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COVID-19, Lockdowns and International Trade: Evidence from Firm-Level Data

João Amador
Banco de Portugal
Nova SBE

Carlos Melo Gouveia
Banco de Portugal

Ana Catarina Pimenta
Banco de Portugal

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Abstract

The COVID-19 pandemics and the lockdowns imposed to mitigate the rise of infections beyond manageable levels strongly affected international trade in the early months of 2020. Although the health crisis and the mobility restrictions associated to lockdowns are closely related, their impacts on international trade have a different nature. This paper uses monthly firm-level trade data for Portuguese firms to measure the impact of lockdowns on nominal export and import flows during 2020 and the first half of 2021, while also assessing the impact of the health crisis. The high time frequency and granularity of the data contribute to the identification of the impact of these obstacles on trade. We conclude that the detrimental impact of lockdowns is sizeable and broadly similar in exports and imports, and the impact of the health conditions is slightly stronger in exports. There is evidence of a lower impact of lockdowns as of June 2020, hinting at a progressive adaptation of international traders to the prevailing circumstances. Notwithstanding this adaptation, the impact of lockdowns partly remerged in the third wave of the pandemics, notably on imports flows. There is also evidence that the impact of lockdowns was stronger for larger firms and for those more integrated in global value chains.

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1. Introduction

The COVID-19 pandemics was the strongest shock faced by the world economy in many decades. The initial impact on international trade flows was very large and comparable to the one recorded in the 2008-2009 great trade collapse. The deterioration in overall health conditions across the world and the containment measures taken by the authorities to limit the number of infections strongly affected the activity of firms, households' consumption decisions and the ability to move goods across borders. Quantifying the impact of these constraints on international trade is our primary research question.

The evolution of overall health conditions, proxied by the number of deaths attributed to COVID-19 per thousand inhabitants, and the adoption of measures restricting the mobility of individuals and the operation of specific sectors, referred as lockdowns, have an impact on both demand and supply of foreign goods and thus on international trade flows. The deterioration in health conditions limits the number of individuals available to work, due to sickness or need to assist relatives. This has a negative effect on the operation of firms, thus affecting supply. The impact of overall health conditions on demand emerges from higher uncertainty and fear of infection, which have a detrimental impact on households' consumption decisions, as discussed in Goolsbee and Syverson (2021). As for lockdowns, the negative impact on supply of goods emerges from restrictions to the mobility of workers and the ensuing absence from work. For example, the closure of schools forces many workers to stay at home to take care of children. In addition, lockdowns involve tight control of border crossings, which burdens the international mobility of goods. The negative impact of lockdowns on demand operates mostly through difficulties by households in acceding to shops and also by means of tighter border controls for those willing to travel.

Therefore, there is not a univocal association between the impact of health conditions and lockdowns and shocks on demand and supply. In this paper we take lockdowns and health conditions as separate dimensions, but put a stronger emphasis on the former. It should be noted that the relevance of measuring the impact of lockdowns goes beyond the COVID-19 pandemic crisis. Public authorities may consider imposing lockdowns with characteristics similar to those of 2020 and 2021 under different circumstances. Climatic prolonged extreme events may justify such action and violent social unrest and military conflicts have historically also led to this type of decisions. Conversely, health crisis that do not require lockdowns may also occur, for example those due to natural disasters as earthquakes.

The correct identification of the impact of health conditions and lockdowns on export and import flows is a challenging task because several confounding effects are at play. One important feature is the global nature of the pandemic crisis, which caused a contraction in economic activity across the world, thus affecting foreign demand for domestic goods and also imports. This effect is heterogeneous across countries and it is likely to be related with the intensity of the pandemics in each period of time. Another very important aspect concerns the existence of

firm-specific characteristics that may impact on their export and import decisions over and above the effect of lockdowns and prevailing health conditions. Impacts accruing to the different type of goods produced and traded by the firm is an obvious example.

Our very rich firm-level monthly database provides strong cross-sectional variation and allows for the utilization of high dimensional fixed effects that control for the referred confounding features. This rich set of fixed effects and the monthly frequency of the data make it possible separately identify the impact of stringency measures and health conditions on trade flows. Indeed, the utilization of high frequency firm-level data to measure the impact of lockdowns and health conditions on international trade is a distinctive feature of our paper. Moreover, we use data that extends up to the end of the first semester of 2021, thus taking aboard the three first waves of the pandemics, which is novel in the literature.

The two panels of Figure 1 plot the aggregate monthly path of nominal exports and imports by Portuguese firms and the average of comparable country-level stringency indices, as reported by Angrist *et al.* (2020) and weighted according to the share of the partner country on each type of trade flow. This figure signals a disconnect between the stringency of lockdowns and trade flows during the period considered, which is very important for identification purposes. There was a sharp contraction of exports and imports at the end of the first quarter of 2020 in parallel with a sharp increase in the weighted stringency index. Although stringency measures only slightly reduced in the second and third quarters of 2020, both export and import flows recovered most of the decline recorded in the first three months of the year. As for the fourth quarter, there was a mild increase in stringency and both international trade flows contracted. In the first quarter of 2021 there was a substantial increase in both trade flows and the weighted stringency index remained relatively stable, while in the second quarter of 2021 all these variables decreased.

Motivated by the richness of the database at hand and by the paths of monthly trade flows and the stringency indicator, there are additional research questions to consider. Firstly, it is important to assess if international traders adapted their activity and procedures in order to operate under lockdowns in destination and origin countries. It is fair to argue that the stronger the learning ability by firms the higher their resilience to shocks. Our monthly-level data makes it possible to estimate the differential impact of lockdowns along quarters, thus providing an empirical answer to this question.

Secondly, the strong heterogeneity in terms of the size of firms operating in foreign markets is likely to interact with their response under lockdown conditions. As for the comparison between traders and non-traders, Borino *et al.* (2021) refers that the former are more affected but also more resilient. The sign of this relationship amongst traders of different sizes is not obvious *a priori* and it is a matter of to be settled empirically. On the one hand, larger traders may have a wider portfolio of clients and suppliers that allows to sustain the operation under lockdowns in specific geographies. On the other hand, smaller traders, dealing with
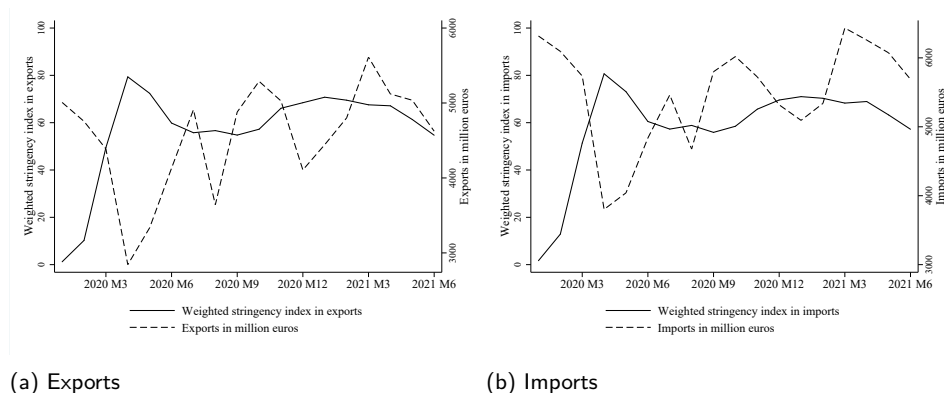
(a) Exports

(b) Imports

Figure 1: Total trade flows and weighted stringency index

Note: The weighted stringency index in exports (imports) corresponds to the stringency index of each destination (origin) country weighted by its weight in total Portuguese exports (imports) in the reference period (2017 to 2019).
Sources: International Trade Data (Statistics Portugal) and `https://covidtracker.bsg.ox.ac.uk/` for the lockdown stringency index.

more limited shipments, may be more agile in overcoming transport restrictions associated with lockdowns.

A related research question concerns heterogeneity in terms of firms' engagement in GVCs, which impacts their ability to cope with the shocks imposed by the lockdowns. It has been acknowledged that the impact of lockdowns on international trade is likely to be transmitted through a network of complex global supply linkages. During the past decades the organization of production at the global level went through deep transformations and became based on global value chains (GVCs). The literature on this topic is vast and some initial thoughtful contributions were Yeats (1998), Hummels *et al.* (2001) and Baldwin (2006). Under this paradigm, firms may specialize in the production of specific parts and components or become assemblers, but they almost always heavily rely on foreign supplies that are incorporated in the production process. Therefore, final goods and services result from value added originated in very different locations, according to comparative advantages defined at a granular level. In this organizational setup, firms tend to maintain low inventories of intermediate goods necessary for production and strongly rely on transportation, logistics and foreign suppliers for just-in-time deliveries. Therefore, if lockdowns trigger disruptions in transportation systems or in the operation of key component suppliers, the impact is large and propagates through the production chain. Such cascading effects have been referred in the literature, for example, in di Mauro *et al.* (2012) and Foti *et al.* (2013). Nevertheless, as the network of countries and firms participating international trade became denser, the likelihood of switching to alternative suppliers in order to make up for a broken link in the supply chain increased.

