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Globalization in the Time of COVID-19

Abstract

The economic effects of a pandemic crucially depend on the extent to which countries are connected in global production networks. In this paper we incorporate production barriers induced by COVID-19 shock into a Ricardian model with sectoral linkages, trade in intermediate goods and sectoral heterogeneity in production. We use the model to quantify the welfare effect of the disruption in production that started in China and quickly spread across the world. We find that the COVID-19 shock has a considerable impact on most economies in the world, especially when a share of the labor force is quarantined. Moreover, we show that global production linkages have a clear role in magnifying the effect of the production shock. Finally, we show that the economic effects of the COVID-19 shock are heterogeneous across sectors, regions and countries, depending on the geographic distribution of industries in each region and country and their degree of integration in the global production network.

JEL-Codes: F100, F110, F140, F600.

Keywords: COVID-19 shock, globalization, production barrier, sectoral interrelations, computational general equilibrium.

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1 Introduction

Globalization allows firms to source intermediate inputs and sell final goods in many different countries. The diffusion of a local shock through input-output linkages and global value chains has been extensively studied (see for example Carvalho et al. (2016)) but little is known on how a pandemic affects global production along with its diffusion.[1]

In this paper we study the role of global production linkages in the transmission of a pandemic shock across countries. We exploit an unprecedented disruption in production in the recent world history, namely the global spread of COVID-19 virus disease, to instruct a multi-country, multi-sector Ricardian model with interactions across tradable and non-tradable sectors observed in the input-output tables. We use the model to quantify the trade and welfare effects of a disruption in production that started in China and then quickly spread across the world. The spread of COVID-19 disease provides a unique set-up to understand and study the diffusion of a global production shock along the global value chains for three main reasons. First, it is possibly the biggest production disruption in the recent world history. With around 2.424.419 cases, 166.256 deaths and millions of people in quarantine around the world to date[2], the spread of COVID-19 disease is the largest pandemic ever experienced in the globalized world.[3] Second, the COVID-19 shock is not an economic shock in its nature, hence its origin and diffusion is independent from the fundamentals of the economy. Third, differently from any other non-economic shock experienced before, it is a global shock. Indeed, while the majority of natural disasters or epidemics have a local dimension, the spread of the COVID-19 disease has been confined to the Chinese province of Hubei only for a few weeks, to then spread across the entire world.

Understanding the effects of a global production disruption induced by a pandemic is complex. We build on the work by Caliendo and Parro (2015) who develop a tractable and simple model that allows to decompose and quantify the role that intermediate goods and sectoral linkages have in amplifying or reducing the impact of a change in tariffs. We extend their framework and introduce a role for policy intervention in deterring production. In our set-up, the policy maker can use the instrument of quarantine as a policy response to deter the COVID-19 virus diffusion; moreover, we account for the geographic distribution of industries

[1] Huang (2019) studies how diversification in global sourcing improves firm resilience to supply chain disruptions during the SARS epidemics in China. We complement his analysis by studying the effect of an epidemic shock that is not geographically confined to a specific region, but it spreads fast in the entire world

[2] as of 20th of April 2020

[3] See Maffioli (2020) for a comparison of COVID-19 with other pandemics in the recent history.

in each region and country and for the labor intensity of each sector of production to have a complete picture of the distribution of the shock across regions and sectors. The policy intervention of quarantine translates into a lockdown, a production barrier that increases the production costs for intermediates and final goods produced for the internal market as well as for the exporting market. We construct a measure of quarantine using two different pillars: first, we use a country level measure for the stringency of the policy intervention of lockdown from Hale (2020). Second, we allow the quarantine to heterogeneously affect each sector in each country using the share of work in a sector that can be performed at home (henceforth *teleworkability*) from Dingel and Neiman (2020). Crucially, in a model with interrelated sectors the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy, both non-tradable and tradable. In our framework, the policy intervention has a direct effect on the cost of each input as well as an indirect effect via the sectoral linkages.[4] Moreover, our modelling choice for the shock allows the spread of COVID-19 disease to also have a direct effect on the cost of non-tradable goods in each economy, hence on domestic trade.

We follow Dekle et al. (2008) and Caliendo and Parro (2015) and solve the model in relative changes to identify the welfare effect of the COVID-19 shock. We perform three different exercises: (i) we include the COVID-19 shock in the model and we estimate a *snap-shot* scenario based on the actual number of COVID-19 cases in each country, (ii) we include the quarantine shock in the model and estimate a quarantine scenario, imposing quarantine to a fraction of the labour force in each country, (iii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 quarantine and an indirect effect coming from the global shock affecting the other countries. We perform the three exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country. The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region and the number of COVID-19 cases in each region or country. We calibrate a 40 countries 50 sectors economy and incorporate the COVID-19 shock to evaluate the welfare effects for each country both in aggregate and at the sectoral level.

We find that the COVID-19 shock has a considerable impact on most economies in the world, especially when a share of the labor force is quarantined. In our quarantine scenario, most of

[4] This feature of the model is a key difference compared to one-sector models or multi-sector models without interrelated sectors, as highlighted by Caliendo and Parro (2015).

the countries experience a drop in real income up to 14%, with the most pronounced drops for India and Turkey.[5] We further decompose the economic impact of the COVID-19 shock by sectors and find that the income drop is widespread across all sectors. Indeed, contrary to drops in tariffs that affect only a subset of sectors, the COVID-19 shock is a production barrier that affects both home and export production in all sectors of the economy. The observed heterogeneity in the sectoral decrease in value added is partially driven by the geography of production in each country combined with the geographic diffusion of the shock, by the inter-sectoral linkages across countries, but also by the heterogeneity in the degree of *teleworkability* across sectors and countries.

The role of the global production linkages in magnifying the effect of the production shock is clear when we decompose the total income change into a *direct* component due to a domestic production shock and an *indirect* component due to global linkages. We show that linkages between countries account for a substantial share of the total income drop observed. Moreover, we estimate a simple econometric model to better understand the determinants of the observed heterogeneity in the income drop accounted for by the *direct* and the *indirect* effect. We find that the degree of trade openness of a country is a key element in explaining the observed heterogeneity.

Finally, to deeper understand the importance of global production networks in the diffusion of the shock, we investigate what would have been the impact of the COVID-19 shock in a less integrated world. To answer this question, we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the current trade barriers in each country and sector by 100 percentage points. First and unsurprisingly, a less integrated world itself implies enormous income losses for the great majority of countries in our sample. Focusing on the economic impact of the COVID-19 shock in a less integrated world compared to a world as of today, we find some interesting results. Indeed, when raising trade costs in all countries, the *indirect* component is lower than in an open economy, but it still accounts for a relevant share of the drop in income due to the COVID-19 shock. In our counterfactual exercise, the increase in trade cost mimics a world with higher trade barriers, but not a complete autarky scenario; countries would still trade, use intermediates from abroad and sell final goods in foreign countries. This finding highlights the importance of inter-sectoral linkages in the transmission of the shock: a higher degree of integration in

[5] Alternatively, one could think of imposing quarantine to 30% of the labor force for two months. Any configuration that distributes quarantined workers across months up to a total of 60% would deliver the same results in this framework. More details on the choice of the level of quarantine are provided in section 4.

the global production network implies that a shock in one country directly diffuses though the trade linkages to other countries. Trade has a two different effects in our model: on the one hand, it smooths the effect of the shock by allowing consumers to purchase and consume goods they wouldn't otherwise be able to consume in a world with production barriers in quarantine. On the other hand, the COVID-19 shock increases production costs of intermediate inputs that are used at home and abroad. Our counterfactual exercise clearly shows that an increase in trade costs would not significantly decrease the impact of the COVID-19 shock across countries. However, increasing trade barriers would imply an additional drop in real income between 14% and 33% across countries.

Our paper is closely related to a growing literature that study the importance of trade in intermediate inputs and global value chains. For example Altomonte and Vicard (2012), Antràs and Chor (2013), Antràs and Chor (2018), Antràs and de Gortari (Forthcoming), Alfaro et al. (2019), Antràs (Forthcoming), Bénassy-Quéré and Khoudour-Casteras (2009), Gortari (2019), Eaton and Romalis (2016), Hummels and Yi (2001), Goldberg and Topalova (2010), Gopinath and Neiman (2013), Halpern and Szeidl (2015)). Our paper is especially close to a branch of this literature that extends the Ricardian trade model of Eaton and Kortum (2002a) to multiple sectors, allowing for linkages between tradable sectors and between tradable and non-tradable.[6] Indeed, our paper is based on the work of Caliendo and Parro (2015) and adds an additional channel through which a policy intervention could affect welfare at home and in other countries, namely a production barrier induced by the spread of the virus. We use an unprecedented shock affecting simultaneously the majority of countries in the world to understand the response of the economy under different production barrier scenarios in free trade and a less integrated world. Moreover, we use the rich structure of the model to show the distribution of the effects of the shock across regions and sectors.

Finally, our paper contributes to the literature evaluating the impact of natural disasters or epidemics on economic activities (see for example the papers by Barrot and Sauvagnat (2016), Boehm et al. (2019), Carvalho et al. (2016), Young (2005) and Huang (2019)). Similar to Boehm et al. (2019), Barrot and Sauvagnat (2016) and Carvalho et al. (2016) and Huang (2019) we also study how a natural disaster or an epidemic affects the economy through the input channels. We add to their work by using a shock that is unprecedented both in its nature and in its effect. Indeed, while a natural disaster is a geographically localized shock that can destroy production plants and affects the rest of the economy and other countries only through input linkages, in our set-up the shock induced by COVID-19 is modelled as a

[6] See for example Dekle et al. (2008), Arkolakis et al. (2012)

policy intervention that constraints production simultaneously in almost all countries in the world. Indeed, in our paper each country is hit by a local shock induced by the spread of the virus at home, and by a foreign shock through the input linkages induced by the spread of corona abroad.[7]

The paper is structured as follows. In section 2 we describe the COVID-19 shock and motivate the rationale of our modeling choice. In section 3 we present the model we use for the quantitative exercise. In section 4 we describe the data used for the quantitative exercise and we present the results. In section 5 we conclude.

2 COVID19 - A production barrier shock

The new coronavirus (the 2019 novel coronavirus disease COVID-19) was first identified in Wuhan city, Hubei Province, China, on December 8, 2019 and then reported to the public on December 31, 2019 (Maffioli (2020)). As of April 20, 2020, the virus has affected 2.424.419 people in the world, causing 166.256 deaths and forcing millions of people in quarantine for several weeks around the world. The exponential contagion rate of the COVID-19 virus has led many governments to implement a drastic shut-down policy, forcing large shares of the population into quarantine. Because of forced quarantine, there is wide consensus that the economic costs of the pandemic will be considerable, as factories, businesses, schools and country boarders have been closed and are going to be closed for several weeks. Moreover, the spread of the COVID-19 disease has followed unpredictable paths, with a marked heterogeneity in the contagion rates across countries and across regions within the same country.

We propose a simple measure that quantifies the intensity of the economic shock, leveraging on the diffusion of COVID-19 across space, the geographical distribution of sectors in each country and the sectoral labor intensity. The virus shock v_i^j can be expressed as

$$v_i^j = \sum_{r=1}^{R} \left(\frac{cases_{ir}}{\sum_{j=1}^{J} l_{ijr}} * \frac{l_{ijr}}{\sum_{r=1}^{R} l_{ijr}} \right) * e^{\gamma_i^j} \tag{1}$$

where l_{ijr} is the total employment of sector j in region r of country i, $cases_{ir}$ is the number

[7] A growing literature in economics exends the SIER model to study the economic consequences of the diffusion of the pandemic under different policy scenarios (see for example Atkeson (2020), Berger (2020), Eichenbaum et al. (2020))

of official cases of COVID-19 in region r of country i, γ_i^j is the share of value added of sector j in country i, $\sum_{j=1}^{J} l_{ijr}$ is the sum of employed individuals across all sectors in a region r of country i, while $\sum_{r=1}^{R} l_{ijr}$ is the sum of employed individuals in a sector j across all regions r of country i. The first term of the formula is a measure of the impact of the COVID-19 on the regional employment. The second term is a measure of the geographic distribution of production in the country, measuring how much each sector is concentrated in a region compared to the rest of the country. The last term is meant to capture the labor intensity of each sector in a country.

