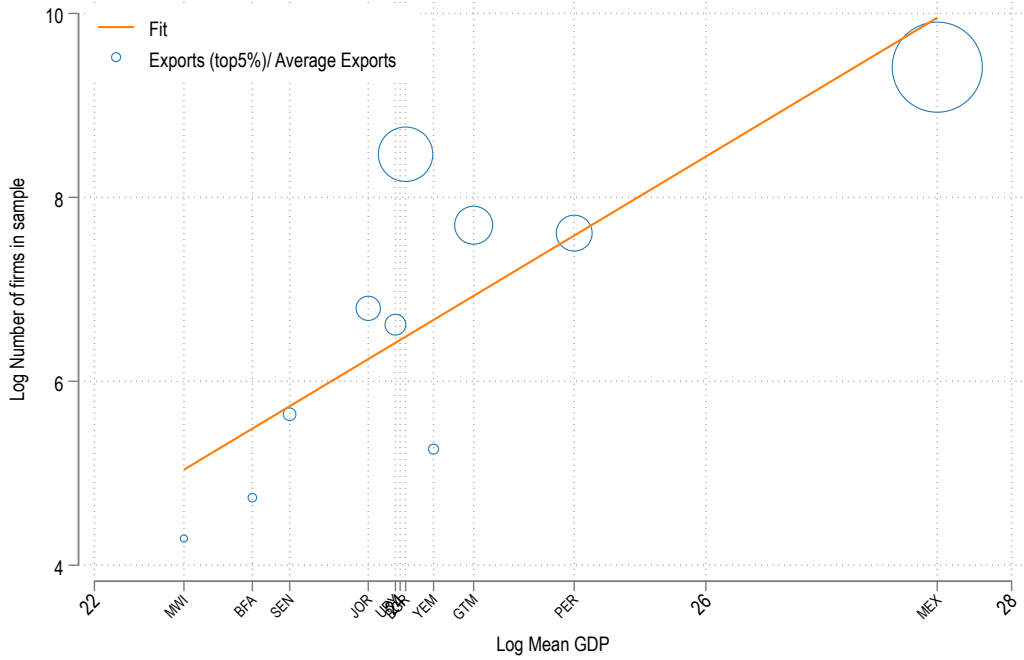


Figure 2: Temperatures across Years

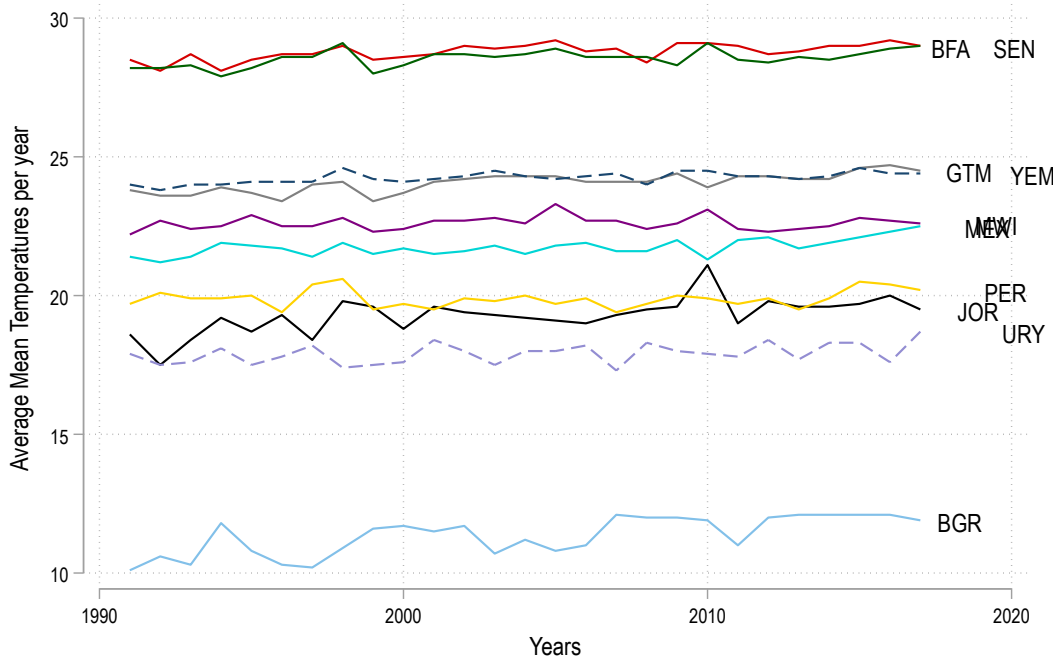




Figure 3: Quantification: Effects of a one standard increase in temperature within country