The empirical testing of these hypothesis is made possible by estimating the differential impact of lockdowns for firms more engaged in GVC, proxied by those where there are foreign capital participations, and also for those operating in sectors where the input-output matrices indicate a higher import content in exports. Assessing the time-varying impact of health conditions and lockdowns during 2020 and 2021 is also a way of shedding light on the resilience of global supply chains.

A similar reasoning can be used to analyse the impacts of lockdowns for specific trade partners. A different impact of lockdowns on international trade flows along the countries dimension, after controlling for the impact of the pandemics on country-specific demand, suggests that geography and GVCs play a role. For example, some trade partners may be more important in terms of origin of value added incorporated in exports, thus leading to different impacts of stringency measures on trade flows. In addition, the geographic location is likely to affect the options in terms of logistics and means of transport, which interact with lockdown measures that reduce mobility.

Our paper contributes to answer the different research questions listed above. Firstly, we compute the overall impact of heath conditions and lockdowns on nominal export and import flows, controlling for firm, trade partner and time specific effects. Secondly, in order to assess adaptability by international traders to the shocks associated to the different waves of the COVID-19 pandemics, we take our preferred econometric specification and estimate the differential impact of health conditions and lockdowns for the four quarters of 2020 and the two initial quarters of 2021. Thirdly, we examine the differential impact of lockdowns along firms' size classes. Fourthly, we detail the results according to firms' status in terms of foreign capital as a proxy for GVC participation, as well as along manufacturing industries and trade partners. Another important underlying contribution of the paper concerns the utilization of up to date high-frequency detailed partner country and product firm-level international trade data.

The paper concludes that the impact of public health crisis and lockdowns on international trade is sizeable. Considering the period from January 2020 to June 2021, under our preferred econometric specification, an increase of 100 COVID-related deaths per million inhabitants led to, on average, a decrease of 2.5 percentage points in nominal exports and a decrease of about 2.2 percentage points in nominal imports. As for the stringency of containment measures, proxied by the composite indicator used, which ranges between zero and 100, a one percentage point increase leads to, on average, a reduction of about 0.15 percentage points in the growth rate of nominal exports and a reduction of approximately 0.13 percentage points in the growth rate of imports. However, when the effects are estimated at the quarterly level, differences emerge. As for exports, the strongest negative impacts of tighter stringency measures are observed in the first two quarters of 2020 and become not statistically different from zero in the last two quarters of 2020, hinting at a progressive adaptation of international traders. However, with the third wave of the pandemics, the detrimental impact of lockdowns on export flows partly emerges in the first quarter of 2021 but it

becomes non-significant in the following quarter. As for imports the quarterly path of coefficients is qualitatively similar. Nonetheless, the impact of health conditions emerges again in the first quarter of 2021 and the detrimental impact of lockdowns is significant in the last quarter of 2020, probably due to a stronger enforcement of existing rules.

As for the relationship between the size of firms and the stringency of containment measures in partner countries, the negative impact is higher for both the largest exporters and the largest importers. In addition, firms with foreign capital, proxying their participation in GVCs, are more severely affected by the stringency of containment measures. In what concerns the different impacts of tighter stringency measures on manufacturing exports, "transport equipment", typically taken as an example of an industry strongly integrated in GVCs, posts the most negative coefficient, while "food and beverages" and "agriculture" do not seem to be affected. The industry labelled as "chemicals", which includes pharmaceutical products, also posts a coefficient that is not significantly different from zero. As for sectoral imports the same pattern is present, with the exception that "food and beverages" posts a negative coefficient. Finally, as for the effects of stronger stringency measures emerging from specific trade partners, Spain is clearly the country with the strongest impact on exports and also with a negative impact on nominal import flows, close to Germany and France. Spain is the largest Portuguese trade partner, its single land border and there are strong supply chains linking the two Iberian countries.

The paper is organized as follows. The next section briefly reviews the related literature. Section 3 describes the database of Portuguese international traders of goods and the details of the stringency index that is used as a proxy for the intensity of lockdowns. In addition, section 3 presents the econometric specifications that allow for the identification of the impact of health conditions and lockdowns on nominal export and import flows. Section 4 presents the results and is organized along five blocks. The initial subsection refers to the overall impact of health conditions and lockdowns on exports and imports. The second subsection examines the time-varying dimension of these impacts on both trade flows. The third subsection analyses the interaction between firms' size and the impact of lockdowns. In the last two sections, we turn to the existence of foreign capital at the firm, with a view to link with the impacts emerging from the operation of GVCs, and examine the sectoral and partner country dimensions. Section 5 presents some concluding remarks.

2. Related literature

The literature about the impacts of the COVID-19 pandemics on the different dimensions of economic activity has been expanding. The early response of the profession to the challenges emerging from the pandemics was presented in Baldwin (2019). Next, as the crisis unfolded the literature split along different strands. The

contributions that are closest to the research questions addressed in our paper relate to the impacts of containment measures targeted at limiting the spread of the virus on overall economic activity, international trade flows and trade policy.

As for the impact of the pandemics on economic activity, Chen *et al.* (2020) uses high-frequency indicators such as electricity consumed, unemployment insurance claims and measures of mobility based on location data for the first months of 2020, together with the number of COVID-19 cases or deaths as a proxy for the severity of the outbreaks. The paper concludes that European countries and US states that experienced larger outbreaks also suffered larger economic losses. In addition, it refers that heterogeneity in impacts is mostly captured by changes in agents' mobility and not the timing of non-pharmaceutical interventions, as measured by the stringency index presented in Angrist *et al.* (2020). In the same vein, Deb *et al.* (2020) quantifies the effects of containment measures on activity using daily global data on real-time emissions, flights, energy consumption, maritime trade, and mobility indices. Authors refer that the decision to implement containment measures is associated to the spread virus, which is itself linked to mobility and activity. The paper addresses causality issues by controlling for the change in the number of infections and deaths the day before implementation of containment measures and using lagged changes in daily economic indicators and country-specific time trends. Results signal a loss of about 15 percent in industrial production over a 30-day period following the implementation of measures. Overall, the research question in these two papers is similar to ours and the underlying explanatory variables and econometric issues are not distant either.

The specific impacts of the pandemics on international trade flows have also been discussed. Espitia *et al.* (2021) studies the effects of the COVID-19 pandemics using monthly trade data for 28 countries and multiple trading partners, at a detailed sector level, between February and June 2020. The aim of the paper is to assess the role of COVID-19 related shocks and sector characteristics on international trade flows. The paper bases on difference-in-differences specifications to explain monthly trade flows by interacting measures of the COVID-19 pandemics with time-invariant sectors' measures of vulnerability to the shock, such as possibility of remote work and GVC participation. Regression results show that the negative trade effects induced by COVID-19 vary widely across sectors. In particular, sectors with a higher share of occupations that can be performed remotely were less impacted by the pandemic and participation in GVCs increased vulnerability to shocks suffered by trade partners.

Cerdeiro and Komaromi (2020) quantifies the causal effect of supply spillovers from lockdown exposure on international trade using a novel dataset of daily bilateral seaborne trade. The trade volume data is associated with the satellite tracking of ships and weight carried, as explained in Cerdeiro *et al.* (2020). Beyond the lockdown exposure variable , which is computed as the weighted average of lockdown measures at the country-day level, as referred in Angrist *et al.* (2020), the preferred specification includes domestic lockdown stringency, domestic cases and deaths in ratio to population, and country and time fixed effects. These controls

and the strong sources of variation in the data allow for the correct identification of the impact of lockdowns on trade flows. The paper finds strong but short-lived supply spillovers, notably in terms of the downstream propagation of lockdowns through GVCs. Although with substantial differences regarding the type of data that is used, our paper is not distant from Cerdeiro and Komaromi (2020) in terms of empirical strategy. Finally, another close contribution is Bricongne *et al.* (2021), which uses French monthly firm-level trade data similar to ours and discusses the effects of the COVID-19 pandemics, with an emphasis on the margins of adjustment of exports and the granular impact of very large traders.

In a somewhat different strand, Liu *et al.* (2021) use a gravity-like approach to study how COVID-19 deaths and lockdowns affected countries' imports from China. Authors find that a country's own deaths and lockdowns significantly reduce imports from China. Conversely, COVID-19 deaths in the main trading partners induce more imports from China. The net effect is, on average, a reduction of nearly 10 percent in imports from China relatively to the pre-pandemic situation. Interestingly, the paper also finds that deaths and lockdowns in previous months tend to increase current imports, suggesting that trade is partially postponed.

Finally, the literature has also been discussing the impact of the COVID-19 pandemics on the future of international trade. Antràs (2020) discusses the observed slowdown in globalisation prior to the pandemics, arguing that there was little systematic evidence of a reversal in the process. However, the paper acknowledges that the pandemics may aggravate policy tensions across countries, thus further darkening globalisation prospects. Bonadio *et al.* (2020) analytically solve and calibrate a model with information of the OECD Inter-Country Input-Output (ICIO) tables to examine the role of GVCs in the relation between the pandemics and GDP developments in 64 countries. The paper simulates a global lockdown as a contraction in labour supply that interacts both with the fraction of work in each sector that can be done remotely and the stringency of lockdown measures. The paper concludes that the average real GDP downturn due to the shock was near 30 percent, with one quarter of it attributed to transmission through GVCs. Importantly, the paper refers that "renationalization" of GVCs do not in general make countries more resilient to contractions associated to pandemic shocks. The counterpart of a lower dependence on foreign inputs is a higher reliance on domestic inputs, which are also potentially disrupted due to domestic lockdowns. In a scenario of shrinking GVCs countries do not benefit from the diversification of risks that come from having alternative foreign suppliers. In the early reflection about the effects of the pandemics on international trade, Baldwin and Tomiura (2020) makes a similar point. Although not directly discussing trade policy, our paper also analyses the impact of lockdowns on GVCs' operation and their resilience.