In our counterfactual exercise we substitute the share of COVID-19 cases over total employment in a region $\frac{cases_{ir}}{\sum_{j=1}^{J} l_{ijr}}$, with a constructed share of people under quarantine ψ_i^j as follows:[8]

$$v_i^j = \sum_{r=1}^{R} \left(\psi_i^j * \frac{l_{ijr}}{\sum_{r=1}^{R} l_{ijr}} \right) * e^{\gamma_i^j} \tag{2}$$

and

$$\psi_i^j = IndexClosure_i * (1 - TW_j) * Duration \tag{3}$$

where $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. The second term of equation 3, $(1 - TW_j)$ contains a key parameter, namely the degree of *teleworkability* of each occupation. Following Dingel and Neiman (2020) we use the information contained in the Occupational Information Network (O*NET) surveys to construct a measure of feasibility of working from home for each sector. Finally, we account for the average duration of strict quarantine, which to date is a month in the data.[9]

Our measure ψ_i^j returns an index of quarantined labor force for each country and sector in our dataset. In fact, it takes into account the extent of the policy restrictions in each country as well as the possibility to work remotely in presence of restrictions for each sector of the economy. Ideally, one would need data on the degree and the duration of the restrictions

[8]Additional details on the choice of the share of people under quarantine and the data used for the quantitative exercise are provided in section 4.

[9]We refer to strict quarantine as the policy restriction that imposes strict and generalized workplace closures. See Hale (2020) for a detailed time-series of government policy responses to the diffusion of the COVID-19 virus.

for each country, region and sector to construct a perfect measure of the quarantine in the counterfactual scenario. However, precise data on the restrictions and duration are only going to be available ex-post; we approximate the quarantine in each country and sector with our measure ψ_i^j that exploits all the information available to date.[10]

Finally, it is important to highlight that the modelling of the production barrier shock presented in equation 2 substantially differs from the modelling of a natural disaster. A natural disaster is a geographically localized shock that can lead to the destruction of production plants, to the loss of human lives and to a lock-down of many economic activities in a country or region. These types of shocks affect the rest of the economy and foreign countries through input linkages (see Carvalho et al. (2016)). In our set-up, the shock induced by COVID-19 virus is modeled as a shock to the production cost of both domestic goods and goods for foreign markets. Moreover, the global nature of the shock implies that most countries are simultaneously affected by the shock both directly – through an increase in the production cost of the goods for domestic consumption – and indirectly – through an increase in the cost of intermediates from abroad and through a decrease in demand of goods produced for the foreign markets. Our set-up crucially allows us to quantify both channels and highlights the importance of the direct effect of the shock on domestic production vis a vis the indirect effect coming from the global production linkages.

To conclude, an economic assessment of the COVID-19 shock should take into account the global spread of the disease, the degree of integration among countries through trade in intermediate goods and the heterogeneity in countries' production structure. In the next section we describe the framework used for the analysis and the mechanisms at work.

3 Theoretical Framework

The quantitative model presented in this section follows the theoretical framework of Caliendo and Parro (2015) and we refer to their paper for a more detailed description of the framework and the model solution. We modify the model allowing for the role of a policy intervention that leads to a production barrier of the form described in section 2. There are N countries, indexed by i and n, and J sectors, indexed by j and k. Sectors are either tradable or non-tradable and labor is the only factor of production. Labor is mobile across sectors and not mobile across countries and all markets are perfectly competitive.

[10] In the appendix we perform a number of sensitivity checks with different duration.

Households. In each country the representative households maximize utility over final goods consumption C_n, which gives rise to the Cobb-Douglas utility function $u(C_n)$ of sectoral final goods with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$.

$$u(C_n) = \prod_{j=1}^{J} C_n^{j\,\alpha_n^j} \tag{4}$$

Income I_n is generated through wages w_n and lump-sum transfers (i.e. tariffs).

Intermediate Goods. A continuum of intermediates can be used for production of each ω^j and producers differ in the efficiency $z_n^j(\omega^j)$ to produce output. The production technology of a good ω^j is

$$q_n^j\left(\omega^j\right) = z_n^j\left(\omega^j\right)\left[l_n^j\left(\omega^j\right)\right]^{\gamma_n^j}\prod_{k=1}^{J}\left[m_n^{k,j}\left(\omega^j\right)\right]^{\gamma_n^{k,j}},$$

with labor $l_n^j\left(\omega^j\right)$ and composite intermediate goods $m_n^{k,j}\left(\omega^j\right)$ from sector k used in the production of the intermediate good ω^j. $\gamma_n^{k,j} \geq 0$ are the share of materials form sector k used in the production of the intermediate good ω^j. The intermediate goods shares $\sum_{k=1}^{J} \gamma_n^{k,j} = 1-\gamma_n^j$ and $\gamma_n^j \geq 0$, which is the share of value added vary across sectors and countries.

Due to constant returns to scale and perfect competition, firms price at unit costs,

$$c_n^j = \Upsilon_j^j w_n^{\gamma_n^j}\prod_{k=1}^{J} P_n^{k\gamma_n^{k,j}}, \tag{5}$$

with the constant Υ_j, and the price of a composite intermediate good from sector k, $P_n^{k\gamma_n^{k,j}}$.

Production Barriers and Trade Costs. Trade can be costly due to tariffs $\tilde{\tau}_{in}^j$ and non-tariff barriers d_{ni}^j (i.e. FTA, bureaucratic hurdles, requirements for standards, or other discriminatory measures). Combined, they can be represented as trade costs κ_{ni}^j when selling a product of sector j from country i to n

$$\kappa_{in}^j = \underbrace{(1+t_{in}^j)}_{\tilde{\tau}_{in}^j}\underbrace{D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}}_{d_{ni}^j} \tag{6}$$

where $t_{in}^j \geq 0$ denotes ad-valorem tariffs, D_{in} is bilateral distance, and $\mathbf{Z}_{in}$ is a vector collecting trade cost shifters.[11]

Additionally, intermediate and final goods are now subject to barriers arising from domestic policy interventions, v_i^j that can potentially deter production. As described in section 2, COVID-19 is modeled as a barrier to production in the affected areas. The key difference when compared to trade costs is that the latter one only directly affects tradable goods, while production barriers can also directly affect non-tradable goods.

Under perfect competition and constant returns to scale, an intermediate or final product (trade and non-tradable) is provided at unit prices, which are subject to v_i^j , κ_{ni}^j and depend on the efficiency parameter $z_i^j\left(\omega^j\right)$.

Producers of sectoral composites in country n search for the supplier with the lowest cost such that

$$p_n^j\left(\omega^j\right) = \min_i \left\{ \frac{c_i^j \kappa_{ni}^j v_i^j}{z_i^j\left(\omega^j\right)} \right\}. \quad (7)$$

Note that v_i is independent of the destination country and thus will also have effects on non-tradeable and domestic sales. In the non-tradable sector, with $k_{in}^j = \infty$, the price of an intermediate good is $p_n^j\left(\omega^j\right) = c_n^j v_n^j / z_i^j\left(\omega^j\right)$.

Composite intermediate product price. The price for a composite intermediate good is given by

$$P_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j v_i^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j} \quad (8)$$

where $A^j = \Gamma\left[1 + \theta^j(1-\eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant. Following Eaton and Kortum (2002b), Ricardian motives to trade are introduced in the model and allow productivity to differ by country and sector.[12] Productivity of intermediate goods producers follows a Fréchet distribution with a location parameter $\lambda_n^j \geq 0$ that varies by country and sector (a measure of absolute advantage) and shape parameter θ^j that varies by sector and captures comparative advantage.[13]. Equation 8 also provides the price index of non-tradable goods and goods confronted with production barriers, which can affect tradable and non-tradable goods. For non-tradable goods the price index is given by $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j v_n^j$.

[11]Iceberg type trade cost in the formulation of Samuelson (1954) are captured by the term $\mathbf{Z}_{in}$

[12]see Caliendo and Parro (2015) for more details.

[13]Convergence requires $1 + \theta^j > \eta^j$.

Firm's output price. Due to the interrelation of the sectors across countries, the existence of production barriers v_i^j has also an indirect effects on the other sectors across countries. A firm in country i can supply its output at price,[14]

$$p_{in}^j(\omega^j) = v_i^j \kappa_{in}^j \frac{c_i^j}{z_i^j(\omega^j)} \tag{9}$$

Consumption prices. Under Cobb-Douglas preferences, the consumers can purchase goods at the consumption prices P_n, which are also dependent on production barriers v_i^j. In fact, with perfect competition and constant-returns to scale, an increase in the costs of production of final goods will directly translate into an increase in consumption prices.

$$P_n = \prod_{j=1}^{J} \left(P_n^j / a_n^j\right)^{a_n^j} \tag{10}$$

Expenditure Shares. The total expenditure on goods of sector j from country n is given by $X_n^j = P_n^j Q_n^j$. Country n's share of expenditure on goods from i is given by $\pi_{ni}^j = X_{ni}^j / X_n^j$, which gives rise to the structural gravity equation.

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j v_i^j\right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^{N} \lambda_i^j \left[c_i^j \kappa_{in}^j v_i^j\right]^{\frac{-1}{\theta^j}}} \tag{11}$$

The bilateral trade shares are affected by the production barriers v_i^j both directly and indirectly through the input bundle c_i^j from equation 3, which contains all information from the IO-tables.

Total expenditure and Trade Balance. The value of gross production Y_i^j of varieties in sector j has to equal the demand for sectoral varieties from all countries $i = 1, \dots, N$ and hence the total expenditure is the sum of expenditure on composite intermediates and the

[14] c_i^j is the minimum cost of an input bundle (see equation 6), where Υ_i^j is a constant, w_i is the wage rate in country i, p_i^k is the price of a composite intermediate good from sector k, which can be affected by production barriers. $\gamma_i^j \geq 0$ is the value added share in sector j in country i, the same parameter we use in equations 2 and 1 when defining the shock v_i^j. $\gamma_i^{k,j}$ denotes the cost share of source sector k in sector j's intermediate costs, with $\sum_{k=1}^{J} \gamma_i^{k,j} = 1$.

expenditure of the households.

The goods market clearing condition is given by

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^k}{(1+\tau_{in}^k)} + \alpha_i^j I_i \tag{12}$$

where national income consists of labor income, tariff rebates R_i and the (exogenous) trade surplus S_i, i.e. $I_i = w_i L_i + R_i - S_i$. X_i^j is country i's expenditure on sector j goods and $M_n^j = \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j$ are country n's imports of sector j good from country i. Thus, the first part on the right hand side gives demand of sectors k in all countries i for intermediate usage of sector j varieties produced in country n, the second term denotes final demand. Tariff rebates are $R_i = \sum_{j=1}^{J} X_i^j \left(1 - \sum_{n=1}^{N} \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)}\right)$.

The second equilibrium condition requires that, for each country n the value of total imports, domestic demand and the trade surplus has to equal the value of total exports including domestic sales, which is equivalent to total output Y_n:

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_n^j + S_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^j}{(1+\tau_{in}^j)} X_i^j = \sum_{j=1}^{J} Y_n^j \equiv Y_n \tag{13}$$

Substituting equation 12 into 13 further implies that the labor market is clear.

Equilibrium in relative changes. We solve for changes in prices and wages after changing the production barriers v to $v\prime$. This gives us an equilibrium in relative changes and follows Dekle et al. (2008).