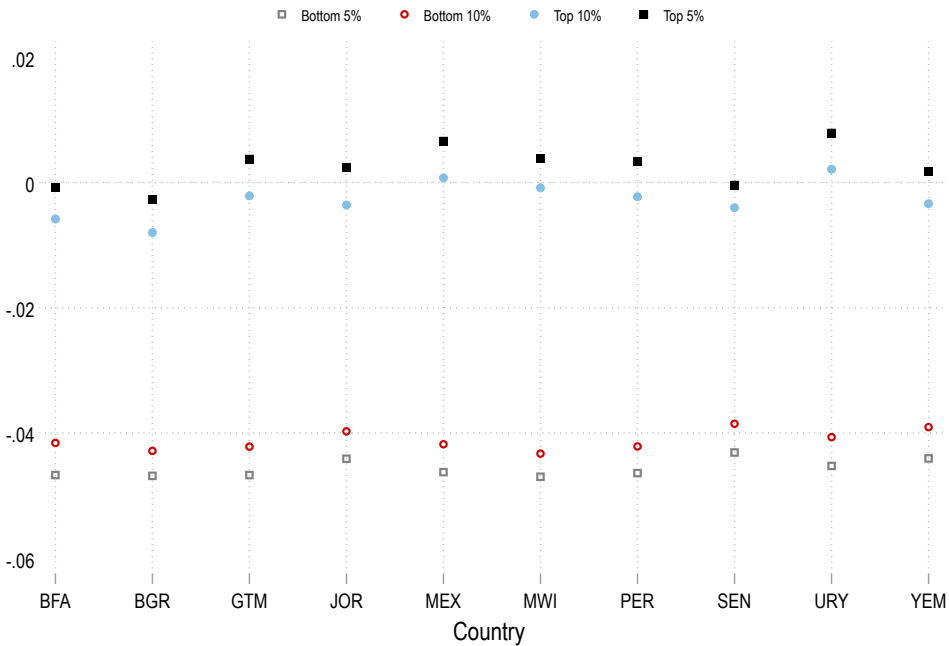
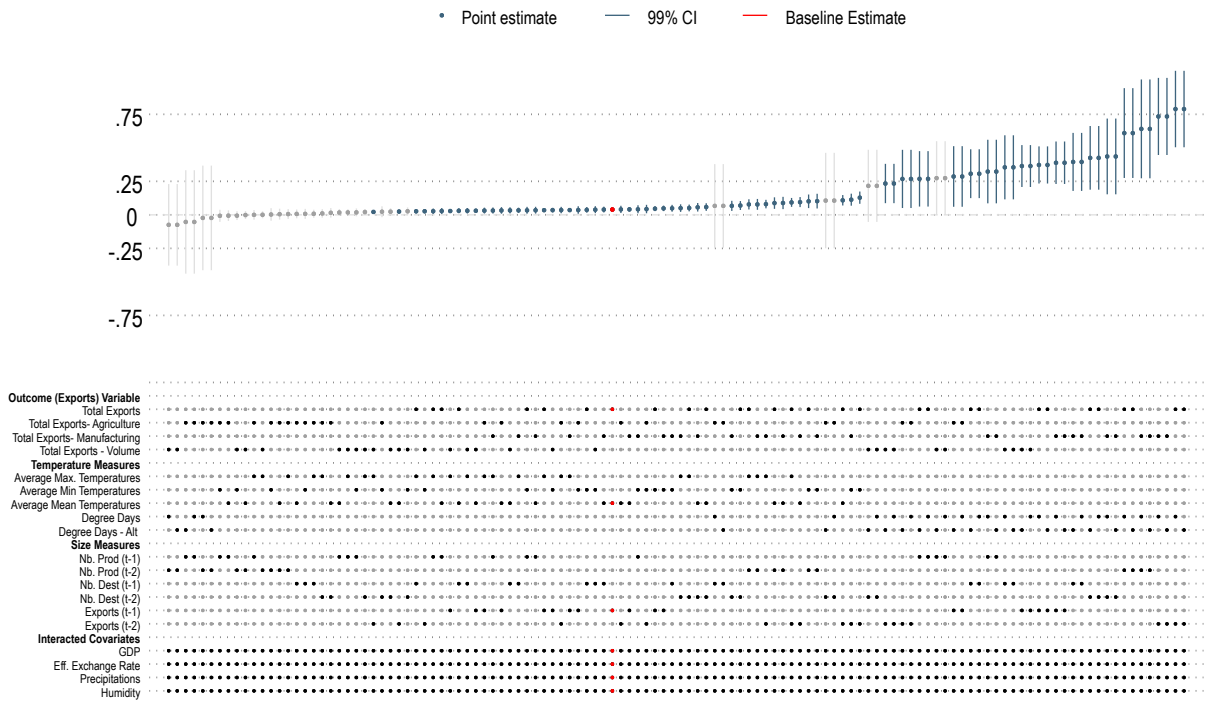