3. Data and empirical strategy

Statistics Portugal (*Instituto Nacional de Estatística*, Portuguese acronym: INE) collects, on a monthly basis, detailed information on export and import transactions of goods by firms located in Portugal, which is used to compute the official international trade statistics. For extra-EU trade the data originally comes from customs returns forms and for intra-EU trade it comes from the Intrastat reports. The dataset includes all transactions with non-EU countries but the intra-EU transactions are subject to the assimilation threshold, i.e., the annual trading value below which Intrastat declaration is not mandatory. The assimilation thresholds in Portugal are 350 thousand euros for EU imports and 250 thousand euros for EU exports.

The database used in this paper includes all transactions reported by firms from January 2020 to June 2021.[1] A transaction record includes the firm tax identification, the three digit firm code of Nomenclature of Economic Activities, the eight digit product code of Combined Nomenclature, the value of the transaction (expressed in current euros) and the destination or origin country. The firm-level data used in this paper covers more than 96 percent of total exports and more than 92 percent of total imports in this period, with 35,731 exporting firms and 130,760 importing firms operating in 2020 and in the first half of 2021.

Beyond international trade information, the database includes firm's total turnover and employment, as well its sector of activity and the share of foreign capital. These variables are originally collected from the *Quadros de Pessoal* dataset for the most recent year available (2019) and externally added to the trade database. Table 1 presents some basic descriptive statistics at the firm-level for the period under analysis.

Firm-level	Exports	Imports
Number of firms	35,731	130,760
Number of partner countries		
- mean	3.4	1.8
- standard deviation	6.8	2.5
- median	1.0	1.0
Flows (Thousand Euros)		
- mean	2,293.6	755.0
- standard deviation	34,067.2	20,813.2
- median	6.2	0.3

Table 1. Description of firm-level trade data in the period January 2020 – June 2021

Firm-level international trade data was complemented with information related to the pandemics. The data on the stringency of containment measures in place

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1. The monthly observations for 2020 correspond to definitive data, which assures high quality in terms of coverage and accurateness.

in each trade partner, on a daily basis, was collected from the Oxford COVID-19 Government Response Tracker. This information is publicly available and put together by a cross-disciplinary Oxford University team of academics and students, led by the Blavatnik School of Government. The database traces a large set of measures, such as school closures, workplace closing, stay-at-home requirements and travel bans and an composite overall Stringency Index is also computed. A full description of the data and the composite index are presented in Angrist *et al.* (2020). The daily data starts on January 2020 and covers about 180 countries. This index has been widely used in the most recent COVID-19 related literature (e.g., Bonadio *et al.* 2020, Chen *et al.* 2020, Deb *et al.* 2020, Naudé and Cameron 2020, Liu *et al.* 2021 and Bricongne *et al.* (2021)).

The monthly average of the overall COVID-19 Stringency Index is our proxy for variation in governments' responses and it is computed as a simple additive score of nine individual indicators measured on an ordinal scale and rescaled to vary from 0 (no restrictions) to 100 (full lockdown). The index takes into account the intensity of each type of restriction, as well as its geographic extent in the country. For example, the impact of a full blown closure of schools is 11 percentage points, the same as maximum constraints in international travel. However, the index cannot capture the degree of enforcement of the containment measures and some indicators may be more related to production and trade (e.g. workspace closing and movement restrictions) than others (e.g. cancel public events and public information campaigns). Although there is co-movement amongst the different types of restrictions, with a view to assess the robustness of the empirical analysis, we also construct different sub-indices and replicate our exercise.

In the same vein we tested direct mobility indicators, such as those publicly available from Google Mobility Reports. These indicators directly track individuals' movements in different contexts but are narrower in terms of their assessment of specific barriers, notably those with impact on cross-border movements. Nonetheless, these indicators could be seen as close substitutes. Table E.3 presents the correlations between specific mobility indices and the Stringency Index, which are generally very high.

The second type of data related to the pandemics used is the number of infections and COVID-related deaths per thousand inhabitants. This information was collected from the COVID-19 Dashboard by the Coronavirus Resource Center of Johns Hopkins University (available at `https://coronavirus.jhu.edu/map.html`).

The monthly export and import flows for each partner-country were visibly affected by the implementation of containment measures, as proxied by increases in the lockdown stringency index. The panels of Figure 2 plot the level of exports and imports and the stringency index from January 2020 to June 2021 for a set of main Portuguese trade partners. There is significant variation but it is clear that the increase in stringency in the first quarter of 2020 was accompanied by a drop in export and import flows in all cases. In the second quarter of 2020 the stringency measures were slightly reduced but trade flows broadly recovered to the

pre-pandemics levels. In the final months of 2020 there was a mild increase in stringency in connection with the second wave of the pandemics and trade flows contracted once more. Lastly, in the first half of 2021, contingency measures were relaxed, in line with the progress in COVID-19 vaccination, specially in the second quarter. Both international trade flows increased in the first quarter of 2021 but declined in the following months.

In order to establish the relationship between the changes in export and import levels and the intensity of containment measures, while taking into account firm-specific characteristics, time effects and partner-country characteristics we estimate a high-dimensional fixed effects model (HDFE, henceforth) separately for exports and imports:[2]:

$$\ln\left(TradeFlow_{ijt_n}\right) - \ln\left(\frac{\sum_{k=2017,2018,2019} TradeFlow_{ijt_k}}{3}\right) = \alpha + \beta.X_{jt} + \gamma_i + \delta_j + \lambda_t + \varepsilon_{ijt} \tag{1}$$

where the dependent variable for each trade flow corresponds to the rate of change (in log differences) of the exports or imports of each firm i either for or from each partner j in a given month t of year n (2020 and 2021) in relation to the average of the same month in the three years, k, before the pandemics (2017, 2018 and 2019). Establishing the reference period in this way deals with potential shifts in trade patterns that may have occurred specifically in 2019.[3] The vector X_{jt} includes the relevant variables in each specification, usually the number of monthly deaths attributed to COVID-19 per thousand inhabitants and the lockdown stringency index, which is our main variable of interest. Our specifications includes firm, γ_i, and country fixed effects, δ_j, to control for time-invariant unobserved factors that are specific to the firm and to the country, respectively, and can impact trade flows. We also consider time fixed effects, λ_t, to account for the macroeconomic conditions. ε_{ijt} is the error term.

In order to reduce endogeneity concerns linked with the existence of an omitted variable simultaneously determining the path of the stringency index, deaths and trade flows, we perform several robustness checks. The panels of Figure 3 plot the number of deaths per thousand inhabitants due to COVID-19 and the stringency index for the main Portuguese trade partners. The visual inspection

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2. We use the algorithm of Guimaraes and Portugal (2010) through the Stata command *reghdfe* (Correia 2016) to estimate the model with three high-dimensional fixed effects.

3. A point worth referring relates to the existence of zeros in several firm-product-partner observations, which accrue to the existence of a reporting threshold or to the actual absence of trade, and are more prevalent at a monthly frequency. Although, year-on-year mid-point growth rates could be calculated, the reading of the estimated coefficients is affected. Moreover, contrary to papers focusing on margins, the partial disregard of the extensive margin of trade is not such a relevant feature in our analysis.
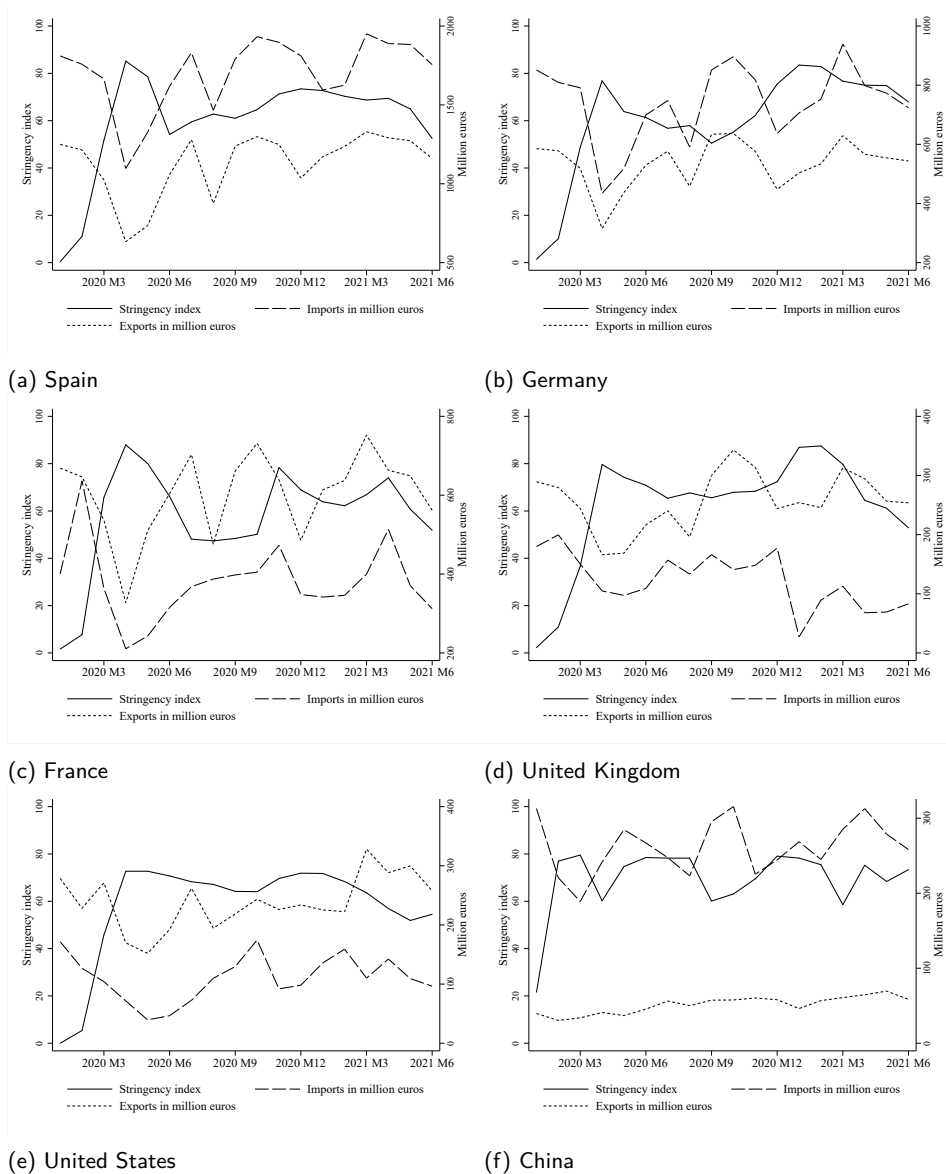
(a) Spain