We solve for counterfactual changes in all variables of interest using the following system of equations:

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^{J} P_n^{k \gamma_n^{k,j}} \tag{14}$$

$$\hat{p}_n^j = \left(\sum_{i=1}^{N} \pi_{in}^j [\hat{\kappa}_{in}^j \hat{v}_i^j \hat{c}_i^j]^{-1/\theta^j} \right)^{-\theta^j} \tag{15}$$

$$\hat{\pi}_{in}^j = \left(\frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \hat{v}_i^j \right)^{-1/\theta^j} \tag{16}$$

$$X_n^{j\prime} = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^{k\prime}}{(1 + \tau_{in}^{k\prime})} + \alpha_i^j I_i^{\prime} \tag{17}$$

$$\frac{1}{B} \sum_{j=1}^{J} F_n^{j\prime} X_n^{j\prime} + s_n = \frac{1}{B} \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j\prime}}{1 + t_{ni}^{j\prime}} X_i^{j\prime} \tag{18}$$

where $\hat{w}_n$ are wage changes, X_n^j are sectoral expenditure levels, $F_n^j \equiv \sum_{i=1}^{N} \frac{\pi_j^{in}}{(1+t_{in}^j)}$, $I_n^{\prime} = \hat{w}_n w_n L_n + \sum_{j=1}^{J} X_n^{j\prime}(1 - F_n^{j\prime}) - S_n$, L_n denotes country n's labor force, and S_n is the (exogenously given) trade surplus. We fix $s_n \equiv S_n/B$, where $B \equiv \sum_n w_n L_n$ is global labor income, to make sure that the system is homogenous of degree zero in prices. The shift in unit costs due to changes in input prices (i.e., wage and intermediate price changes) is laid out in equation (14).

Changes in production barriers $\hat{v}_i^j$ directly affect the sectoral price index p_n^j, and thus translate into changes of the unit costs (see equation 15). The trade shares in equation 16 respond to change in the production costs, unit costs, and prices. The productivity dispersion parameter θ^j governs the intensity of the reaction. Equation 17 ensures goods market clearing in the new equilibrium and the balanced trade condition is given by equation 18.

Solving the model in relative changes allows abstracting from the estimation of some structural parameters of the model, such as total factor productivity or trade costs.[15] In the next sections we describe the data and the set of parameters we use to calibrate the baseline economy as well as the data used to construct the production shock v_i^j. Moreover, we provide a description of the counterfactuals exercises we perform together with results.

[15] We refer the reader to Caliendo and Parro (2015) for a complete explanation of the hat algebra. Intuitively, the solution method mimics the difference in difference set-up, hence allows to abstract from data on parameters that do not change in response to the shock.

4 Quantifying the trade and welfare effect of COVID-19.

In this section we evaluate the welfare effects from the increase in the production barrier caused by the spread of COVID-19. We use data from different sources in order to calibrate the model to our base year. To provide a realistic picture of the effect of COVID-19, we maximize the number of countries covered in our sample conditional on having reliable information on tariffs, production and trade flows. Our quantification exercise requires a large number of data, which we gather combining different sources.[16]

First, we use the World Input-Output Database (WIOD). It contains information on sectoral production, value added, bilateral trade in final and intermediate goods by sector for 43 countries and a constructed rest of the world (RoW). WIOD allows us to extract bilateral input-output tables and expenditure levels for 56 sectors, which we aggregate into 50 industries. This aggregation concerns mostly services; we keep the sectoral detail in the manufacturing and agricultural industries. Data on bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB).

Second, a crucial element for the quantification exercise is to measure the intensity of the COVID-19 shock across countries as detailed in equations 1 and 2. For this end, we use information on the number of corona cases ($cases_{ir}$) in each country and region from multiple sources. We use the database from the Johns Hopkins Coronavirus Resource Center[17] and we combine it with information from national statistical offices for Italy, Germany, Spain and Portugal. This procedure returns the number of official COVID-19 cases as of April 16th in each of the 43 countries of our dataset, with regional disaggregation for the US, Italy, China, Germany, Spain and Portugal.[18]

Third, our measure of the shock as detailed in equations 1 and 2 requires information on employment by country-region and sector. This data is crucial to account for the geographical distribution of sectors across each country as well as for the COVID-19 shares over employment in a country-region. We combine different sources: for the EU, we use the information contained in Eurostat, while for the US we use IPUMScps to construct employment by state(region) and sector of activity.[19] The construction of employment by sector

[16]A more detailed description of the different data sources can be found in Appendix A.1.

[17]For further details, visit the following website: `https://coronavirus.jhu.edu/`

[18]We collect regional information on COVID-19 official cases for all the countries that provide it at the date of writing the paper.

[19]More information on the construction of the employment matrices is detailed in the appendix.

and province in China required two different data sources: first, we use the information from the National Bureau of Statistic of China for the year 2018 on employment by region and sector[20]. However, the information for manufacturing and services provided by the National Bureau of Statistic of China is not disaggregated into sub-sectors. We complement this information with the employment shares by region and sector from the 2000 census to retrive the employment level of manufacturing and services[21]. This procedure returns employment shares by region and sector for 50 sectors and each province in China in 2018.[22].

Fourth, constructing the quarantine index ψ_i^j requires information on the degree of restriction for each country ($IndexClosure_i$), on the degree of *teleworkability* of each occupation and on the duration of the strict quarantine. We use the index on government responses to the COVID-19 diffusion of the University of Oxford (`https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker`), where $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. Moreover, we follow Dingel and Neiman (2020) and construct a measure of the degree of *teleworkability* of each occupation. We use the information contained in the Occupational Information Network (O*NET) surveys to construct a measure of feasibility of working from home for each sector.[23] Finally, using the information contained in the dataset on government responses to the COVID-19 from the University of Oxford, we account for the average duration of strict quarantine, which we estimate to be of one month. We refer to strict quarantine as the policy restriction that imposes strict and generalized

[20]See `http://www.stats.gov.cn/english/` for a general overview of the data collected by the NBSC, and `http://data.stats.gov.cn/english/` for employment data at regional level.

[21]We thank Matilde Bombardini for kindly providing us the employment shares by region and industry from the 2000 Chinese Census used in the paper Bombardini and Li (2016). More details on the construction of the region-sector employment shares for China is provided in the appendix.

[22]Data on employment at sector-region level are not available for some countries in our sample, and we construct a simpler version of equation 1, $v_i^j = \frac{c_i}{\sum_{j=1}^{J} l_{ij}} * e^{\gamma_i^j}$. In this case, the formula does not capture the geographical distribution of sectors in the country, but accounts for the sectoral distribution of employment and for their labor intensity. This is the case for Australia, Brazil, Canada, India, Indonesia, Japan, Korea, Mexico, Russia, Taiwan, RoW.

[23]Some *sensitive* sectors of the economy are excluded by each government from the restrictive measures. We account for *sensitive* sectors by increasing the share of employment that can be teleworkable to 0.8 in each of the *sensitive* sectors. The list of sensitive sectors include (ISIC rev 3 sectoral classification): Agricolture (sector 1), Fishing (sector 3), Electricity and gas (sector 23), Water supply (sector 24), Sewage and Waste (sector 25), Postal and courier (sector 34), Human health and social work (sector 49).

workplace closures.[24]

We use this extensive set of data to construct our measure for the COVID-19 shock and to instruct the model to perform counterfactual analysis. As described in section 3, we follow Dekle et al. (2008) and Caliendo and Parro (2015) and solve the model in relative changes to identify the welfare effect of the COVID-19 shock. We perform three different exercises: (i) we include the COVID-19 shock in the model as in equation 1 and we estimate a *snap-shot* scenario based on the actual number of COVID-19 cases in each country (*Shock-1* in the tables and figures), (ii) we include the quarantine shock in the model as in equation 2 and estimate a quarantine scenario, imposing quarantine to a fraction of the labour force in each countries (*Shock-2* in the tables and figures), (iii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 quarantine and an indirect effect coming from the global shock affecting the other countries. We perform the three exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country.

4.1 Open economy

Change in Welfare, Value Added and Trade

In this section, we present the results of the change in welfare, sectoral value added and trade for each country in our sample and both the *snap-shot* and the quarantine scenario. The formula for the welfare change is

$$\hat{W}_n = \frac{\hat{I}_n}{\prod_{j=1}^{J} (\hat{p}_n^j)^{\alpha_n^j}}$$

where $\hat{W}_n$ is the change in welfare of country n, $\hat{I}_n$ is the change in nominal income of country n and $\prod_{j=1}^{J} (\hat{p}_n^j)^{\alpha_n^j}$ is the change in the price index for country n in each sector j. The aggregated welfare results of the *snap-shot* and the quarantine scenario by country are presented in table 1. In column 2 and 5 we present the real income drops from the *snap-shot* scenario (shock 1), assuming no quarantine for any country in the world.[25] In this case, we

[24]See Hale (2020) for a detailed time-series of government policy responses to the diffusion of the COVID-19 virus.

[25]It is important to highlight that this scenario would however imply a tremendous cost in terms of human lives that our model does not account for.

find real income drops up to almost 2.9% for Spain, with heterogeneous effects depending mainly on the actual COVID-19 cases in each country of our sample. In figure 1 we present graphical evidence on the relation between corona cases and the (log) change in real income across countries.[26]

In the quarantine scenario (shock 2) in the open economy in table 1 (columns 3 and 6), we include quarantine as presented in equation 2. Countries have heterogeneous *treatments* depending on the restrictiveness of the policy measures, on the share of workforce employed in each sector of the economy and on the degree of *teleworkability* of each sector. Results in table 1 show that most countries with quarantined labor force experience a drop in real income above 10%, with the only exception of Sweden. Indeed, Sweden did not implement any coercive and generalized restriction to the workforce, unless infected with the COVID-19 virus disease.[27]

In tables 2, we further investigate the sectoral distribution of the economic impact of the COVID-19 shock. We find that the drop in value added (in billions US dollars) is widespread across all sectors, but it is especially pronounced for services, intermediate resource manufacturing and wholesale and retail trade across all countries and both in the *snap-shot* scenario (*Shock-1*) as well as in the quarantine scenario (*Shock-2*). In absolute terms, the strongest drops in value added are experienced in the services sectors, which include services such as accommodation and food, real estate, and also public services.[28] In relative terms, the drops in sectoral value added are the highest in the sectors of textiles and electrical equipment for Italy, pharmaceuticals and motor vehicles for Germany, manufacturing and machinery equipment for the US and textiles and electrical equipment for China (see table A1 in the Appendix).

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[26] The size of shock 1 across all countries is shown in Appendix A.1 in figure A4 and zooms into the EU member states in figure A6a.

[27] It is crucial to note that the number of COVID-19 cases as well as the countries that implement quarantine is in continuous evolution, hence the point estimates of this scenario might change as the spread of the COVID-19 disease affects more countries and more people. The focus of this paper is to highlight the importance of global production networks in the diffusion of a global shock and on how to use a simple theoretical framework to provide insights on the heterogeneous effects of the COVID-19 shock across countries and across sector under different scenarios, rather than providing the absolute numbers of the drop in real income due to the COVID-19 shock. We will constantly update the results of the paper to account for the new cases as well as for the number of countries in quarantine. The results presented in this version are supposed to provide a first *snap-shot* of the economic effect of the COVID-19 shock. A more complete picture will be available when the full information of COVID-19 cases, quarantined countries and share of people in quarantine is available.

[28] Table 2 provides the results for selected countries and regions and aggregated sectors. See table A3 for the aggregation of the 50 WIOD-sectors. All results for the sectoral value added changes for each of the sectors in all countries can be retrieved from the authors.

The impact of the COVID-19 shock on countries' trade is presented in table 3. For the case of Italy, we observe a severe decline in exports in billions US Dollars in intermediate resource manufacturing, machinery equipment and textiles. Germany faces a decrease in exports especially marked in the motor vehicle industry, as well as in the intermediate resource manufacturing sector and machinery and equipment. The US has a severe drop in exports in the service sector, followed by the intermediate resource manufacturing and wholesales trade while China experiences the biggest drop in exports in the sectors of electrical equipment, intermediate resource manufacturing and textiles.

Both the results in tables 2 and 3 present a clear picture of the structure of comparative advantages of each economy, highlighting the importance of accounting for sectoral production linkages and inter-sectoral trade when studying the economic impact of a global shock. Moreover, these results suggest that the production structure of each economy, as well as their centrality in the global value chains might have heterogeneous roles in explaining the size of the observed income drops across the countries.