Figure 4: Specification Curve: Estimated  $\gamma$  Across Specification Choices



N = 120 ; Mean = 0.152 ; sd = 0.198

Figure 5: Counterfactual: differences in aggregate export responses

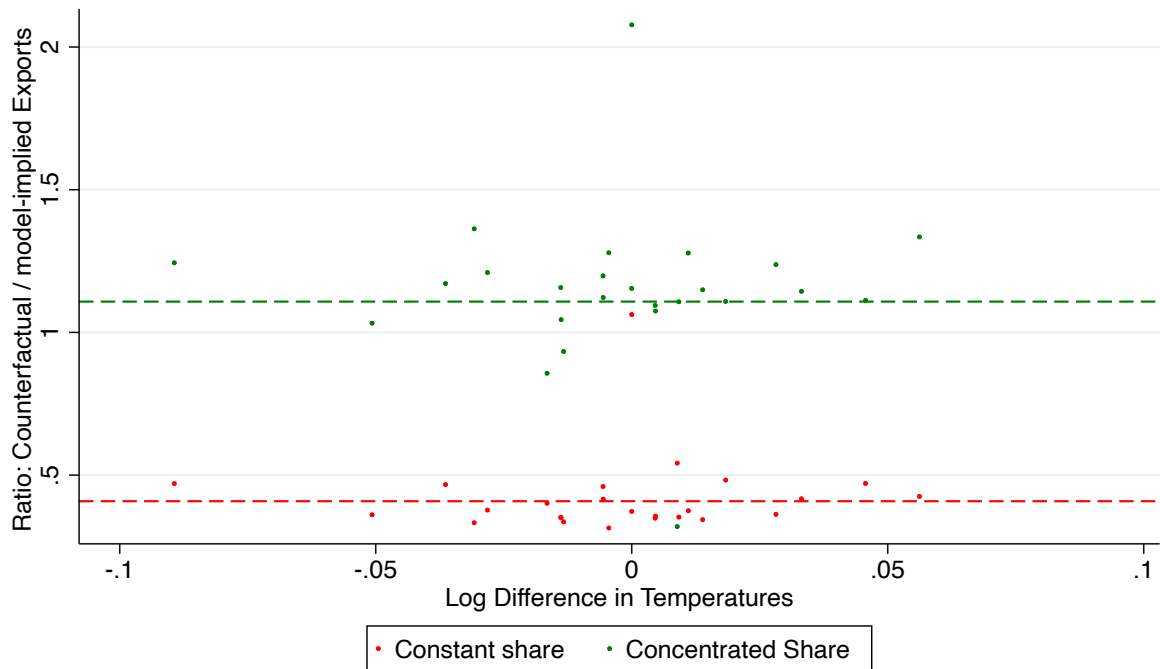
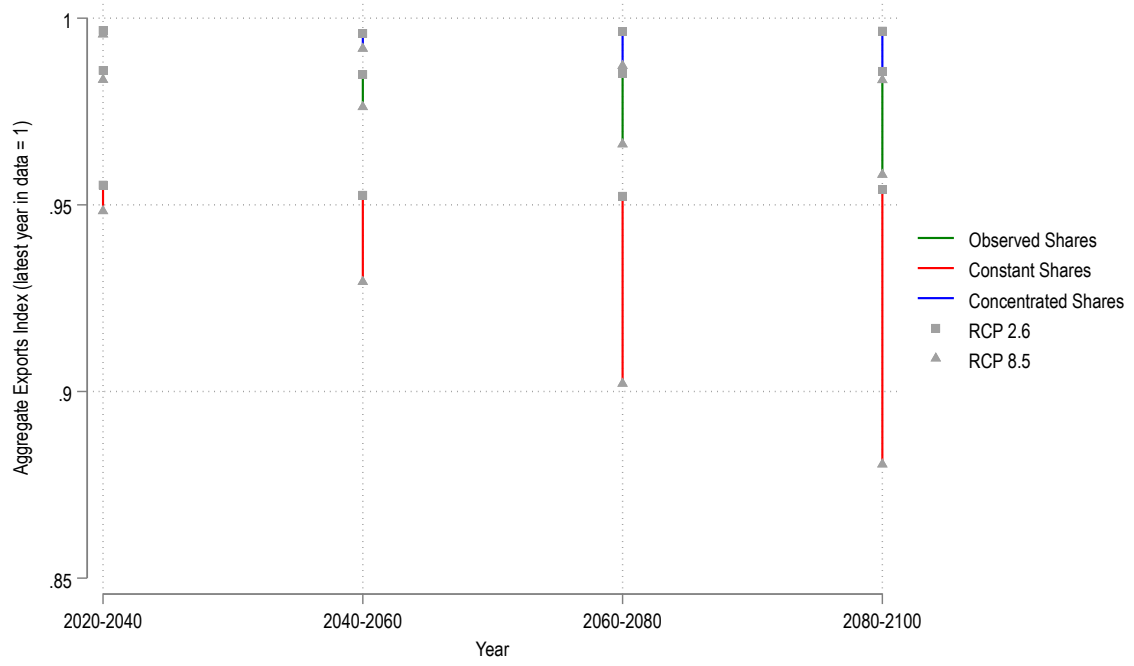