(b) Germany

(c) France

(d) United Kingdom

(e) United States

(f) China

Figure 2: Total trade flows and stringency index by partner country

Sources: International Trade Data (Statistics Portugal) and `https://covidtracker.bsg.ox.ac.uk/` for the lockdown stringency index.

of the graphs shows an absence of co-movement between the two series, which could be associated with an omitted variable. In addition, we run regression 1 using the lagged stringency index as the independent variable. This basic procedure would potentially break the endogeneity link since changes in containment measures

in previous months are less likely to affect negatively current trade flows. The results obtained do not change significantly, thus giving us comfort in terms of the interpretation of baseline results.

(a) Spain

(b) Germany

(c) France

(d) United Kingdom

(e) United States

(f) China
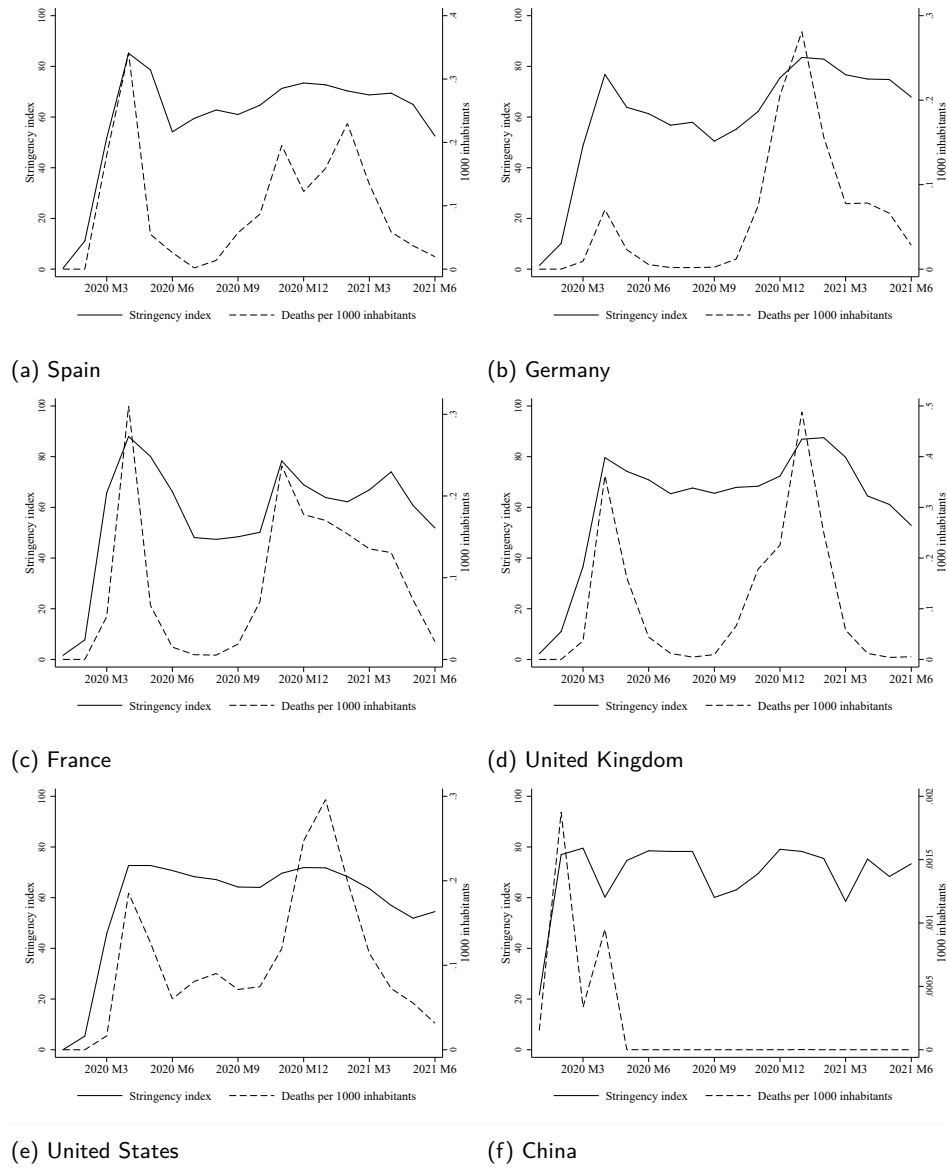
Figure 3: Stringency index and deaths per thousand inhabitants due to COVID-19 by partner country

Sources: `https://covidtracker.bsg.ox.ac.uk/` for the lockdown stringency index and `https://coronavirus.jhu.edu` for deaths per thousand inhabitants due to COVID-19.

4. Results

This section presents the results from our empirical exercise organized along five blocks: the overall impact of stringency measures on nominal export and import flows, the time-varying dimension of this effect during the six quarters from the beginning of 2020 to mid-2021, the differential impact of lockdowns in relation to firm's size, the differential impact related to the presence of foreign capital as a proxy for GVC participation and, finally, the impacts at industry and country level dimensions.

4.1. Exports and imports

The estimates obtained for the specification presented in regression 1 taking monthly growth rates of nominal exports of Portuguese firms from January 2020 up to June 2021 are presented in Table 2. The first and second columns consider the number of deaths per thousand inhabitants and the stringency index separately, while the third column takes them jointly. In all cases, the coefficients are negative and highly significant. The inclusion of firm, destination country and time fixed effects allows for robust conclusions regarding the impact of stringency measures on international trade flows. The comparison of the coefficients estimated for the impact of the number of deaths and for the stringency index in the three specifications offers further evidence on the independence of the two effects estimated. When variables are taken together in the regression, coefficients for deaths and for the stringency index do not strongly change their magnitude relatively to the specification where they are taken separately and both remain highly significant with the expected signal. It is worth noticing that the estimates for the three cases are obtained from the sample used for the most complete specification, thus enabling the comparison of results.

Taking the last column of Table 2 as our preferred specification, we conclude that one percentage point increase in the stringency index leads to, on average, a negative change in the growth rate of nominal exports of approximately 0.15 percentage points. Another reading would be that full stringency (index equal to 100) would approximately reduce exports by about 15 percentage points in comparison with the reference period. However, this figure is plagued by the poor approximation of the difference in logarithms to the growth rate of a variable when changes are large. As for the coefficient of the number of deaths, it signals that one additional death per million inhabitants reduces the rate of change of nominal exports by approximately 0.025 percentage points.

The estimates obtained for imports are presented in Table 3 and are organized in the same way described above for exports. Coefficients for the number of deaths and the lockdown stringency index are negative and significant in all specifications. The consistency along the three specifications is also maintained. On average, under the preferred one, with both deaths and the stringency index included, an increase of one percentage point in the stringency index leads to a negative change

VARIABLES	(1) HDFE	(2) HDFE	(3) HDFE
Deaths per thousand	-31.197***		-25.250***
	(3.806)		(3.994)
Stringency index		-0.213***	-0.149***
		(0.031)	(0.032)
Constant	16.755***	26.449***	24.712***
	(0.367)	(1.745)	(1.764)
Observations	447,535	447,535	447,535
Adjusted R-squared	0.117	0.117	0.117
Firm FE	YES	YES	YES
Country FE	YES	YES	YES
Time FE	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2. Stringency of lockdowns and firms' exports

Notes: Estimates obtained with the sample used for specification in third column. The dependent variable corresponds to the rate of change of exports by each firm to a given country in a given month of the period January 2020 - June 2021 relatively to the reference period (average of firm's exports for that country in the corresponding months of 2017, 2018 and 2019).