Decomposition of the Effects

What is the share of the real income drop due to COVID-19 shock that comes from the disruption of production in each country? What is the share that comes from a drop in trade through global production networks? To decompose the real income changes observed in table 1 we use the structural model and perform a counterfactual exercise in which we shock each country individually. This allows us to isolate the direct production effect of the COVID-19 shock on each country from the indirect effect that each other country experience through the global production network. We perform the following decomposition:

$$\forall i \neq j \; : \; \hat{W}_i = \Bigg(\underbrace{\hat{W}_i^D(v_i)}_{\text{Direct}} + \underbrace{\sum_{j=1}^{J} \hat{W}_i^I(v_j)}_{\text{Indirect}} \Bigg) \times \underbrace{\Bigg(1 - \hat{W}_i(v_{ALL}) \Bigg)}_{\text{Global}} \tag{19}$$

where $\hat{W}_i^D(v_i)$ is the direct (D) change in real income of country i when only country i is hit by the COVID-19 shock (v_i), $\sum_{j=1}^{J} \hat{W}_i^I(v_j)$ is the sum of the indirect (I) real income changes in country i when any other country j is treated with the COVID-19 shocks (v_j), $\hat{W}_i(v_{ALL})$ is the total change in real income of country i when all countries are affected by the COVID-19 shock (v_{ALL}), and $\hat{W}_i$ is the sum of the three different components from the decomposition. We perform the decomposition with both *Shock-1* and *Shock-2*.

Suppose, for example, that Germany is the only country hit by the COVID-19 virus disease; in this case, the real income of Germany would drop because of the disruption in production that the COVID-19 shock provokes to the German economy, what we call the *direct* effect in our decomposition. Suppose now that Italy is the only country affected by the COVID-19 shock. In this case, we would observe a drop in real income for Germany as well, which is driven by the drop in trade between Germany and Italy, as well as by the increase in the cost of intermediates that Germany buys from Italy. This is what we call the *indirect* effect. Summing over the *indirect* effects for Germany will provide us the total *indirect* effect, namely the drop in real income that Germany faces when each other country is shocked individually.

The third term of our decomposition is the difference between the sum of the direct and the indirect effects for Germany from the decomposition and the drop in real income observed for Germany in the counterfactual exercise in which we shock all the countries at same time. We call this component the *global* adjustment. Indeed, when we shock all the countries with quarantine at the same time, the observed income drop differs from the sum of the direct and the indirect effect from the decomposition. This points to the importance of using a GE framework with input-output linkages and trade when studying the effect of a global shock to local economies. In fact, when shocked all together, each country keeps the relative importance in the world trade networks, hence the structure of comparative advantages remains the same and the total effect of the shock is smaller for each of them. On the contrary, when only one country is hit by the COVID-19 shock, that country faces an increase in the production costs of the goods produced for the domestic and for the foreign markets and loses its role in the global production networks, thus experiencing an additional drop in income.

Figures 2 and 3 present a graphical representation of each part of the decomposition for the *snap-shot* scenario (*Shock-1*) as well as for the quarantine scenario (*Shock-2*). Figure 2 and table 4 present the results for the *snap-shot* scenario (*Shock-1*): we observe a marked heterogeneity both in the total size of the income drop, but also in the share of each component of the the decomposition. Without quarantine, the total income drop would be between 3% (Spain) and 0.1% (India). Moreover, the share of the total shock that is accounted for by the *indirect* effect varies substantially across countries, accounting for the biggest shares in countries that have a smaller number of COVID-19 cases, thus experiencing a smaller *direct* effect due to disruption in production.

Figure 3 and table 5 show the results of the decomposition for the quarantine scenario (*Shock-2*). In this case, each country is hit by a shock that accounts for the restrictiveness of the policy implemented as explained in section 2. It is straightforward to notice the heterogeneity in the relative importance of the *direct* as well as the *indirect* components of the shock across countries. Moreover, the share of the total drop in real income accounted for by the *direct* effect is systematically higher for European countries than for the other countries in our sample, with the exceptions of Korea and Taiwan. To better understand the heterogeneities observed in figure 3 and table 5, we construct a simple measure of trade openness as the sum of imports and exports over total income of the country ($\frac{X_i+M_i}{I_i}$). Using the data from the baseline economy and the results of counterfactual economy, we investigate if our measure of openness is correlated with a higher *indirect* effect. We estimate the following model:

$$\sum_{j=1}^{J} \hat{W}_i^I(v_j) = \beta_0 + \beta_1 \frac{X_i + M_i}{I_i} + \beta_2 \hat{W}_i + \beta_3 HHI\_M + \beta_4 HHI\_output + I_i + \epsilon_i \tag{20}$$

where $HHI\_M = \sum_{n=1}^{N} \left(\frac{M_{ni}}{\sum_{n=1}^{N} M_{ni}} \right)^2 \forall i \neq n$ is an Herfindahl index of diversification in trade partners. The fraction shows the imports of country i, M_{ni} from origin country n, over the sum of all Imports of country i; the higher the number of trading partners and the more diversified its importing sources are, the lower is the HHI of diversification. $HHI\_output = \sum_{j=1}^{J} \left(\frac{output_i^j}{\sum_{j=1}^{J} output_i^j} \right)^2 \forall i \neq n$ is an index of specialization in production. The fraction within the brackets presents the output in sector j, in country i, over the total output of country i. The higher the HHI of specialization, the lower is the degree of specialization in the country.[29]

Table 7 presents the results of this exercise. Indeed, countries with a higher degree of openness experience a higher *indirect* effect. Moreover, accounting for initial income and total size of the real income drop allows us to have a robust estimation across all columns. This simple exercise confirms that openness is correlated with a higher global production network shock; in fact, countries that rely more on international partners both for intermediate supplies as well as for exporting their goods experience a higher *indirect* shock. It is important to clarify that this exercise compares countries with different degrees of openness conditional on receiving the same drop in real income. However, it does not allow us to answer the following counterfactual question: "what would have happened if the world was less integrated? Would the total drop in real income due to the COVID-19 be smaller in a less integrated world? In the next section, we leverage on our model to answer these questions.

[29]Similarly, we construct an index of diversification of exports. Results using the index of diversification of exports are similar to the ones using the diversification in imports.

4.2 Less Integrated World

In this section we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the trade costs in each country and sector by a 100 percentage points. First and unsurprisingly, a less integrated world itself implies enormous income losses for all countries in our sample. Tables 8 and 9 show the real income changes for all countries in the sample for *shock-1* and *shock-2* in a less integrated world. In both tables, column 2 and 7 present the real income losses stemming from the increase in trade costs by a 100 percentage points. Column 3 and 8 show the real income changes stemming from the COVID-19 shocks in a less integrated economy, while columns 4 and 9 present the welfare effects due to the COVID-19 shocks in the open economy (as in table 1). Finally, columns 5 and 10 (Δ Shock 1 and Δ Shock2) present the difference between the real income drop due to the COVID-19 shocks in a less integrated vs. open economy.

The COVID19 shock is smaller for all countries in the less integrated economy than in the open economy under both shocks. Indeed, in a less integrated world countries experience an enormous reduction in real income due to the increase in trade costs, hence the additional effect of the global pandemic shock plays a relatively smaller role. Indeed, in tables 12 and 13, we present the results of the decomposition from equation 19 in a less integrated world. Interestingly, when raising trade costs in all countries, the *indirect* component is lower that in open economy, but it still accounts for a relevant share of the drop in income due to the COVID-19 shock. In our counterfactual exercise, the increase in trade cost mimics a world with higher trade barriers, but not a complete autarky scenario; countries would still trade, use intermediates from abroad and sell final goods in foreign countries.

This finding highlights the importance of inter-sectoral linkages in the transmission of the shock: a higher degree of integration in the global production network implies that a shock in one country directly diffuses though the trade linkages to other countries. Trade has two different effects in our model: on the one hand, it smooths the effect of the shock by allowing consumers to purchase and consume goods they wouldn't otherwise be able to consume in a world with production barriers in quarantine. On the other hand, the COVID-19 shock increases production costs of intermediate inputs that are used at home and abroad. Our counterfactual exercise clearly shows that an increase in trade costs would not significantly decrease the impact of the COVID-19 shock across countries. However, increasing trade barriers would imply an additional drop in real income between 14% and 33% across countries.

5 Conclusions

This study extends the general equilibrium framework developed by Caliendo and Parro (2015) to evaluate the economic impact of the COVID-19 shock. We model the COVID-19 shock as a production barrier that deters production for home consumption and for exports through a temporary drop in the labor units available in each country. The spread of COVID-19 disease provides a unique set-up to understand and study the diffusion of a global production shock along the global value chains. However, understanding the effects of a global production disruption induced by a pandemic is complex. In this paper, the modeling choice of the shock takes into account the geography of the diffusion of the COVID-19 shock across regions and countries, the geographical distribution of sectors in each country and the labour intensity of each sector of production to return a reliable measure of the impact of the COVID-19 disease as a production barrier. Crucially, in a model with interrelated sectors the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy, both non-tradable and tradable. In our framework, the COVID-19 shock has a direct effect on the cost of each input as well as an indirect effect via the sectoral linkages.

We perform three different exercises: (i) we include the COVID-19 shock in the model and we estimate a *snap-shot* scenario based on the actual number of COVID-19 cases in each country, (ii) we include the quarantine shock and estimate a quarantine scenario, imposing quarantine to a fraction of the labour force in each countries, (iii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 quarantine and an indirect effect coming from the global shock affecting the other countries. We perform the three exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country. The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region and the number of COVID-19 cases in each region or country. We calibrate a 40 countries 50 sector economy and incorporate the COVID-19 shock to evaluate the welfare effects for each country both in aggregate and at the sectoral level.

We show that the shock dramatically reduces real income for all countries in all counterfactual scenarios and that sectoral interrelations and global trade linkages have a crucial role in explaining the transmission of the shock across countries. COVID-19 shock is a pandemic shock, hence it has a contemporaneous effect in many countries and to all sectors of production. We use the model to perform a model-based identification of the effect of COVID-19 shock and provide evidence on the importance of global trade linkages and inter-sectoral trade when studying the effect of a global shock to production on the welfare of each country. Certainly, this model abstract from many other aspects related to the diffusion of the COVID-19 disease which are the topic of study of epidemiologist, medical doctors and statisticians. Moreover, we do not account for the health consequences of the pandemic itself. We believe that understanding how the COVID-19 virus disease spreads across regions is outside the scope of this paper. In our framework, the spread of COVID-19 disease is modeled an exogenous shock that allows us to study the diffusion of the production disruption along the global value chains and to highlight the importance of modeling and including sectoral interrelations to quantify the economic impact of the COVID-19 shock.

References

Alfaro, L., Antràs, P., Chor, D., Conconi, P., 2019. Internalizing global value chains: A firm-level analysis. Journal of Political Economy 127, 509–559. URL: https://www.journals.uchicago.edu/doi/10.1086/700935.

Altomonte, C, F.D.M.G.O.A.R., Vicard, V., 2012. Global value chains during the great trade collapse: a bullwhip effect? Firms in the international economy: Firm heterogeneity meets international business .

Antràs, P., Forthcoming. Conceptual aspects of global value chains. World Bank Economic Review .

Antràs, P., Chor, D., 2013. Organizing the global value chain. Econometrica 81, 2127–2204. URL: http://onlinelibrary.wiley.com/doi/10.3982/ECTA10813/abstract. from March 2013.

Antràs, P., Chor, D., 2018. On the Measurement of Upstreamness and Downstreamness in Global Value Chains. Taylor & Francis Group. pp. 126–194.

Antràs, P., de Gortari, A., Forthcoming. On the geography of global value chains.

Arkolakis, C., Costinot, A., Rodríguez-Clare, A., 2012. New trade models, same old gains? American Economic Review 102, 94–130. URL: http://www.aeaweb.org/articles?id=10.1257/aer.102.1.94, doi:10.1257/aer.102.1.94.

Atkeson, A., 2020. What Will Be the Economic Impact of COVID-19 in the US? Rough Estimates of Disease Scenarios. Working Paper 26867. National Bureau of Economic Research. URL: http://www.nber.org/papers/w26867, doi:10.3386/w26867.

Barrot, J.N., Sauvagnat, J., 2016. Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks *. The Quarterly Journal of Economics 131, 1543–1592. URL: https://doi.org/10.1093/qje/qjw018, doi:10.1093/qje/qjw018.

Bénassy-Quéré, A, Y.D.L.F., Khoudour-Casteras, D., 2009. Economic crisis and global supply chains. Mimeo .