Figure 6: Projected exports over 80 years under alternative scenarios



# Appendix for

## Temperatures, Firm Size and Exports in Developing Countries

Clément Nedoncelle<sup>1</sup> Julien Wolfersberger<sup>1,2</sup>

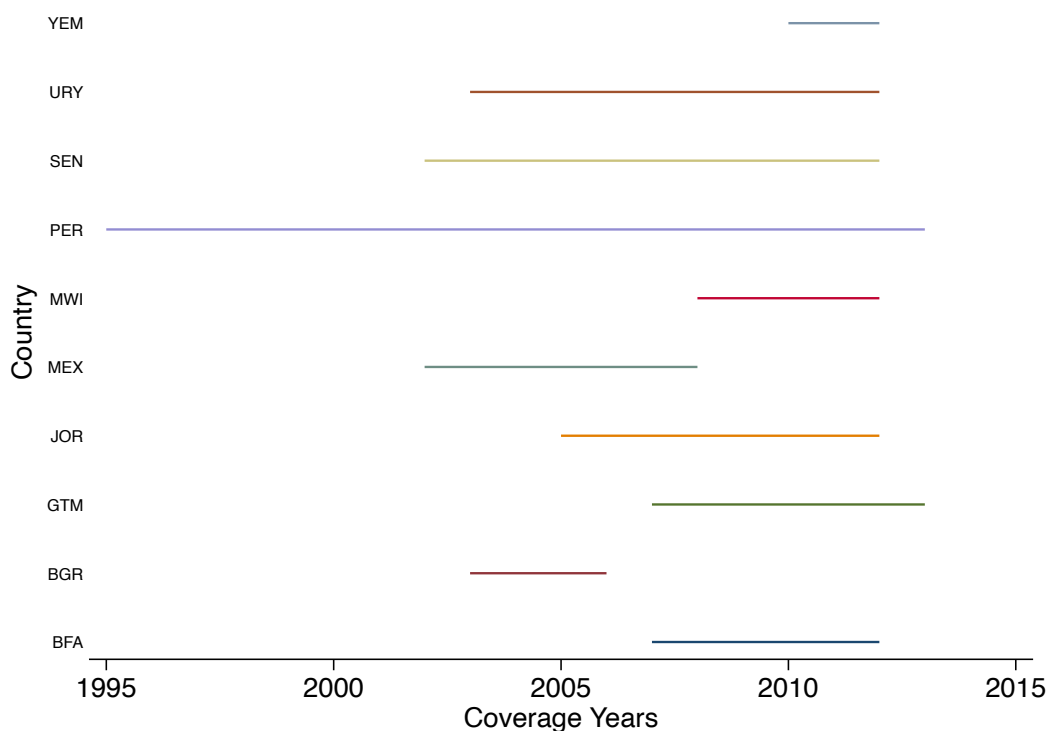
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## A Data Information

### A.1 Coverage

Figure A.1: Country Coverage Across Years



### A.2 Alternative Measure of Weather: Degree-Days

Our estimations also account for potential non linearities in the temperatures (Schlenker and Roberts, 2009). We use data from the NOAA Global Historical Climatology Network, Daily (GHCN-D), providing averaged temperatures at the weather station - country -day dimensions (for our sample countries, this represents around 19 000 000 observations). We have aggregated that data by computing the daily average temperature by country. Armed with these country  $i$  average temperatures (in degrees Celsius) at the daily  $d$  level,  $T_{idt}$ , we have converted them into so-called country-year degree-days,  $DD_{it}$ , using the following formula:

$$DD_{it} = \begin{cases} 0 & \text{if } T_{idt} \leq 8C \\ T_{idt} - 8 & \text{if } 8C < T_{idt} \leq 32C \\ 24 & \text{if } T_{idt} > 32C \end{cases}$$

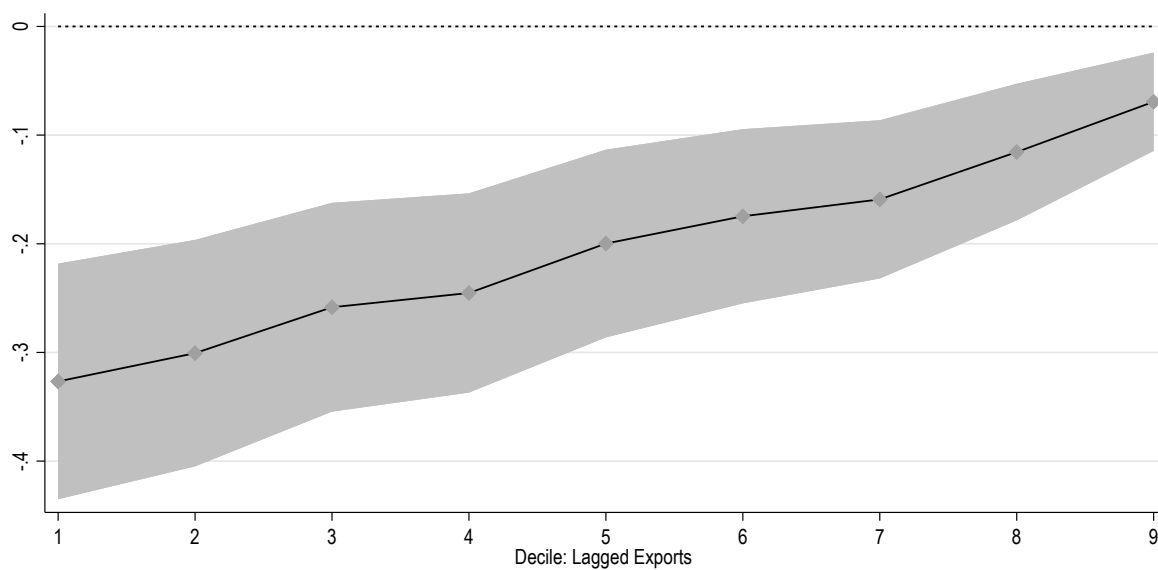
We thus obtain a country-year measure of temperatures, which captures both the number of days of

“large temperatures” and a cumulative measure of these “large temperatures”.