VARIABLES	(1) HDFE	(2) HDFE	(3) HDFE
Deaths per thousand	-28.265***		-22.013***
	(3.667)		(3.901)
Stringency index		-0.196***	-0.133***
		(0.029)	(0.031)
Constant	5.749***	14.999***	13.088***
	(0.357)	(1.699)	(1.727)
Observations	522,687	522,687	522,687
Adjusted R-squared	0.120	0.120	0.120
Firm FE	YES	YES	YES
Country FE	YES	YES	YES
Time FE	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3. Stringency of lockdowns and firms' imports

Notes: Estimates obtained with the sample used for specification in third column. The dependent variable corresponds to the rate of change of imports by each firm to a given country in a given month of the period January 2020 - June 2021 relatively to the reference period (average of firm's imports for that country in the corresponding months of 2017, 2018 and 2019).

in the growth rate of nominal exports of about 0.13 percentage points, a number slightly smaller than the one obtained for exports. The coefficients for the number

of deaths is also smaller than the one obtained for exports, suggesting that deaths abroad have a lower impact for imports than for exports. Although supply effects also play a role, this corresponds to the expected result as health conditions abroad are likely to affect foreign rather than domestic demand decisions.

The coefficients of specifications where the lockdown stringency index is taken with lags are presented in columns 1 and 2 of tables E.1 and E.2 in Appendix E. Results of the one lag specification remain significant and qualitatively unchanged. Comparatively to our baseline result, the coefficient for the lockdown stringency index is less negative for exports and more negative for imports. The coefficients obtained under the two lag specification are not significant at a 5 percent significance level. As for the use of alternative variables to assess mobility constraints, as those publicly available from Google Mobility Reports, coefficients are presented in columns 3 and 4 of tables E.1 and E.2 and our main results remain qualitatively unchanged. These coefficients are positive as higher mobility is equivalent to lower restrictions (Table E.3).

The Angrist *et al.* (2020) stringency index is a key ingredient in many COVID-related empirical exercises. In order to ascertain the robustness of results we run regressions with two variants of the index: one excluding dimensions that are not expected to interfere with traders' activity and one keeping only dimensions closely related to mobility. We construct the sub-indices with the same methodology of the overall stringency index and results are presented in Table E.4 in Appendix E. The coefficients in the regressions are qualitatively similar to those obtained in the baseline specification, thus sustaining our conclusions. Comparing with the benchmark specification, coefficients associated with the sub-index that excludes only some dimensions, in columns 1 and 3 of Table E.4, are slightly lower for exports and slightly higher for imports. In turn, the coefficients associated with the more strict sub-index are both smaller but significant and with the expected signal. In addition, we ran regressions for each individual dimension separately and the indicator of international travel controls came out significant and with a magnitude higher than the baseline specification for the case of imports.

Another discussion concerns using the number of COVID-19 reported cases instead of deaths per thousand inhabitants as a proxy for health conditions. We have tested this alternative and, although some coefficients were consistent, overall results were not satisfactory as estimates would sometimes change sign. This is not a surprising feature. It has been acknowledged that the number of reported cases is strongly associated with the intensity of testing, which is quite different across time and countries. Therefore, deaths per thousand inhabitants are a much more reliable monthly source of information.

Overall, results show that the pandemics had a sizeable impact on trade both due to restrictions to movement, as proxied by the lockdown stringency index, and due to confidence or demand effects, which are proxied the number of deaths per thousand inhabitants. Nevertheless, this impact does not seem to have been uniform along the successive waves of the pandemics, thus time-varying effects are the focus of the next subsection.

4.2. Time-varying effects

As the pandemics evolved up to the first half of 2021, one salient feature was the recovery of international trade flows, which raised the hypothesis of adaptation by firms to prevailing restrictions. The time-varying impact of lockdowns was estimated using our preferred specification and a set of categorical variables that identify each of the six quarters between the beginning of 2020 and the first half of 2021 and interact with the stringency index. The rich set of firm, country and time fixed effects is maintained.

The estimated coefficients and the 95 percent confidence interval for exports are plotted in Figure 4. Results show that the impact of lockdowns was strongest in the first two quarters of 2020. In the last two quarters of 2020, the upper bound of the confidence interval is above zero, i.e., the coefficients are not statistically significant at a 5 percent significance level. This path suggests that firms may have indeed adapted their activities in order to operate under the effect of containment measures. However, the negative impact partly emerges again in the first quarter of 2021, with the third wave of the pandemics and a probable stricter enforcement of containment measures, and returns to non-significant in the second quarter of 2021. As regards imports, this pattern is also visible, though in the last quarter of 2020 the coefficient remains significant, nonetheless less negative than in the second quarter of 2020 (Figure 5).
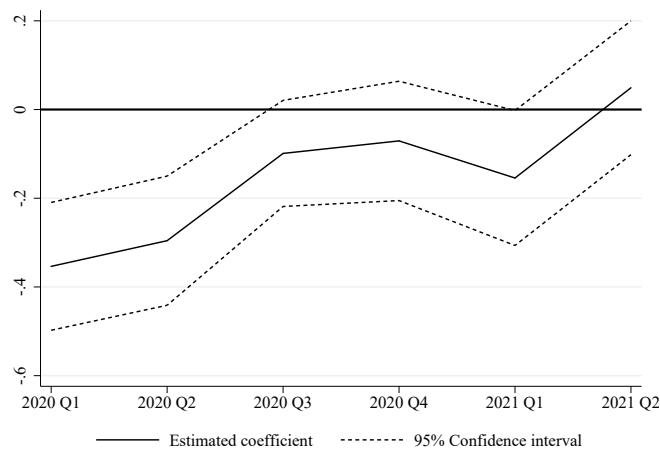
Figure 4: Quarterly impact of lockdowns on exports in 2020 and first half of 2021

Notes: Estimation results in the Table A.1.

As for the impact of health conditions on quarterly firm-level trade flows, although there are differences in terms of relative magnitude, the quarterly pattern is close to the one registered for the stringency of lockdowns in the case of exports, but it remains negative and significant in the third quarter of 2020 and non-significant in the first quarter of 2021. Moreover, as for imports, health conditions did not impact on the last two quarters of 2020 at a 5 percent significance level and got negative and significant in the first quarter of 2021. As previously mentioned, to interpret the impact of foreign health conditions in imports is not straightforward. These results are presented in Table A.1 in Appendix A.
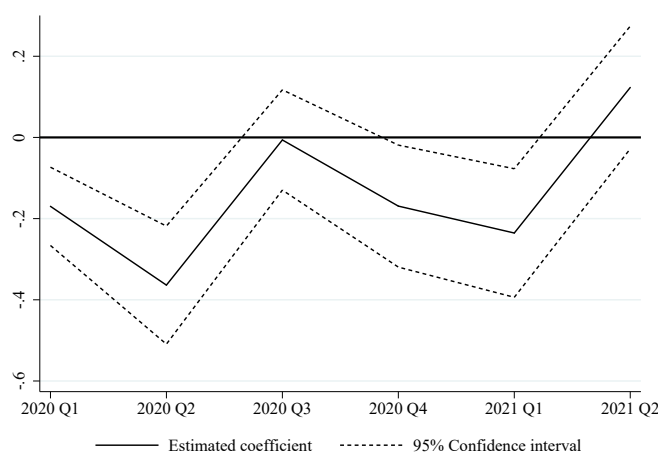
Figure 5: Quarterly impact of lockdowns on imports in 2020 and first half of 2021

Notes: Estimation results in the Table A.1.

4.3. Size of traders

The size of traders is an important heterogeneity dimension that may have affected the response of their trade flows to the pandemics and related lockdowns. In this subsection we turn to this issue and run high-dimensional fixed effect regressions that control for the size of firms as measured by a combination of total turnover and employment in 2019. The econometric procedure is similar to the one used to identify the quarterly effects presented in the previous subsection, with size dummies that interact with the stringency index. Firms are labelled along four

categories: micro, small, medium and large. The classification criterion corresponds to the definition used by the European Commission.[4]

The results for exports are plotted in Figure 6 and show that the negative impact of the stringency of containment measures adopted in the destination countries increases with the firm size. This result is also obtained by Bricongne *et al.* (2021). Similarly, larger importers are also more affected by the lockdowns in the origin countries (Figure 7). Modelling this differential impact and finding explanations for this result is beyond the scope of this paper. Nevertheless, it is reasonable to argue that larger firms deal with larger shipments, thus being less agile in finding ways of countervailing restrictions and finding alternatives for transportation, when compared with smaller ones.
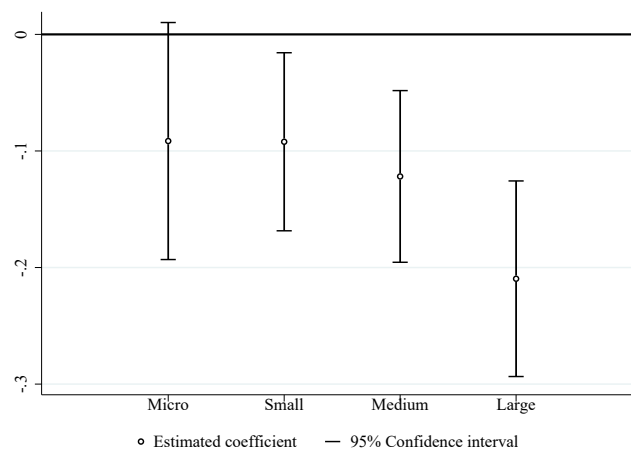
Figure 6: Impact of lockdowns on exports by firm size

Notes: Estimation results in the Table B.1.