Berger, D., H.K.M.S., 2020. An seir infectious disease model with testing and conditional quarantine. Mimeo .

Boehm, C.E., Flaaen, A., Pandalai-Nayar, N., 2019. Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tōhoku earthquake. The Review of Economics and Statistics 101, 60–75.

Bombardini, M., Li, B., 2016. Trade, Pollution and Mortality in China. Working Paper 22804. National Bureau of Economic Research. URL: http://www.nber.org/papers/w22804, doi:10.3386/w22804.

Caliendo, L., Parro, F., 2015. Estimates of the Trade and Welfare Effects of NAFTA. Review of Economic Studies 82, 1–44.

Carvalho, V., Nirei, M., Saito, Y., Tahbaz-Salehi, A., 2016. Supply chain disruptions: Evidence from the great east japan earthquake. Mimeo .

Dekle, R., Eaton, J., Kortum, S., 2008. Global rebalancing with gravity: Measuring the burden of adjustment. IMF Economic Review 55, 511–540.

Dingel, J.I., Neiman, B., 2020. How many jobs can be done at home? Mimeo .

Eaton, J., Kortum, S., 2002a. Technology, Geography, and Trade. Econometrica 70, 1741–1779.

Eaton, J., Kortum, S., 2002b. Technology, geography, and trade. Econometrica 70, 1741–1779.

Eaton, J, S.K.B.N., Romalis, J., 2016. Trade and the global recession. American Economic Review 106, 3401–38.

Eichenbaum, M.S., Rebelo, S., Trabandt, M., 2020. The Macroeconomics of Epidemics. Working Paper 26882. National Bureau of Economic Research. URL: `http://www.nber.org/papers/w26882`, doi:`10.3386/w26882`.

Goldberg, Pinelopi K., A.K.N.P., Topalova, P., 2010. Imported in- termediate inputs and domestic product growth: Evidence from india. Quarterly Journal of Economics 125, 1727–67.

Gopinath, G., Neiman, B., 2013. Trade adjustment and productivity in large crises. American Economic Review 104, 793–831. URL: `http://dx.doi.org/10.1257/aer.104.3.793`.

Gortari, A.D., 2019. Disentangling global value chains. Mimeo .

Hale, Thomas, A.P.T.P.S.W., 2020. Variation in government responses to covid-19. Blavatnik School of Government Working Paper .

Halpern, L., K.M., Szeidl, A., 2015. Imported inputs and productivity. American Economic Review .

Huang, H., 2019. Germs, roads and trade: Theory and evidence on the value of diversification in global sourcing. Mimeo .

Hummels, D., I.J., Yi, K., 2001. The nature and growth of vertical specialization in world trade. Journal of International Economics 54, 75–96.

Maffioli, E.M., 2020. How is the world responding to the 2019 coronavirus disease compared with the 2014 west african ebola epidemic? the importance of china as a player in the global economy. The American Journal of Tropical Medicine and Hygiene URL: `https://www.ajtmh.org/content/journals/10.4269/ajtmh.20-0135`, doi:`https://doi.org/10.4269/ajtmh.20-0135`.

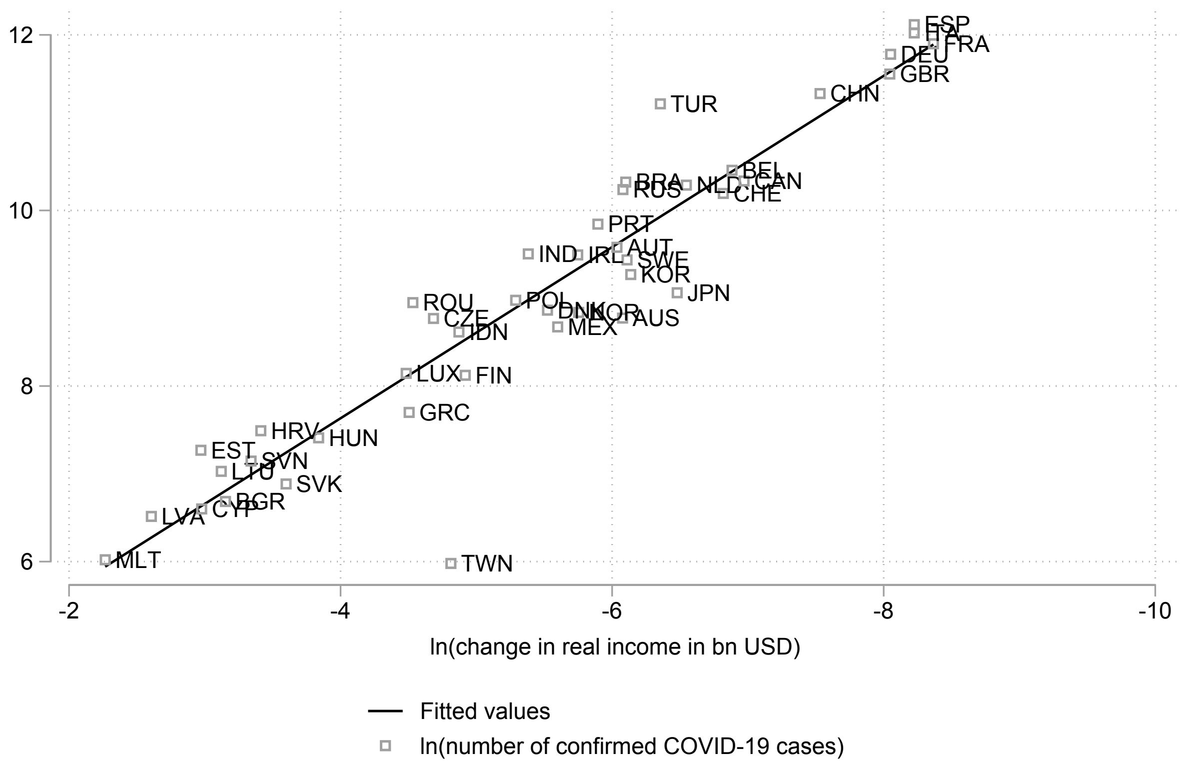
Samuelson, P.A., 1954. The transfer problem and transport costs, ii: Analysis of effects of trade impediments. The Economic Journal 64, 264–289. URL: http://www.jstor.org/stable/2226834.

Timmer, M., Dietzenbacher, E., Los, B., Stehrer, R., Vries, G., 2015. An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production. Review of International Economics 23, 575–605.

Young, A., 2005. The gift of the dying: The tragedy of aids and the welfare of future african generations. The Quarterly Journal of Economics 120, 423–466. URL: http://www.jstor.org/stable/25098743.

Figures

Figure 1: Corona Cases and change in welfare



Note: The figure shows the correlation between the log change in real income across countries over the number of COVID-19 cases per country.

Figure 2: Disentangled real income changes, scenario i

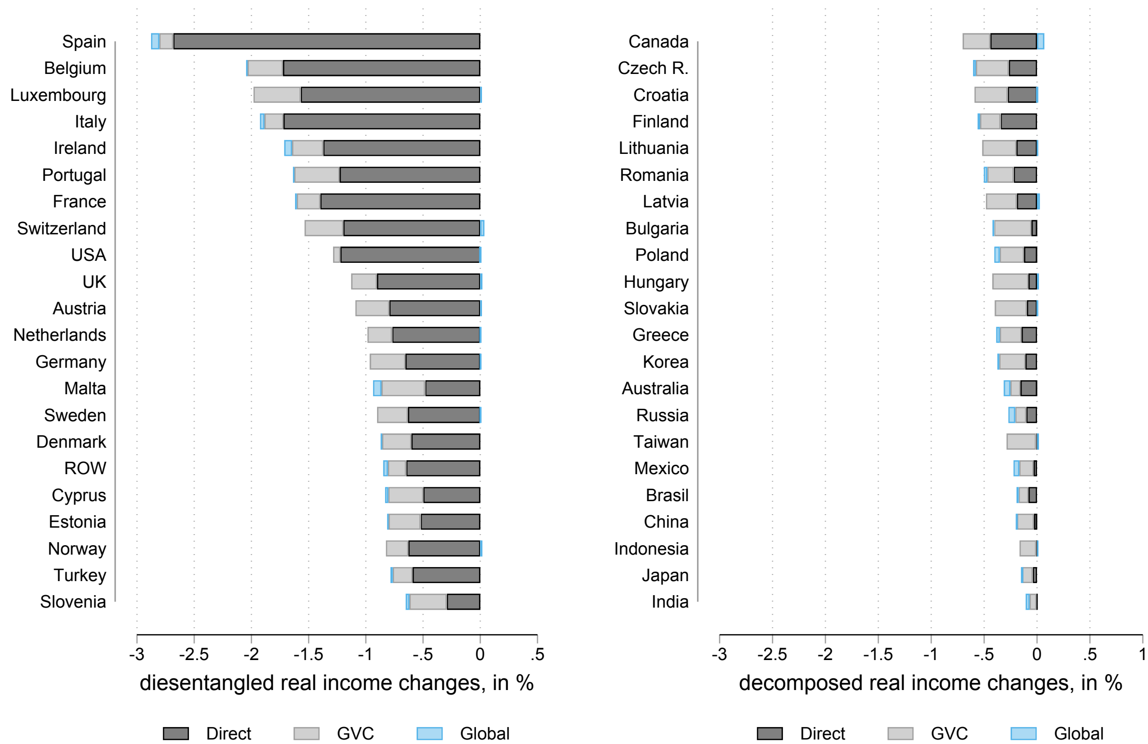
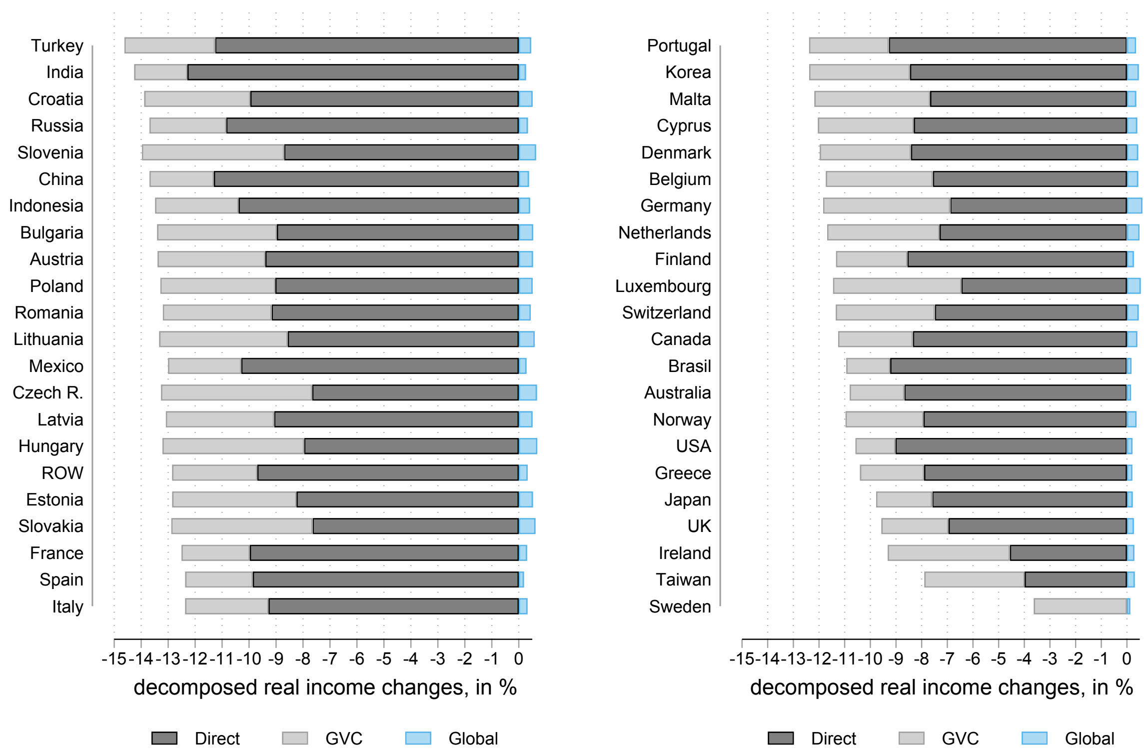