**Robustness.** For robustness checks, we have computed an alternative measure of degree-days, using 8°C and 34°C as thresholds in the computation above.

## B Additional Results: Firm-year dimension

Figure B.1: Variation across Deciles: Estimated  $\gamma_d$  for  $d = 1 \dots 9$



Note: The figure plots the estimated  $\{\gamma_d\}_{d=\{1..9\}}$  from:

$$Exports_{ft} = \alpha Temp_{i(f)t} + \delta Covariates_{it} + \sum_{d=1}^{10} \beta_d \mathbb{1}[Decile_{ft-1} = d] + \sum_{d=1}^{10} \gamma_d (\mathbb{1}[Decile_{ft-1} = d] \times Temp_{i(f)t}) + FE + \varepsilon_{ft}$$

Table B.1: Results: PPML Estimator

	Dep. Variable: Firm-level Exports, ( $X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Mean Temp.	0.023 (0.018)	0.032* (0.018)	-0.008 (0.043)	-0.239*** (0.053)	
GDP	0.604*** (0.127)	0.719*** (0.126)	0.741*** (0.128)	0.566*** (0.183)	
Ireer <sub><i>i</i></sub>	-0.756*** (0.159)	-0.597*** (0.152)	-0.579*** (0.155)	0.397* (0.211)	
Exports ( $t - 1$ )	0.431*** (0.012)	0.431*** (0.012)	0.378*** (0.048)	-0.419** (0.204)	-0.236 (0.234)
Precipitations		-1.056*** (0.121)	-1.057*** (0.121)	1.227* (0.666)	
Humidity		1.621*** (0.230)	1.631*** (0.229)	-4.211*** (1.047)	
Mean Temp. $\times$ Exports ( $t - 1$ )			0.003 (0.002)	0.014*** (0.003)	0.011*** (0.004)
Precipitations $\times$ Exports ( $t - 1$ )				-0.096** (0.043)	-0.087* (0.050)
Humidity $\times$ Exports ( $t - 1$ )				0.288*** (0.066)	0.255*** (0.076)
GDP $\times$ Exports ( $t - 1$ )				-0.001 (0.008)	-0.002 (0.008)
Ireer <sub><i>i</i></sub> $\times$ Exports ( $t - 1$ )				-0.048*** (0.009)	-0.047*** (0.009)
Observations	186222	186222	186222	154831	153783
$R^2$					
Firm FE	x	x	x	x	x
Sector-Year FE	x	x	x	x	
Country-Sector-Year FE					x
Cluster	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.



Table B.2: Results: Dynamic Panel Estimation

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Exports (t-1)	1.251*** (0.039)	1.239*** (0.038)	-4.929*** (0.355)	-2.194*** (0.412)	-8.792*** (0.644)
Exports (t-2)					-0.132*** (0.004)
Temperatures	-0.781*** (0.268)	-0.990*** (0.270)	-19.548*** (1.459)	-6.720*** (1.231)	-27.393*** (2.135)
GDP	-1.320*** (0.028)	-1.291*** (0.028)			
Preci.		-0.517*** (0.085)		-1.380*** (0.209)	-3.982*** (0.290)
Humidity		0.568*** (0.145)			
Temperatures $\times$ Exports (t-1)			1.560*** (0.118)	0.480*** (0.100)	2.135*** (0.163)
Preci. $\times$ Exports (t-1)				0.076*** (0.017)	0.310*** (0.023)
Observations	135712	135712	135712	135712	94785

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . All specifications include firm FE and year FE. All variables are in logs.