4.4. Foreign capital as a proxy for GVC participation

The differential impact of lockdowns emerging from the participation of firms in GVCs is another important empirical question. The main obstacle in this analysis is finding a variable that accurately describes the firms' engagement in GVCs.

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4. According to the Recommendation of the European Commission 2003/361/EC, the category of micro-sized comprises firms that employ fewer than 10 workers and an annual turnover or total annual balance sheet not in excess of 2 million euros. In turn, small firms employ fewer than 50 people and have an annual turnover or total annual balance sheet not in excess of 10 million euros. The medium-sized firms employ fewer than 250 people and have an annual turnover not in excess of 50 million euros or a total annual balance sheet not in excess of 43 million euros. Thus, the large firms are those that do not belong to any of the aforementioned categories.
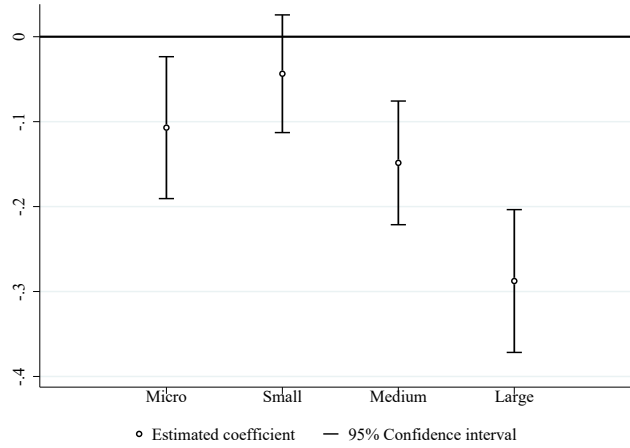
Figure 7: Impact of lockdowns on imports by firm size

Notes: Estimation results in the Table B.1.

The absence of firm-level input-output matrices makes it necessary to find proxy variables. One possibility is to simply use the share of imports on firm's total trade. However, many firms are not two-way traders simply because they are part of larger groups where GVC operations take place. Conversely, many firms import and export as part of their wholesale trade activity, which does not reflect GVC engagement. Another alternative is to associate GVC participation to *upstreamness* as defined in Antras *et al.* (2012). Nevertheless, the latter concept places firms in the production chain and is not a direct measure of their involvement in complex GVCs. In this paper we take the existence of foreign capital at the firm-level as a proxy for their participation in GVCs. The association between foreign capital and GVCs has been established in several papers. Some examples are Cadestin *et al.* (2018) and Adarov and Stehrer (2021). It is relevant to note that, in our database, industries with the highest percentage of firms with foreign capital are also those with the highest import content. In practical terms, we define a binary variable for firms with and without foreign capital. Establishing a more restrictive threshold does not significantly change the results because the distribution of foreign capital shares has high density on lower and upper tails. This information was externally included in our database and originally available at the *Quadros de Pessoal* dataset for 2019. The percentage of foreign capital is not reported for 13 percent of observations in exports and 26 percent in imports.

Table 4 replicates previous analysis, now with the focus on foreign capital participation. It shows that the detrimental impact of lockdowns is higher for firms with foreign capital, i.e., those more integrated in GVCs, for both export and import flows. Although the sample is not directly comparable, the magnitude of the impact of lockdowns is larger than in the baseline specification. This result

is not surprising as the bottlenecks originated by limitations to mobility arising from containment measures affect primarily firms which are mostly dependent on internal supply chains.

VARIABLES	(1) Exports	(2) Imports
Deaths per thousand		
No foreign capital	-32.523***	-27.058***
	(4.516)	(4.493)
With foreign capital	-7.394	-7.846
	(6.815)	(5.999)
Stringency		
No foreign capital	-0.100***	-0.125***
	(0.034)	(0.033)
With foreign capital	-0.241***	-0.163***
	(0.042)	(0.039)
Constant	22.643***	11.263***
	(1.846)	(1.828)
Observations	412,949	476,874
R-squared	0.133	0.136
Firm FE	YES	YES
Country FE	YES	YES
Time FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4. Impact of lockdowns on export and import flows for firms with and without foreign capital

Notes: "Foreign capital" is a binary variable for firms with and without foreign capital. The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

4.5. Industries and trade partners

Our database contains detailed information relatively to the goods traded by the firms and the partner countries involved. This makes it possible to assess the different impact of lockdowns across manufacturing industries and further discuss the impact of such containment measures on international supply chains. Firstly, we perform this sectoral analysis by organizing firms along their main economic activity, defined by the NACE Rev.2 classification and creating a set of categorical variables that identify each manufacturing industry. The set of high dimensional fixed effects is also included. Secondly, we follow the same strategy for the trade partner dimension.

Figure 8 plots the coefficients associated to the lockdown stringency index for the main manufacturing industries in terms of export flows. In the horizontal axis, sectors are ordered from the highest to the lowest import content, as reported in Rua and Cardoso (2019). The coefficient estimated for "transport equipment" is by far the most negative. This industry posts a high import content (71.2 percent) and has

been widely identified as highly integrated in GVCs (e.g., Blázquez and González-Díaz 2016 and Sturgeon and Biesebroeck 2011). Conversely, industries such as "agriculture", "food" and "chemicals" present coefficients that are not statistically different from zero. In the latter case, although there is a high import content (50.4 percent) the industry includes pharmaceutical products, whose demand has not been affected by containment measures. It is also relevant to note that industries like "footwear" and "textiles", whose import content is lower (40.6 and 38.1 percent, respectively), post coefficients for the stringency index that are negative and statistically significant. These sectors produce on the basis of clear seasonal patterns and have been quite affected by the stringency measures, notably the closure of retail trade, i.e., the access of consumers to new clothing and footwear collections was limited. In addition, these industries are more labour-intensive and thus more affected by the absence of workers due to containment measures.

○ Estimated coefficient   — 95% Confidence interval
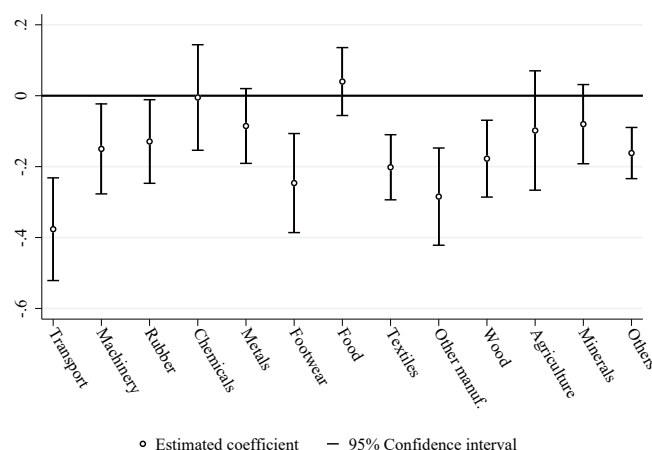
Figure 8: Impact of lockdowns on exports by sector

Notes: Estimation results in the Table C.2. The industries represented are, respectively, Transport equipment; Machinery; Rubber and plastics; Chemicals; Metals; Footwear; Food and beverages; Textiles and wearing apparel; Other manufacturing; Wood and paper; Agriculture, forestry and fishing and Other minerals. The correspondence between these manufacturing industries and NACE Rev.2 is presented in Table C.1. Industries are ordered from the highest to the lowest import content, as reported in Rua and Cardoso (2019).

The analysis was replicated for firm-level import flows and results are presented in Figure 9. In this case, many industries post coefficients that are not statistically different from zero. Nevertheless, the coefficient for the "transport equipment" is again the most negative and statistically significant. The "footwear" and "textiles" industries also present negative and significant coefficients, signalling that containment measures adopted in partner countries led to lower imports of these products, probably due to disruptions in foreign production.
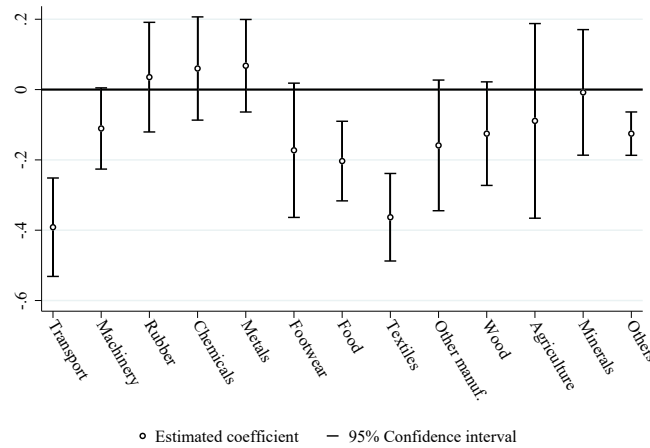
Figure 9: Impact of lockdowns on imports by sector

Notes: Estimation results in the Table C.2. The industries represented are, respectively, Transport equipment; Machinery; Rubber and plastics; Chemicals; Metals; Footwear; Food and beverages; Textiles and wearing apparel; Other manufacturing; Wood and paper; Agriculture, forestry and fishing and Other minerals. The correspondence between these manufacturing industries and NACE Rev.2 is presented in Table C.1. Industries are ordered from the highest to the lowest import content, as reported in Rua and Cardoso (2019).