Figure 3: Disentangled real income changes, scenario ii



Tables

Table 1: Welfare change across countries (in %) - Open Economy - Shock 1

	Open Economy			Open Economy	
Country	(Shock 1) in %	(Shock 2) in %	Country	(Shock 1) in %	(Shock 2) in %
Australia	-0.31	-10.65	India	-0.11	-13.99
Austria	-1.08	-12.87	Indonesia	-0.15	-13.07
Belgium	-2.04	-11.30	Japan	-0.14	-9.55
Brasil	-0.19	-10.76	Luxembourg	-1.97	-10.92
Bulgaria	-0.42	-12.88	Malta	-0.94	-11.82
Canada	-0.63	-10.85	Mexico	-0.22	-12.72
China	-0.19	-13.32	Netherlands	-0.98	-11.19
Croatia	-0.59	-13.37	Norway	-0.81	-10.59
Cyprus	-0.83	-11.65	Poland	-0.40	-12.78
Czech R.	-0.60	-12.59	Portugal	-1.64	-12.03
Denmark	-0.87	-11.54	ROW	-0.85	-12.52
Estonia	-0.81	-12.33	Romania	-0.50	-12.75
Finland	-0.56	-11.07	Russia	-0.27	-13.36
France	-1.62	-12.20	Slovakia	-0.39	-12.27
Germany	-0.96	-11.24	Slovenia	-0.65	-13.34
Greece	-0.38	-10.19	Spain	-2.88	-12.18
Hungary	-0.40	-12.53	Sweden	-0.90	-3.50
Ireland	-1.71	-9.04	Switzerland	-1.50	-10.89
Italy	-1.93	-12.05	Taiwan	-0.27	-7.59
Korea	-0.38	-11.92	Turkey	-0.79	-14.17
Latvia	-0.46	-12.58	UK	-1.11	-9.30
Lithuania	-0.51	-12.74	USA	-1.29	-10.36

Note: The table presents the aggregated real income changes in % for every country. Column 2 and 5 show the real income changes in the snap-shot scenario assuming no quarantine for any country (shock 1) in the open economy. Columns 3 and 6 present the real income changes in % for the quarantine scenario (shock 2) in the open economy. Equation 2 highlights how we included the shock.

Table 2: Change in value added in bn USD - Open Economy

Panel A: Shock 1 - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-0.85	-0.26	-2.79	-1.50	-3.85	-10.04
Food, Beverages, Tabacco	-0.66	-0.59	-3.08	-0.74	-4.93	-3.10
Mining, Quarrying	-0.17	-0.07	-5.93	-0.87	-1.38	-14.83
Textiles	-0.71	-0.10	-0.33	-0.13	-1.53	-1.23
Electrical Equipment	-0.58	-1.08	-4.23	-0.05	-3.41	-2.49
Machinery, Equipment	-0.99	-1.51	-2.10	-0.69	-5.06	-1.97
Motor Vehicles	-0.22	-1.42	-1.57	-0.58	-2.82	-1.79
Intm. Resources Manufacturing	-2.00	-2.11	-8.01	-1.66	-10.22	-6.67
Manufacturing, nec.	-0.40	-0.47	-2.84	-0.45	-2.54	-1.47
Pharmaceuticals	-0.22	-0.33	-1.21	-0.19	-2.00	-1.00
Chemicals	-0.37	-0.60	-3.52	-0.27	-2.77	-1.34
Electricity, Water, Gas	-1.01	-1.03	-4.12	-0.38	-6.62	-5.94
Construction	-1.89	-1.59	-8.53	-1.33	-12.45	-9.23
Wholesale, Retail Trade	-4.30	-3.25	-27.17	-1.28	-25.47	-18.75
Transport	-2.18	-1.53	-5.81	-0.67	-11.22	-8.22
Accommodation and Food	-1.38	-0.53	-6.26	-0.36	-7.81	-3.07
Real Estate	-5.31	-3.80	-26.49	-1.05	-26.34	-10.58
Public Services	-3.81	-3.90	-37.83	-0.89	-25.37	-12.83
Social Services	-2.45	-2.64	-15.79	-0.36	-17.45	-5.22
Services, nec.	-9.52	-8.57	-55.14	-3.14	-61.37	-30.13

Panel B: Shock 2 - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-5.18	-2.80	-22.03	-132.75	-31.80	-228.74
Food, Beverages, Tabacco	-4.07	-6.51	-25.11	-55.36	-40.21	-79.95
Mining, Quarrying	-1.00	-0.66	-47.01	-76.51	-12.78	-269.77
Textiles	-3.85	-1.08	-2.98	-35.60	-11.21	-35.28
Electrical Equipment	-3.10	-10.99	-34.56	-61.85	-29.66	-69.01
Machinery, Equipment	-6.90	-17.12	-19.13	-33.98	-47.81	-40.02
Motor Vehicles	-1.80	-17.14	-15.00	-29.62	-30.99	-44.66
Intm. Resources Manufacturing	-12.14	-23.40	-66.55	-138.77	-89.86	-185.15
Manufacturing, nec.	-2.86	-5.76	-25.69	-20.24	-23.62	-33.83
Pharmaceuticals	-1.35	-3.86	-9.99	-10.78	-16.39	-15.97
Chemicals	-1.91	-5.99	-27.53	-30.54	-20.82	-38.87
Electricity, Water, Gas	-6.20	-11.77	-34.00	-32.23	-55.30	-115.63
Construction	-11.78	-18.40	-69.02	-93.81	-103.05	-228.11
Wholesale, Retail Trade	-26.21	-36.11	-218.86	-136.29	-206.58	-466.48
Transport	-13.11	-16.40	-46.44	-61.45	-90.10	-192.99
Accommodation and Food	-8.59	-6.04	-50.55	-26.73	-55.60	-75.05
Real Estate	-32.89	-43.89	-213.44	-78.04	-209.44	-257.97
Public Services	-23.51	-44.49	-305.83	-61.71	-206.75	-329.16
Social Services	-15.23	-31.00	-127.22	-24.96	-142.41	-125.95
Services, nec.	-58.43	-96.33	-444.32	-250.79	-490.24	-680.97

Note: The table presents the sectoral value added changes, in bn USD for selected countries, Italy, Germany, USA, and China. The upper part of the table presents the results for shock 1 in an open economy. The second part presents the results in the case of shock 2 in an open economy. Column 6 reports the value added results for EU28, which are weighted by the initial value added by country. Column 7 shows the value added weighted results for all remaining countries. Further, sectors are aggregated into broader categories (see table A3 in the Appendix).

Table 3: Change of sectoral trade, in bn USD - Shock 1 - Open Economy

Panel A: Shock 1 - Changes of Exports - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-0.07	-0.15	-0.24	-0.11	-1.40	-2.12
Food, Beverages, Tabacco	-0.16	-0.91	-0.21	-0.54	-3.89	-3.10
Mining, Quarrying	-0.01	-0.10	-0.28	-0.11	-0.97	-10.86
Textiles	-0.37	-0.26	-0.06	-2.74	-1.54	-3.49
Electrical Equipment	-0.34	-1.61	-0.81	-6.59	-4.96	-6.59
Machinery, Equipment	0.21	-1.68	-0.42	-2.53	-3.54	-2.78
Motor Vehicles	0.01	-2.45	-0.26	-0.84	-5.13	-5.95
Intm. Resources Manufacturing	-0.81	-2.71	-1.59	-3.33	-11.08	-10.90
Manufacturing, nec.	0.05	-0.81	-0.93	-2.12	-2.21	-3.50
Pharmaceuticals	-0.07	-0.56	-0.39	-0.30	-2.14	-1.14
Chemicals	-0.31	-1.50	-0.70	-0.72	-5.00	-3.31
Electricity, Water, Gas	-0.04	-0.33	-0.24	-0.05	-1.28	-0.64
Construction	-0.02	-0.03	-0.00	-0.14	-0.59	-0.22
Wholesale, Retail Trade	-0.22	-0.91	-1.75	-1.78	-5.92	-3.83
Transport	-0.14	-0.46	-0.86	-0.88	-4.04	-3.80
Accommodation and Food	-0.00	-0.10	-0.01	-0.09	-0.37	-1.21
Real Estate	-0.02	-0.02	-0.02	0.00	-0.14	-0.07
Public Services	-0.13	-0.18	-0.99	-0.04	-2.64	-2.57
Social Services	-0.01	-0.01	-0.02	-0.01	-0.11	-0.18
Services, nec.	-0.32	-1.46	-3.41	-1.03	-10.22	-5.89

Panel B: Shock 1 - Changes of Imports - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-0.35	-0.35	-0.74	-0.08	-2.23	-1.00
Food, Beverages, Tabacco	-0.82	-0.58	-1.22	0.11	-5.15	-2.03
Mining, Quarrying	-0.84	-0.52	-3.19	-0.37	-5.25	-3.55
Textiles	-0.75	-0.47	-2.18	0.01	-3.76	-2.40
Electrical Equipment	-0.86	-1.42	-4.77	-0.18	-7.37	-7.05
Machinery, Equipment	-0.76	-0.74	-2.06	0.36	-4.62	-3.14
Motor Vehicles	-0.78	-1.00	-4.17	0.31	-6.00	-2.75
Intm. Resources Manufacturing	-1.94	-2.19	-4.98	-0.11	-13.37	-9.12
Manufacturing, nec.	-0.46	-0.60	-2.06	0.24	-3.94	-3.25
Pharmaceuticals	-0.46	-0.25	-0.68	0.08	-2.61	-0.80
Chemicals	-0.84	-0.95	-1.85	-0.18	-5.48	-2.45
Electricity, Water, Gas	-0.23	-0.20	-0.21	0.00	-1.52	-0.47
Construction	-0.07	-0.10	-0.04	-0.00	-0.56	-0.35
Wholesale, Retail Trade	-0.75	-0.78	-0.88	-0.03	-5.35	-7.02
Transport	-0.50	-0.53	-0.65	-0.04	-4.09	-4.80
Accommodation and Food	-0.09	-0.09	-0.09	-0.01	-0.78	-0.79
Real Estate	-0.02	-0.01	-0.00	-0.00	-0.13	-0.10
Public Services	-0.30	-0.17	-1.56	-0.01	-3.78	-0.89
Social Services	-0.01	-0.01	-0.07	-0.00	-0.14	-0.11
Services, nec.	-0.87	-1.45	-2.23	-0.05	-10.64	-7.63

Note: The table presents the sectoral export and import changes under shock 1 in an open economy. The upper part of the table shows the changes in exports in bn USD for the selected countries and regions, while the lower part of the table shows the sectoral import changes for the same countries and regions under shock 1 in the open economy.

Table 4: Decomposition of real income changes - Shock 1 - Open Economy

Country	Direct Effect in %	GVC Effect in %	GE Effect in %	Country	Direct Effect in %	GVC Effect in %	GE Effect in %
Australia	-0.156	-0.095	-0.062	Korea	-0.110	-0.247	-0.018
Austria	-0.796	-0.296	0.014	Latvia	-0.191	-0.292	0.026
Belgium	-1.724	-0.310	-0.010	Lithuania	-0.195	-0.322	0.009
Brasil	-0.080	-0.094	-0.020	Luxembourg	-1.569	-0.413	0.015
Bulgaria	-0.053	-0.353	-0.015	Malta	-0.483	-0.381	-0.073
Canada	-0.442	-0.261	0.068	Mexico	-0.032	-0.136	-0.055
China	-0.029	-0.161	-0.004	Netherlands	-0.771	-0.215	0.003
Croatia	-0.277	-0.314	0.002	Norway	-0.629	-0.196	0.018
Cyprus	-0.498	-0.306	-0.027	Poland	-0.123	-0.229	-0.052
Czech R.	-0.266	-0.311	-0.027	Portugal	-1.229	-0.396	-0.012
Denmark	-0.602	-0.256	-0.010	ROW	-0.648	-0.160	-0.040
Estonia	-0.522	-0.279	-0.011	Romania	-0.220	-0.250	-0.033
Finland	-0.345	-0.193	-0.023	Russia	-0.102	-0.104	-0.065
France	-1.398	-0.206	-0.014	Slovakia	-0.096	-0.303	0.006
Germany	-0.654	-0.311	0.005	Slovenia	-0.293	-0.326	-0.031
Greece	-0.146	-0.206	-0.033	Spain	-2.684	-0.121	-0.072
Hungary	-0.081	-0.341	0.018	Sweden	-0.632	-0.269	0.003
India	-0.005	-0.065	-0.036	Switzerland	-1.197	-0.338	0.036
Indonesia	-0.008	-0.158	0.013	Taiwan	-0.009	-0.279	0.019
Ireland	-1.373	-0.272	-0.067	Turkey	-0.591	-0.174	-0.020
Italy	-1.720	-0.166	-0.039	UK	-0.903	-0.225	0.018
Japan	-0.040	-0.101	-0.001	USA	-1.223	-0.063	0.000

Note: The table reports the real income changes decomposed into the direct production effect (columns 2 and 6), the indirect global value chains effect (columns 3 and 7)and into the additional GE effect that occurs due to the global nature of the shock and its feedback general equilibirum effects (columns 4 and 8).