Table B.3: Results: Intensive Margin - Subsamples

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Temperatures	0.022 (0.118)	-0.008 (0.126)		0.118 (0.122)	0.027 (0.126)	
GDP	2.545*** (0.686)	2.590*** (0.690)		4.660*** (0.634)	4.727*** (0.623)	
REER	-3.816*** (1.427)	-3.862*** (1.427)		-8.307*** (1.375)	-8.292*** (1.350)	
Preci.	0.012 (0.597)	-0.019 (0.602)		-1.429** (0.563)	-1.510*** (0.555)	
Humidity	-1.636 (1.414)	-1.532 (1.433)		0.904 (1.405)	1.175 (1.390)	
Exports ( $t - 1$ )	0.174*** (0.025)	0.114 (0.091)	-3.192*** (1.046)	0.228*** (0.017)	0.060 (0.074)	-4.550*** (1.458)
Temperatures $\times$ Exports ( $t - 1$ )		0.003 (0.005)	0.042*** (0.011)		0.008** (0.004)	0.089*** (0.015)
REER $\times$ Exports ( $t - 1$ )			0.678*** (0.117)			0.812*** (0.138)
Preci. $\times$ Exports ( $t - 1$ )			-0.397** (0.163)			-0.953*** (0.247)
Humidity $\times$ Exports ( $t - 1$ )			0.807*** (0.293)			1.736*** (0.441)
GDP $\times$ Exports ( $t - 1$ )			-0.053** (0.025)			-0.067*** (0.023)
Observations	28354	28354	28156	87297	87297	87112
$R^2$	0.889	0.889	0.893	0.879	0.880	0.883
Sample	AGR	AGR	AGR	MAN	MAN	MAN
Firm FE	x	x	x	x	x	x
Country FE		x			x	
Sector-Year FE	x	x		x	x	
Country-Year FE						
Country-Sector-Year FE			x			x
Cluster	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.4: Results: Intensive Margin - Subsamples by continent

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )		
	(1)	(2)	(3)
Exports ( $t - 1$ )	-0.957 (1.326)	4.645*** (0.995)	1.944*** (0.295)
Temperatures $\times$ Exports ( $t - 1$ )	0.057*** (0.021)	0.046*** (0.016)	0.016* (0.008)
Preci. $\times$ Exports ( $t - 1$ )	-0.139 (0.174)	-0.322** (0.143)	-0.706*** (0.098)
Humidity $\times$ Exports ( $t - 1$ )	0.207 (0.266)	0.203 (0.199)	0.850*** (0.109)
GDP $\times$ Exports ( $t - 1$ )	-0.017 (0.059)	-0.189*** (0.039)	-0.034*** (0.008)
Observations	3703	7524	145762
$R^2$	0.860	0.871	0.882
Sample	Africa	Asia	America
Firm FE	x	x	x
Country-Sector-Year FE	x	x	x
Cluster	ctry-sec-yr	ctry-sec-yr	ctry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.5: Results: Intensive Margin - Excluding Mexico

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Temperatures	-0.016 (0.016)	-0.148*** (0.036)	-0.133*** (0.035)		
GDP	0.489*** (0.096)	0.528*** (0.095)	-0.276** (0.120)		
Humidity	-0.176 (0.214)	-0.122 (0.214)	-0.325 (0.212)		
Preci.	-0.187* (0.108)	-0.205* (0.108)	-0.075 (0.107)		
Exports ( $t - 1$ )	0.358*** (0.009)	0.157*** (0.055)	-1.322*** (0.171)	-1.356*** (0.184)	-1.401*** (0.189)
Temperatures $\times$ Exports ( $t - 1$ )		0.010*** (0.003)	0.010*** (0.003)	0.009*** (0.003)	0.011*** (0.003)
GDP $\times$ Exports ( $t - 1$ )			0.060*** (0.006)	0.060*** (0.007)	0.050*** (0.007)
Preci. $\times$ Exports ( $t - 1$ )					-0.096*** (0.034)
Humidity $\times$ Exports ( $t - 1$ )					0.199*** (0.059)
Observations	91840	91840	91840	76242	76242
$R^2$	0.888	0.889	0.889	0.913	0.913
Firm FE	x	x	x	x	x
Country FE					
Sector-Year FE	x	x	x		
Country-Year FE					
Country-Sector-Year FE				x	x
Cluster	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.6: Results: Intensive Margin - Excluding Small Exports

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Temperatures	-0.019 (0.017)	-0.097*** (0.033)	-0.184*** (0.034)		
GDP	1.884*** (0.145)	1.912*** (0.145)	2.353*** (0.193)		
Humidity	2.367*** (0.323)	2.387*** (0.322)			
Preci.	-1.493*** (0.166)	-1.493*** (0.165)			
Exports ( $t - 1$ )	0.309*** (0.010)	0.184*** (0.050)	1.095*** (0.165)	0.872*** (0.167)	-0.808*** (0.175)
Temperatures $\times$ Exports ( $t - 1$ )		0.006** (0.002)	0.012*** (0.003)	0.007** (0.003)	0.015*** (0.003)
GDP $\times$ Exports ( $t - 1$ )			-0.040*** (0.007)	-0.029*** (0.007)	0.014** (0.006)
Preci. $\times$ Exports ( $t - 1$ )					-0.245*** (0.032)
Humidity $\times$ Exports ( $t - 1$ )					0.468*** (0.052)
Observations	167844	167844	167844	138444	138444
$R^2$	0.878	0.878	0.878	0.916	0.916
Firm FE	x	x	x	x	x
Country FE					
Sector-Year FE	x	x	x		
Country-Year FE					
Country-Sector-Year FE				x	x
Cluster	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.7: Results: Intensive Margin - Other firm characteristics