The analysis at the partner country level follows the same approach adopted above for industries. We include in the regression a set of categorical variables that identify important trade partners, over and above the firm-level, country and time fixed effects. Results for exports and imports with the main Portuguese trade partners are presented in figures 10 and 11, respectively. In both figures the countries in the horizontal axis are ordered from the highest to the lowest weight as sources of value added embodied in Portuguese exports, as reported by OECD (2005). The analysis of the coefficients estimated for the impact of the stringency measures on exports shows that they are more negative in Spain, Germany, France and United Kingdom. These are the four main Portuguese export partners but they are also key suppliers of intermediate products necessary for Portuguese exporters. One German automotive multinational accounts for an important share of Portuguese exports and Amador and Stehrer (2014) has also documented the Iberian GVCs as important. Results for the stringency coefficient are not significantly different from zero in the cases of Italy and China. The number of Portuguese firms exporting to China is relatively small, which implies the widening of the confidence intervals.

The analysis concerning import partners conveys a somewhat different message (Figure 11). The coefficients are more negative and statistically significant in the United Kingdom, Italy and China. Given our interpretation of the coefficients, containment measures imposed in these countries affected their ability to meet
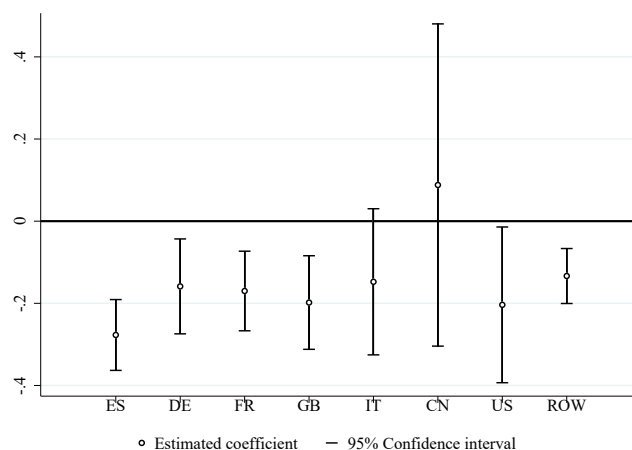
Figure 10: Impact of stringency of lockdowns on export flows by destination country

Notes: Estimation results in the Table D.1. Countries in the horizontal axis are ordered from the highest to the lowest weight as sources of value added embodied in Portuguese exports, as reported by OECD (2005). "ES" stands for Spain, "DE" for Germany, "FR" for France, "GB" for United Kingdom, "IT" for Italy, "CN" for China, "US" for United States and "ROW" for Rest of the World.
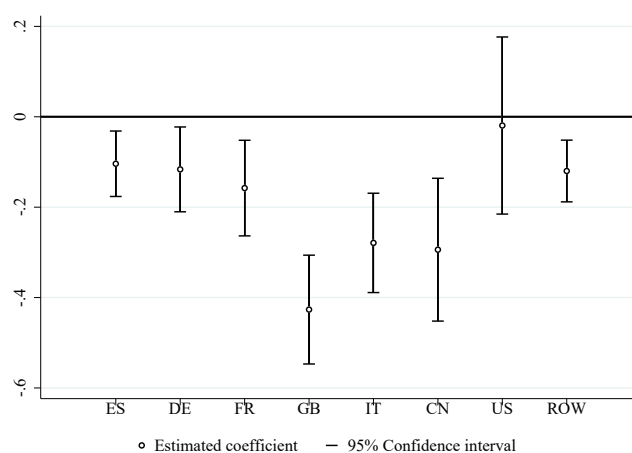
Figure 11: Impact of stringency of lockdowns on import flows by origin country

Notes: Estimation results in the Table D.1. Countries in the horizontal axis are ordered from the highest to the lowest weight as sources of value added embodied in Portuguese exports, as reported by OECD (2005). "ES" stands for Spain, "DE" for Germany, "FR" for France, "GB" for United Kingdom, "IT" for Italy, "CN" for China, "US" for United States and "ROW" for Rest of the World.

Portuguese orders, possibly due to tighter border controls or disturbances in their production.

5. Concluding remarks

The impact of the COVID-19 pandemics in the world economy was strong in several dimensions, and also in what concerns international trade flows. It is quite relevant to assess the impact of lockdowns on these flows, notably along time and in terms of firms' basic heterogeneity dimensions. Knowledge about the ability demonstrated by international traders to adapt to the measures underpinning lockdowns is valuable because this type of restrictions may be implemented under different future contexts. Understanding how firm's size interacts with these impacts is also important to design economic policy responses. Lastly, knowledge about the differential impact associated to the participation in GVCs, proxied by foreign capital participations, and also along industries and trade partners, hints at the interplay between lockdowns and the operation of international supply chains.

We conclude that the effects of lockdowns on trade flows are sizeable and similar for exports and imports. The quarterly impact of lockdowns on trade has diminished as of the second half of 2020, signalling strong adaptability by firms to operate under adverse circumstances regarding mobility and working conditions. The third wave of the pandemics in late 2020 and early 2021, brought about a stronger impact of lockdowns, possibly due to stronger enforcement of existing containment measures, but such effect wore off in the second quarter of 2021. In addition, the detrimental impact of lockdowns increases with firm size, both in exports and imports. Moreover, firms with foreign capital, industries with high import content and the trade partners that are more important as sources of value added to be embodied in exports are also those where the negative impact of lockdowns on trade is estimated to be larger.

The future of international trade is likely to be affected by the pandemic crisis. Firstly, the pre-existing protectionist trends may be reinforced by some governments' drive to promote domestic production as a shield against prolonged and severe supply chain disruptions. These concerns do not seem to be supported by our results. Although the most affected firms are those typically linked to GVCs, international traders evidenced a very strong degree of adaptation and managed to operate with containment measures. Nevertheless, after this experience, firms may have decided to re-optimize production and supply chains, a development that will be interesting to assess empirically in the near future. Secondly, the pandemics has been reinforcing the upward trend in international trade of non-tourism services, notably those associated to communications and data. The quantitative impact of lockdowns in international trade of non-tourism services is a dimension not analysed in this paper but it stands as an interesting path for research going forward.

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Appendix A: Time-varying effects

VARIABLES	(1) Exports	(2) Imports
Deaths per thousand		
2020		
1st Quarter	-46.275***	-31.929***
	(15.070)	(11.032)
2nd Quarter	-71.659***	-45.318***
	(7.502)	(6.917)
3rd Quarter	-67.651***	9.857
	(24.487)	(25.287)
4th Quarter	0.249	12.079*
	(7.239)	(6.857)
2021		
1st Quarter	-12.986*	-38.022***
	(7.514)	(7.600)
2nd Quarter	-0.621	9.312
	(9.316)	(9.569)
Stringency		
2020		
1st Quarter	-0.354***	-0.170***
	(0.073)	(0.049)
2nd Quarter	-0.296***	-0.364***
	(0.074)	(0.074)
3rd Quarter	-0.099	-0.006
	(0.061)	(0.063)
4th Quarter	-0.071	-0.169**
	(0.069)	(0.077)
2021		
1st Quarter	-0.154**	-0.235***
	(0.078)	(0.081)
2nd Quarter	0.049	0.123
	(0.077)	(0.077)
Constant	23.538***	13.248***
	(1.919)	(2.020)
Observations	447,535	522,687
R-squared	0.139	0.145
Firm FE	YES	YES
Country FE	YES	YES
Time FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.1. Impact of stringency of lockdowns on export and import flows for each quarter of 2020 and 2021

Notes: These results are graphically represented in Figures 4 and 5. The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

Appendix B: Size of traders

VARIABLES	(1) Exports	(2) Imports
Deaths per thousand		
Micro	-21.069*	-30.748***
	(10.976)	(7.936)
Small	-32.252***	-42.045***
	(6.440)	(5.303)
Medium	-32.560***	-22.425***
	(5.494)	(5.963)
Large	-10.651	17.632**
	(7.033)	(7.362)
Stringency		
Micro	-0.091*	-0.107**
	(0.052)	(0.043)
Small	-0.092**	-0.044
	(0.039)	(0.035)
Medium	-0.122***	-0.149***
	(0.038)	(0.037)
Large	-0.210***	-0.288***
	(0.043)	(0.043)
Constant	22.512***	10.986***
	(1.846)	(1.826)
Observations	412,949	476,874
R-squared	0.133	0.137
Firm FE	YES	YES
Country FE	YES	YES
Time FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.1. Impact of stringency of lockdowns on export and import flows by firm size

Notes: These results are graphically represented in Figures 6 and 7. The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