Table 5: Decomposition of real income changes - Shock 2 - Open Economy

Country	Direct Effect in %	GVC Effect in %	GE Effect in %	Country	Direct Effect in %	GVC Effect in %	GE Effect in %
Australia	-8.677	-2.127	0.159	Korea	-8.455	-3.928	0.459
Austria	-9.398	-3.994	0.525	Latvia	-9.072	-4.014	0.508
Belgium	-7.564	-4.168	0.435	Lithuania	-8.567	-4.763	0.588
Brasil	-9.225	-1.710	0.179	Luxembourg	-6.454	-5.000	0.534
Bulgaria	-8.970	-4.437	0.531	Malta	-7.671	-4.508	0.359
Canada	-8.341	-2.914	0.402	Mexico	-10.292	-2.714	0.283
China	-11.307	-2.385	0.375	Netherlands	-7.305	-4.377	0.492
Croatia	-9.954	-3.929	0.511	Norway	-7.930	-3.037	0.374
Cyprus	-8.306	-3.736	0.397	Poland	-9.029	-4.260	0.511
Czech R.	-7.661	-5.603	0.671	Portugal	-9.282	-3.106	0.354
Denmark	-8.417	-3.552	0.433	ROW	-9.696	-3.155	0.328
Estonia	-8.241	-4.606	0.522	Romania	-9.165	-4.032	0.443
Finland	-8.556	-2.783	0.268	Russia	-10.849	-2.844	0.335
France	-9.973	-2.531	0.305	Slovakia	-7.646	-5.239	0.616
Germany	-6.890	-4.949	0.599	Slovenia	-8.702	-5.271	0.637
Greece	-7.905	-2.495	0.211	Spain	-9.862	-2.502	0.188
Hungary	-7.960	-5.252	0.685	Sweden	0.000	-3.629	0.129
India	-12.286	-1.970	0.263	Switzerland	-7.487	-3.860	0.454
Indonesia	-10.388	-3.095	0.416	Taiwan	-3.988	-3.905	0.301
Ireland	-4.562	-4.761	0.286	Turkey	-11.263	-3.359	0.455
Italy	-9.279	-3.090	0.322	UK	-6.952	-2.615	0.268
Japan	-7.592	-2.183	0.221	USA	-9.024	-1.556	0.217

Note: The table reports the real income changes decomposed into the direct production effect (columns 2 and 6), the indirect global value chains effect (columns 3 and 7)and into the additional GE effect that occurs due to the global nature of the shock and its feedback general equilibirum effects (columns 4 and 8).

Table 6: Shares of decomposed real income changes - Open Economy

Country	Shock 1		Shock 2		Country	Shock 1		Shock 2	
	direct	indirect	direct	indirect		direct	indirect	direct	indirect
Australia	0.499	0.501	0.815	0.185	Ireland	0.802	0.198	0.505	0.495
Austria	0.738	0.262	0.730	0.270	Italy	0.893	0.107	0.770	0.230
Belgium	0.843	0.157	0.670	0.330	Japan	0.282	0.718	0.795	0.205
Bulgaria	0.125	0.875	0.697	0.303	Korea	0.292	0.708	0.709	0.291
Brasil	0.414	0.586	0.858	0.142	Latvia	0.417	0.583	0.721	0.279
Canada	0.696	0.304	0.769	0.231	Lithuania	0.384	0.616	0.672	0.328
Switzerland	0.798	0.202	0.687	0.313	Luxembourg	0.798	0.202	0.591	0.409
China	0.149	0.851	0.849	0.151	Malta	0.515	0.485	0.649	0.351
Cyprus	0.599	0.401	0.713	0.287	Mexico	0.143	0.857	0.809	0.191
Czech R.	0.441	0.559	0.608	0.392	Netherlands	0.784	0.216	0.653	0.347
Germany	0.681	0.319	0.613	0.387	Norway	0.779	0.221	0.749	0.251
Denmark	0.694	0.306	0.730	0.270	Poland	0.305	0.695	0.707	0.293
Spain	0.933	0.067	0.810	0.190	Portugal	0.751	0.249	0.771	0.229
Estonia	0.642	0.358	0.669	0.331	ROW	0.765	0.235	0.774	0.226
Finland	0.615	0.385	0.773	0.227	Romania	0.438	0.562	0.719	0.281
France	0.864	0.136	0.818	0.182	Russia	0.376	0.624	0.812	0.188
UK	0.814	0.186	0.748	0.252	Slovakia	0.244	0.756	0.623	0.377
Greece	0.379	0.621	0.776	0.224	Slovenia	0.450	0.550	0.653	0.347
Croatia	0.470	0.530	0.744	0.256	Sweden	0.704	0.296	0.000	1.000
Hungary	0.200	0.800	0.635	0.365	Taiwan	0.034	0.966	0.525	0.475
Indonesia	0.050	0.950	0.795	0.205	Turkey	0.753	0.247	0.795	0.205
India	0.048	0.952	0.878	0.122	USA	0.951	0.049	0.871	0.129

Note: The table reports decomposed real income changes in shares. The total real income change is composed into the direct and indirect (GVC + GE) effect, as reported in tables 4 and 5.

Table 7: Openness, trade diversification and specialization in production

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	log(indirect)	log(indirect)	log(indirect)	log(direct)	log(direct)	log(direct)
log(Openness)	0.639[a]	0.921[a]	0.902[a]	-0.299[a]	-0.383[a]	-0.386[a]
	(0.185)	(0.118)	(0.109)	(0.070)	(0.032)	(0.031)
log(Specialization)		-8.380[a]	-7.903[a]		2.661[a]	2.733[a]
		(1.220)	(1.157)		(0.429)	(0.384)
log(Diversification)			-0.446			-0.070
			(0.434)			(0.136)
Constant	1.155[b]	1.192[a]	1.140[a]	-0.913[a]	-1.036[a]	-1.038[a]
	(0.561)	(0.377)	(0.368)	(0.275)	(0.229)	(0.228)
Controls	X	X	X	X	X	X
Observations	44	44	44	43	43	43
Adjusted R^2	0.697	0.839	0.841	0.924	0.958	0.957

Note: Robust standard errors in parenthesis.

Table 8: Real income changes (in %)- Shock 1 - Less integrated vs. Open Economy

Country	Less integrated Economy		Open Economy	Δ	Country	Less integrated Economy		Open Economy	Δ
	Trade Costs	Shock 1	Shock 1	Shock 1		Trade Costs	Shock 1	Shock 1	Shock 1
Australia	-18.36	-0.27	-0.31	0.04	Korea	-21.77	-0.32	-0.38	0.06
Austria	-22.59	-0.84	-1.08	0.24	Latvia	-30.80	-0.32	-0.46	0.14
Belgium	-27.05	-1.49	-2.04	0.56	Lithuania	-30.00	-0.37	-0.51	0.14
Brasil	-13.98	-0.18	-0.19	0.01	Luxembourg	-29.65	-1.43	-1.97	0.53
Bulgaria	-33.50	-0.29	-0.42	0.14	Malta	-34.43	-0.62	-0.94	0.32
Canada	-20.02	-0.51	-0.63	0.12	Mexico	-17.38	-0.20	-0.22	0.03
China	-17.12	-0.20	-0.19	-0.00	Netherlands	-19.99	-0.81	-0.98	0.17
Croatia	-27.89	-0.43	-0.59	0.16	Norway	-19.55	-0.66	-0.81	0.15
Cyprus	-31.14	-0.58	-0.83	0.25	Poland	-23.09	-0.32	-0.40	0.08
Czech R.	-21.68	-0.49	-0.60	0.11	Portugal	-24.12	-1.23	-1.64	0.40
Denmark	-19.91	-0.71	-0.87	0.16	ROW	-29.33	-0.60	-0.85	0.25
Estonia	-31.87	-0.56	-0.81	0.26	Romania	-27.35	-0.38	-0.50	0.13
Finland	-22.12	-0.44	-0.56	0.12	Russia	-20.91	-0.23	-0.27	0.04
France	-18.87	-1.31	-1.62	0.31	Slovakia	-25.90	-0.31	-0.39	0.08
Germany	-19.44	-0.79	-0.96	0.17	Slovenia	-26.58	-0.49	-0.65	0.16
Greece	-24.02	-0.31	-0.38	0.08	Spain	-18.31	-2.32	-2.88	0.56
Hungary	-22.13	-0.33	-0.40	0.07	Sweden	-22.61	-0.70	-0.90	0.20
India	-13.84	-0.10	-0.11	0.00	Switzerland	-19.72	-1.22	-1.50	0.28
Indonesia	-18.60	-0.14	-0.15	0.01	Taiwan	-24.39	-0.22	-0.27	0.05
Ireland	-21.57	-1.37	-1.71	0.34	Turkey	-18.55	-0.64	-0.79	0.14
Italy	-16.61	-1.60	-1.93	0.33	UK	-20.38	-0.88	-1.11	0.22
Japan	-14.63	-0.14	-0.14	0.00	USA	-13.06	-1.11	-1.29	0.17

Note: The table presents the aggregated real income changes in % for every country. Column 2 and 6 show the real income changes solely driven by the increase in trade costs by 100 percentage points. Column 3 and 7 present the real income changes in % driven by the COVID-19 shock under a Less integrated economy. Column 4 and 8 present the shock i under an open economy (similar to table 1). Column 5 and 9 present the difference between the shock under an open vs. a Less integrated economy. Equation 2 highlights how we included the shock.

Table 9: Welfare Change across Countries, in Percent - Shock 2 - Less integrated vs. Open Economy

Country	Less integrated Economy		Open Economy	Δ	Country	Less integrated Economy		Open Economy	Δ
	Trade Costs	Shock 2	Shock 2	Shock 2		Trade Costs	Shock 2	Shock 2	Shock 2
Australia	-18.36	-8.70	-10.65	1.94	Korea	-21.77	-9.26	-11.92	2.66
Austria	-22.59	-9.96	-12.87	2.90	Latvia	-30.80	-8.71	-12.58	3.87
Belgium	-27.05	-8.25	-11.30	3.05	Lithuania	-30.00	-8.97	-12.74	3.77
Brasil	-13.98	-9.30	-10.76	1.45	Luxembourg	-29.65	-7.76	-10.92	3.16
Bulgaria	-33.50	-8.56	-12.88	4.32	Malta	-34.43	-7.76	-11.82	4.06
Canada	-20.02	-8.68	-10.85	2.17	Mexico	-17.38	-10.53	-12.72	2.20
China	-17.12	-10.90	-13.32	2.42	Netherlands	-19.99	-8.92	-11.19	2.27
Croatia	-27.89	-9.66	-13.37	3.71	Norway	-19.55	-8.51	-10.59	2.08
Cyprus	-31.14	-8.04	-11.65	3.61	Poland	-23.09	-9.81	-12.78	2.97
Czech R.	-21.68	-9.85	-12.59	2.74	Portugal	-24.12	-9.14	-12.03	2.89
Denmark	-19.91	-9.24	-11.54	2.29	ROW	-29.33	-8.82	-12.52	3.70
Estonia	-31.87	-8.41	-12.33	3.92	Romania	-27.35	-9.31	-12.75	3.44
Finland	-22.12	-8.63	-11.07	2.44	Russia	-20.91	-10.55	-13.36	2.81
France	-18.87	-9.89	-12.20	2.31	Slovakia	-25.90	-9.07	-12.27	3.20
Germany	-19.44	-9.03	-11.24	2.21	Slovenia	-26.58	-9.78	-13.34	3.55
Greece	-24.02	-7.80	-10.19	2.39	Spain	-18.31	-9.94	-12.18	2.24
Hungary	-22.13	-9.75	-12.53	2.78	Sweden	-22.61	-2.82	-3.50	0.68
India	-13.84	-12.01	-13.99	1.98	Switzerland	-19.72	-8.77	-10.89	2.13
Indonesia	-18.60	-10.69	-13.07	2.38	Taiwan	-24.39	-5.80	-7.59	1.79
Ireland	-21.57	-7.10	-9.04	1.94	Turkey	-18.55	-11.52	-14.17	2.64
Italy	-16.61	-10.03	-12.05	2.02	UK	-20.38	-7.45	-9.30	1.85
Japan	-14.63	-8.21	-9.55	1.35	USA	-13.06	-9.04	-10.36	1.32

Note: The table presents the aggregated real income changes in % for every country. Column 2 and 6 show the real income changes solely driven by the increase in trade costs by 100 percentage points. Column 3 and 7 present the real income changes in % driven by the COVID-19 shock under a Less integrated economy. Column 4 and 8 present the shock i under an open economy (similar to table 1). Column 5 and 9 present the difference between the shock under an open vs. a Less integrated economy. Equation 2 highlights how we included the shock.