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Exports ( $t - 1$ )	-1.154*** (0.196)	-1.055*** (0.199)	-1.105*** (0.198)	-1.158*** (0.196)	-1.175*** (0.195)	-1.175*** (0.195)
Temp. $\times$ Exports ( $t - 1$ )	0.023*** (0.003)	0.023*** (0.003)	0.023*** (0.003)	0.024*** (0.003)	0.023*** (0.003)	0.024*** (0.003)
Preci. $\times$ Exports ( $t - 1$ )	-0.414*** (0.046)	-0.400*** (0.047)	-0.408*** (0.046)	-0.414*** (0.046)	-0.404*** (0.046)	-0.409*** (0.046)
Humidity $\times$ Exports ( $t - 1$ )	0.718*** (0.072)	0.698*** (0.073)	0.711*** (0.072)	0.718*** (0.072)	0.700*** (0.073)	0.710*** (0.073)
GDP $\times$ Exports ( $t - 1$ )	0.023*** (0.006)	0.019*** (0.006)	0.021*** (0.006)	0.023*** (0.006)	0.023*** (0.006)	0.023*** (0.006)
Experience (t-1)		-0.240* (0.140)				
Temp. $\times$ Experience (t-1)		0.002 (0.007)				
Cont. Experience (t-1)			-0.107 (0.073)			
Temp. $\times$ Cont. Experience (t-1)			-0.001 (0.004)			
Nb HS6 Prod. (t-1)				0.020 (0.039)		
Temp. $\times$ Nb HS6 Prod. (t-1)				-0.001 (0.002)		
Nb Dest. (t-1)					0.108** (0.048)	
Temp. $\times$ Nb Dest. (t-1)					-0.001 (0.002)	
Nb Prod-Dest. (t-1)						0.049* (0.029)
Temp. $\times$ Nb Prod-Dest. (t-1)						-0.001 (0.001)
Observations	176024	176024	176024	176024	176024	176024
$R^2$	0.882	0.883	0.883	0.882	0.882	0.882
Firm FE	x	x	x	x	x	x
Country-Sector-Year FE	x	x	x	x	x	x
Cluster	cuntry-sec-yr	cuntry-sec-yr	cuntry-sec-yr	cuntry-sec-yr	cuntry-sec-yr	cuntry-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.8: Results: Intensive Margin - Non-Linear Effects of Temperatures

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )				
	(1)	(2)	(3)	(4)	(5)
Temperatures	-2.596*** (0.285)	-2.568*** (0.282)	-0.887*** (0.142)	-1.015*** (0.150)	-1.045*** (0.139)
Temperatures $\times$ Temperatures	0.083*** (0.009)	0.080*** (0.009)	0.021*** (0.004)	0.021*** (0.004)	0.019*** (0.004)
GDP	2.430*** (0.492)	2.596*** (0.485)	2.060*** (0.146)	2.480*** (0.195)	1.600*** (0.136)
Humidity	3.877*** (1.344)	3.947*** (1.336)	2.263 (1.564)		-7.507*** (1.642)
Preci.	-2.393*** (0.515)	-2.409*** (0.513)	-4.247*** (0.945)		1.250 (0.960)
REER	-1.777 (1.082)	-2.056* (1.071)			
Exports ( $t - 1$ )	0.221*** (0.015)	0.081 (0.068)	0.181*** (0.052)	1.049*** (0.163)	-1.283*** (0.188)
Temperatures $\times$ Exports ( $t - 1$ )		0.007** (0.003)	0.006** (0.003)	0.011*** (0.003)	0.027*** (0.003)
Humidity $\times$ Humidity			0.018 (0.180)		0.010 (0.176)
Preci. $\times$ Preci.			0.201*** (0.068)		0.217*** (0.068)
GDP $\times$ Exports ( $t - 1$ )				-0.038*** (0.006)	0.025*** (0.006)
Humidity $\times$ Exports ( $t - 1$ )					0.770*** (0.071)
Preci. $\times$ Exports ( $t - 1$ )					-0.447*** (0.046)
Observations	111895	111895	176912	176912	176912
$R^2$	0.875	0.875	0.875	0.874	0.876
Firm FE	x	x	x	x	x
Sector-Year FE	x	x	x	x	x
Cluster	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr	cnty-sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Country-HS2 Sector-Year level. All variables are in logs.