Appendix C: Manufacturing industries

Sector		NACE Rev. 2	
1	Transport equipment	29	Manufacture of motor vehicles, trailers and semi-trailers
		30	Manufacture of other transport equipment
2	Machinery	26	Manufacture of computer, electronic and optical products
		27	Manufacture of electrical equipment
		28	Manufacture of machinery and equipment n.e.c.
3	Rubber and plastics	22	Manufacture of rubber and plastic products
4	Chemicals	20	Manufacture of chemicals and chemical products
		21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
5	Metals	24	Manufacture of basic metals
		25	Manufacture of fabricated metal products, except machinery and equipment
6	Footwear	15	Manufacture of leather and related products
7	Food and beverages	10	Manufacture of food products
		11	Manufacture of beverages
8	Textiles and wearing apparel	13	Manufacture of textiles
		14	Manufacture of wearing apparel
9	Other manufacturing	31	Manufacture of furniture
		32	Other manufacturing
10	Wood and paper	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
		17	Manufacture of paper and paper products
		18	Printing and reproduction of recorded media
11	Agriculture, forestry and fishing	01	Crop and animal production, hunting and related service activities
		02	Forestry and logging
		03	Fishing and aquaculture
12	Other minerals	23	Manufacture of other non-metallic mineral products
		05	Mining of coal and lignite
		06	Extraction of crude petroleum and natural gas
		07	Mining of metal ores
		08	Other mining and quarrying

Table C.1. Manufacturing breakdown

Notes: Industries are organized in descending order of the imported content of exports, according to the most recent input-output matrices published by Statistic Portugal (with reference to the year 2017).

VARIABLES	(1) Exports	(2) Imports
Deaths per thousand		
Transport equipment	9.240	33.371***
	(14.825)	(12.925)
Machinery	-8.811	26.379**
	(13.061)	(12.199)
Rubber and plastics	-20.082*	-26.477
	(11.537)	(16.623)
Chemicals	9.870	2.438
	(15.527)	(16.263)
Metals	-21.577**	-22.815
	(10.049)	(14.299)
Footwear	-23.662	-73.546***
	(17.791)	(21.887)
Food and beverages	-38.991***	22.080*
	(8.789)	(12.272)
Textiles and wearing apparel	-45.696***	-20.725
	(8.952)	(14.331)
Other manufacturing	-50.619***	-57.442***
	(14.190)	(22.221)
Wood and paper	-4.636	2.334
	(10.617)	(16.968)
Agriculture, forestry and fishing	-27.436	-8.082
	(21.293)	(31.838)
Other minerals	-41.330***	-1.878
	(11.315)	(20.479)
Other sectors	-26.152***	-34.705***
	(6.160)	(4.346)
Stringency		
Transport equipment	-0.376***	-0.391***
	(0.074)	(0.071)
Machinery	-0.150**	-0.111*
	(0.065)	(0.059)
Rubber and plastics	-0.129**	0.035
	(0.060)	(0.080)
Chemicals	-0.005	0.060
	(0.076)	(0.075)
Metals	-0.085	0.068
	(0.054)	(0.067)
Footwear	-0.246***	-0.173*
	(0.071)	(0.097)
Food and beverages	0.040	-0.203***
	(0.049)	(0.058)
Textiles and wearing apparel	-0.202***	-0.363***
	(0.047)	(0.064)
Other manufacturing	-0.285***	-0.159*
	(0.070)	(0.095)
Wood and paper	-0.178***	-0.125*
	(0.055)	(0.075)
Agriculture, forestry and fishing	-0.098	-0.089
	(0.086)	(0.141)
Other minerals	-0.080	-0.008
	(0.057)	(0.091)
Other sectors	-0.162***	-0.125***
	(0.037)	(0.031)
Constant	24.777***	13.004***
	(1.765)	(1.727)
Observations	447,535	522,687
R-squared	0.139	0.145
Firm FE	YES	YES
Country FE	YES	YES
Time FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.2. Impact of stringency of lockdowns on export and import flows by activity sector

Notes: These results are graphically represented in Figures 8 and 9. The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

Appendix D: Partner countries

VARIABLES	(1) Exports	(2) Imports
Deaths per thousand		
Spain	-61.733***	-49.388***
	(8.366)	(6.281)
Germany	-0.066	-2.626
	(15.117)	(11.409)
France	-63.969***	-27.830**
	(11.010)	(12.615)
United Kingdom	-40.177***	-10.226
	(10.279)	(11.815)
Italy	-29.406*	-13.897
	(17.843)	(10.016)
China	1,882.189	4,877.553*
	(6,637.550)	(2,684.030)
United States	2.262	-33.094
	(23.885)	(26.820)
Rest of the World	-10.302**	-8.406*
	(4.640)	(4.888)
Stringency		
Spain	-0.277***	-0.104***
	(0.044)	(0.037)
Germany	-0.159***	-0.116**
	(0.059)	(0.048)
France	-0.170***	-0.158***
	(0.049)	(0.054)
United Kingdom	-0.198***	-0.427***
	(0.058)	(0.061)
Italy	-0.148	-0.279***
	(0.091)	(0.056)
China	0.088	-0.294***
	(0.200)	(0.081)
United States	-0.204**	-0.019
	(0.097)	(0.100)
Rest of the World	-0.134***	-0.120***
	(0.034)	(0.035)
Constant	26.033***	14.900***
	(1.795)	(1.818)
Observations	447,535	522,687
R-squared	0.139	0.145
Firm FE	YES	YES
Country FE	YES	YES
Time FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.1. Impact of stringency of lockdowns on export and import flows by destination country

Notes: These results are graphically represented in Figures 10 and 11. The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

Appendix E: Robustness tests

VARIABLES	(1) HDFE	(2) HDFE	(3) HDFE	(4) HDFE
Deaths per thousand	-29.957***	-30.252***	-20.911***	-16.336***
	(3.842)	(3.856)	(4.169)	(4.340)
Stringency – 1 month lag	-0.069**			
	(0.032)			
Stringency – 2 months lag		0.058*		
		(0.032)		
Transit-station mobility			0.211***	
			(0.033)	
Retail mobility				0.229***
				(0.031)
Constant	20.330***	13.513***	21.721***	21.018***
	(1.681)	(1.772)	(0.910)	(0.719)
Observations	447,529	420,868	435,280	435,544
Adjusted R-squared	0.117	0.119	0.119	0.119
Firm FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.1. Stringency of lockdowns, retail and transit-station Google mobility and firms' exports

Notes: The dependent variable corresponds to the rate of change of the exports of each firm for a given country in a given month of 2020 and the first half of 2021 in relation to the reference period (average of each firm exports for that country and month in 2017, 2018 and 2019).

VARIABLES	(1) HDFE	(2) HDFE	(3) HDFE	(4) HDFE
Deaths per thousand	-24.736***	-29.394***	-11.654***	-14.362***
	(3.708)	(3.721)	(4.232)	(4.383)
Stringency – 1 month lag	-0.218***			
	(0.029)			
Stringency – 2 months lag		-0.025		
		(0.030)		
Transit-station mobility			0.236***	
			(0.033)	
Retail mobility				0.143***
				(0.030)
Constant	17.538***	6.724***	9.022***	6.091***
	(1.619)	(1.710)	(0.890)	(0.722)
Observations	522,684	492,133	490,747	490,738
Adjusted R-squared	0.120	0.122	0.120	0.120
Firm FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.2. Stringency of lockdowns, retail and transit-station Google mobility and firms' imports

Notes: The dependent variable corresponds to the rate of change of the imports of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm imports for that country and month in 2017, 2018 and 2019).

	Transit-station mobility	Retail mobility
All countries	-60.34	-62.62
Portugal	-86.81	-67.66
Spain	-73.06	-70.98
Germany	-85.48	-75.26
France	-84.70	-83.18
United Kingdom	-94.63	-80.58
United States	-91.74	-72.87

Table E.3. Correlation between the stringency index and the transit-station and retail mobility (in percentage)

Note: There is no information for China in Google Mobility Reports.

VARIABLES	(1) Exports	(2) Exports	(3) Imports	(4) Imports
Deaths per thousand	-24.878***	-28.665***	-19.184***	-24.444***
	(4.032)	(3.898)	(3.960)	(3.739)
C1,C2,C5,C6,C7,C8 index	-0.128***		-0.152***	
	(0.028)		(0.026)	
C6,C7,C8 index		-0.061***		-0.087***
		(0.023)		(0.021)
Constant	22.008***	19.499***	12.231***	9.917***
	(1.212)	(1.075)	(1.188)	(1.068)
Observations	447,562	447,562	522,699	522,699
R-squared	0.139	0.139	0.145	0.145
Firm FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.4. Alternative indices of lockdowns' stringency

Notes: The C1,C2,C5,C6,C7,C8 index comprises school closures (C1), workplace closing (C2), public transportation (C5), stay at home order (C6), restrictions on internal movement (C7) and international travel controls (C8). The C6,C7,C8 index includes the last three indicators. These sub-indices are constructed with the methodology of the overall stringency index (`https://github.com/OxCGRT/covid-policy-tracker/blob/master/documentation/index_methodology.md`). The dependent variable corresponds to the rate of change of the exports and imports, respectively, of each firm for a given country in a given month of 2020 and of the first half of 2021 in relation to the reference period (average of each firm exports and imports, respectively, for that country and month in 2017, 2018 and 2019).

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