Table B.9: Results: Intensive Margin: alternative clustering level

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Temperatures	0.096 (0.141)	0.096 (0.141)	0.012 (0.145)	-0.190** (0.086)		
GDP	5.107*** (0.498)	5.107*** (0.498)	5.178*** (0.493)	5.236*** (0.663)		
Humidity	0.252 (1.828)	0.252 (1.828)	0.486 (1.796)			
Preci.	-1.249* (0.719)	-1.249* (0.719)	-1.316* (0.708)			
REER	-8.630*** (1.272)	-8.630*** (1.272)	-8.651*** (1.253)	-14.678*** (1.358)		
Exports ( $t - 1$ )	0.221*** (0.014)	0.221*** (0.014)	0.063 (0.041)	0.306 (0.289)	0.508** (0.223)	-1.643** (0.659)
Temperatures $\times$ Exports ( $t - 1$ )			0.008*** (0.002)	0.042*** (0.005)	0.026*** (0.004)	0.040*** (0.006)
REER $\times$ Exports ( $t - 1$ )				0.719*** (0.072)	0.312*** (0.045)	0.409*** (0.058)
GDP $\times$ Exports ( $t - 1$ )				-0.160*** (0.015)	-0.086*** (0.009)	-0.054*** (0.012)
Preci. $\times$ Exports ( $t - 1$ )						-0.277*** (0.095)
Humidity $\times$ Exports ( $t - 1$ )						0.571*** (0.178)
Observations	111895	111895	111895	111895	91172	91172
$R^2$	0.875	0.875	0.875	0.876	0.916	0.916
Firm FE	x	x	x	x	x	x
Country FE						
Sector-Year FE	x	x	x	x		
Country-Year FE						
Country-Sector-Year FE					x	x
Cluster	Cty-Sec.	Cty-Sec.	Cty-Sec.	Cty-Sec.	Cty-Sec.	Cty-Sec.

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the Sector-Country level. All variables are in logs.



Table B.10: Results: Intensive Margin: alternative clustering level

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Temperatures	0.096 (0.111)	0.096 (0.111)	0.012 (0.110)	-0.190** (0.085)		
GDP	5.107*** (0.636)	5.107*** (0.636)	5.178*** (0.625)	5.236*** (0.836)		
Humidity	0.252 (1.266)	0.252 (1.266)	0.486 (1.271)			
Preci.	-1.249** (0.522)	-1.249** (0.522)	-1.316** (0.519)			
REER	-8.630*** (1.324)	-8.630*** (1.324)	-8.651*** (1.296)	-14.678*** (2.248)		
Exports ( $t - 1$ )	0.221*** (0.016)	0.221*** (0.016)	0.063 (0.062)	0.306 (0.249)	0.508** (0.218)	-1.643*** (0.625)
Temperatures $\times$ Exports ( $t - 1$ )			0.008** (0.003)	0.042*** (0.006)	0.026*** (0.005)	0.040*** (0.006)
REER $\times$ Exports ( $t - 1$ )				0.719*** (0.114)	0.312*** (0.054)	0.409*** (0.058)
GDP $\times$ Exports ( $t - 1$ )				-0.160*** (0.023)	-0.086*** (0.014)	-0.054*** (0.015)
Preci. $\times$ Exports ( $t - 1$ )						-0.277*** (0.086)
Humidity $\times$ Exports ( $t - 1$ )						0.571*** (0.160)
Observations	111895	111895	111895	111895	91172	91172
$R^2$	0.875	0.875	0.875	0.876	0.916	0.916
Firm FE	x	x	x	x	x	x
Country FE						
Sector-Year FE	x	x	x	x		
Country-Year FE						
Country-Sector-Year FE					x	x
Cluster	sec-yr	sec-yr	sec-yr	sec-yr	sec-yr	sec-yr

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the sector-Year level. All variables are in logs.

Table B.11: Results: Intensive Margin: alternative clustering level

	Dep. Variable: Firm-level Exports, ( $\ln X_{ft}$ )					
	(1)	(2)	(3)	(4)	(5)	(6)
Temperatures	0.096 (0.077)	0.096 (0.077)	0.012 (0.078)	-0.190*** (0.050)		
GDP	5.107*** (0.392)	5.107*** (0.392)	5.178*** (0.390)	5.236*** (0.346)		
Humidity	0.252 (0.861)	0.252 (0.861)	0.486 (0.869)			
Preci.	-1.249*** (0.334)	-1.249*** (0.334)	-1.316*** (0.336)			
REER	-8.630*** (0.887)	-8.630*** (0.887)	-8.651*** (0.879)	-14.678*** (0.850)		
Exports ( $t - 1$ )	0.221*** (0.006)	0.221*** (0.006)	0.063** (0.027)	0.306* (0.172)	0.508*** (0.195)	-1.643*** (0.383)
Temperatures $\times$ Exports ( $t - 1$ )			0.008*** (0.001)	0.042*** (0.003)	0.026*** (0.003)	0.040*** (0.004)
REER $\times$ Exports ( $t - 1$ )				0.719*** (0.034)	0.312*** (0.035)	0.409*** (0.040)
GDP $\times$ Exports ( $t - 1$ )				-0.160*** (0.008)	-0.086*** (0.009)	-0.054*** (0.009)
Preci. $\times$ Exports ( $t - 1$ )						-0.277*** (0.046)
Humidity $\times$ Exports ( $t - 1$ )						0.571*** (0.086)
Observations	111895	111895	111895	111895	91172	91172
$R^2$	0.875	0.875	0.875	0.876	0.916	0.916
Firm FE	x	x	x	x	x	x
Country FE						
Sector-Year FE	x	x	x	x		
Country-Year FE						
Country-Sector-Year FE					x	x
Cluster	firm	firm	firm	firm	firm	firm

Note: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard Errors are clustered at the firm level. All variables are in logs.

## C Additional Aggregate Results

Figure C.1: Robustness in differences between aggregate export responses