Table 10: Disentangling the real income changes in a Less integrated economy - Share of Direct, Indirect and Trade Cost Effect - Shock 1 - Less integrated Economy

	Shock 1				Shock 1		
Country	Direct	Indirect	Trade Costs	Country	Direct	Indirect	Trade Costs
Australia	0.007	0.008	0.986	Korea	0.004	0.011	0.986
Austria	0.026	0.010	0.964	Latvia	0.004	0.006	0.990
Belgium	0.044	0.009	0.948	Lithuania	0.004	0.008	0.988
Brasil	0.005	0.008	0.987	Luxembourg	0.036	0.010	0.954
Bulgaria	0.001	0.007	0.992	Malta	0.009	0.009	0.982
Canada	0.017	0.008	0.975	Mexico	0.002	0.010	0.989
China	0.001	0.010	0.989	Netherlands	0.030	0.009	0.961
Croatia	0.007	0.008	0.985	Norway	0.025	0.008	0.967
Cyprus	0.011	0.008	0.982	Poland	0.004	0.010	0.986
Czech R.	0.009	0.013	0.978	Portugal	0.036	0.013	0.951
Denmark	0.023	0.011	0.966	ROW	0.015	0.005	0.980
Estonia	0.011	0.006	0.983	Romania	0.006	0.008	0.986
Finland	0.012	0.008	0.980	Russia	0.004	0.007	0.989
France	0.055	0.009	0.935	Slovakia	0.003	0.009	0.988
Germany	0.027	0.012	0.961	Slovenia	0.008	0.010	0.982
Greece	0.004	0.008	0.987	Spain	0.104	0.008	0.888
Hungary	0.003	0.012	0.985	Sweden	0.021	0.009	0.970
India	0.000	0.007	0.993	Switzerland	0.046	0.012	0.942
Indonesia	0.000	0.007	0.993	Taiwan	0.000	0.009	0.991
Ireland	0.048	0.012	0.940	Turkey	0.025	0.009	0.967
Italy	0.078	0.010	0.912	UK	0.033	0.008	0.958
Japan	0.002	0.007	0.991	USA	0.074	0.005	0.922

Note: This table decomposes the real income changes under shock 1, in the less integrated world, into its components: the share of the direct, indirect and trade cost effect.

Table 11: Disentangling the real income changes in a Less integrated economy - Share of Direct, Indirect and Trade Cost Effect - Shock 2 - Less integrated Economy

	Shock 2				Shock 2		
Country	Direct	Indirect	Trade Costs	Country	Direct	Indirect	Trade Costs
Australia	0.258	0.063	0.678	Korea	0.205	0.094	0.702
Austria	0.220	0.086	0.694	Latvia	0.156	0.064	0.780
Belgium	0.154	0.079	0.766	Lithuania	0.152	0.079	0.770
Brasil	0.333	0.067	0.600	Luxembourg	0.123	0.084	0.792
Bulgaria	0.138	0.065	0.797	Malta	0.117	0.066	0.816
Canada	0.229	0.074	0.697	Mexico	0.299	0.078	0.623
China	0.317	0.072	0.611	Netherlands	0.203	0.106	0.691
Croatia	0.188	0.069	0.743	Norway	0.225	0.078	0.697
Cyprus	0.144	0.061	0.795	Poland	0.207	0.091	0.702
Czech R.	0.191	0.122	0.688	Portugal	0.207	0.067	0.725
Denmark	0.230	0.087	0.683	ROW	0.175	0.056	0.769
Estonia	0.137	0.072	0.791	Romania	0.177	0.077	0.746
Finland	0.213	0.068	0.719	Russia	0.268	0.067	0.665
France	0.277	0.067	0.656	Slovakia	0.159	0.100	0.741
Germany	0.198	0.119	0.683	Slovenia	0.172	0.097	0.731
Greece	0.186	0.059	0.755	Spain	0.280	0.072	0.648
Hungary	0.193	0.112	0.694	Sweden	0.000	0.111	0.889
India	0.401	0.064	0.535	Switzerland	0.212	0.096	0.692
Indonesia	0.283	0.082	0.635	Taiwan	0.097	0.095	0.808
Ireland	0.127	0.121	0.752	Turkey	0.301	0.082	0.617
Italy	0.286	0.091	0.624	UK	0.196	0.072	0.732
Japan	0.278	0.082	0.641	USA	0.350	0.060	0.591

Note: This table decomposes the real income changes under shock 2, in the less integrated world, into its components: the share of the direct, indirect and trade cost effect.

Table 12: Decomposition of the real income changes economy - Shock 1 - Less integrated Economy

	Shock 1					Shock 1			
Country	Direct	Indirect	GE	Trade Costs	Country	Direct	Indirect	GE	Trade Costs
Australia	-0.124	-0.124	-0.021	-18.361	Korea	-0.082	-0.285	0.048	-21.767
Austria	-0.608	-0.221	-0.011	-22.586	Latvia	-0.127	-0.187	-0.007	-30.795
Belgium	-1.243	-0.255	0.012	-27.053	Lithuania	-0.135	-0.253	0.022	-29.996
Brasil	-0.068	-0.113	-0.004	-13.982	Luxembourg	-1.134	-0.301	0.000	-29.646
Bulgaria	-0.035	-0.245	-0.006	-33.503	Malta	-0.312	-0.311	0.008	-34.429
Canada	-0.343	-0.097	-0.070	-20.019	Mexico	-0.028	-0.140	-0.029	-17.380
China	-0.023	-0.160	-0.011	-17.123	Netherlands	-0.619	-0.194	0.003	-19.994
Croatia	-0.195	-0.237	0.004	-27.888	Norway	-0.501	-0.162	0.004	-19.545
Cyprus	-0.337	-0.250	0.006	-31.143	Poland	-0.092	-0.227	-0.005	-23.089
Czech R.	-0.210	-0.268	-0.014	-21.684	Portugal	-0.915	-0.322	0.003	-24.121
Denmark	-0.479	-0.255	0.027	-19.907	ROW	-0.445	-0.113	-0.037	-29.326
Estonia	-0.350	-0.198	-0.009	-31.869	Romania	-0.155	-0.229	0.007	-27.346
Finland	-0.263	-0.175	-0.006	-22.117	Russia	-0.083	-0.221	0.074	-20.908
France	-1.117	-0.170	-0.021	-18.866	Slovakia	-0.069	-0.265	0.026	-25.896
Germany	-0.538	-0.263	0.011	-19.443	Slovenia	-0.212	-0.263	-0.017	-26.575
Greece	-0.109	-0.170	-0.030	-24.020	Spain	-2.150	-0.182	0.014	-18.312
Hungary	-0.065	-0.305	0.035	-22.134	Sweden	-0.483	-0.210	-0.009	-22.607
India	-0.001	-0.015	-0.085	-13.838	Switzerland	-0.963	-0.283	0.029	-19.719
Indonesia	-0.007	-0.118	-0.015	-18.603	Taiwan	-0.003	-0.194	-0.021	-24.390
Ireland	-1.096	-0.254	-0.025	-21.573	Turkey	-0.477	-0.168	0.004	-18.546
Italy	-1.414	-0.213	0.031	-16.612	UK	-0.704	-0.173	-0.008	-20.375
Japan	-0.033	-0.101	-0.003	-14.631	USA	-1.048	-0.027	-0.037	-13.055

Note: This table decomposes the real income changes under shock 1, in the less integrated world, into its four components: direct, indirect, GE and trade cost effect.

Table 13: Decomposition of the real income changes economy - Shock 1 - Less integrated Economy

	Shock 2					Shock 2			
Country	Direct	Indirect	GE	Trade Costs	Country	Direct	Indirect	GE	Trade Costs
Australia	-6.986	-1.896	0.177	-18.361	Korea	-6.355	-3.386	0.481	-21.767
Austria	-7.175	-3.172	0.383	-22.586	Latvia	-6.174	-2.862	0.328	-30.795
Belgium	-5.442	-3.150	0.346	-27.053	Lithuania	-5.904	-3.507	0.442	-29.996
Brasil	-7.751	-1.769	0.217	-13.982	Luxembourg	-4.614	-3.499	0.350	-29.646
Bulgaria	-5.806	-3.117	0.366	-33.503	Malta	-4.955	-3.133	0.329	-34.429
Canada	-6.561	-2.271	0.147	-20.019	Mexico	-8.336	-2.516	0.325	-17.380
China	-8.885	-2.354	0.338	-17.123	Netherlands	-5.866	-3.443	0.386	-19.994
Croatia	-7.055	-2.989	0.379	-27.888	Norway	-6.325	-2.461	0.272	-19.545
Cyprus	-5.649	-2.694	0.304	-31.143	Poland	-6.825	-3.406	0.420	-23.089
Czech R.	-6.019	-4.337	0.505	-21.684	Portugal	-6.901	-2.525	0.288	-24.121
Denmark	-6.701	-2.930	0.388	-19.907	ROW	-6.688	-2.324	0.193	-29.326
Estonia	-5.522	-3.244	0.361	-31.869	Romania	-6.473	-3.263	0.427	-27.346
Finland	-6.539	-2.350	0.256	-22.117	Russia	-8.439	-2.535	0.426	-20.908
France	-7.954	-2.173	0.234	-18.866	Slovakia	-5.555	-4.012	0.499	-25.896
Germany	-5.645	-3.837	0.455	-19.443	Slovenia	-6.271	-3.984	0.472	-26.575
Greece	-5.914	-2.048	0.161	-24.020	Spain	-7.900	-2.347	0.309	-18.312
Hungary	-6.166	-4.129	0.545	-22.134	Sweden	0.000	-2.915	0.091	-22.607
India	-10.366	-1.795	0.152	-13.838	Switzerland	-6.029	-3.120	0.383	-19.719
Indonesia	-8.299	-2.705	0.315	-18.603	Taiwan	-2.919	-3.073	0.191	-24.390
Ireland	-3.630	-3.744	0.275	-21.573	Turkey	-9.064	-2.859	0.398	-18.546
Italy	-7.610	-2.805	0.384	-16.612	UK	-5.448	-2.210	0.207	-20.375
Japan	-6.345	-2.066	0.205	-14.631	USA	-7.722	-1.426	0.108	-13.055

Note: This table decomposes the real income changes under shock 2, in the less integrated world, into its four components: direct, indirect, GE and trade cost effect.

A Appendix

A.1 Appendix: Data Sources and Description

The next section describes the data sources used for the construction of the COVID-19 shocks and for the counterfactual simulations.

Data needed for the simulation. We use data from World Input-Output database (WIOD) as our main data source for the simulations. It provides information on bilateral intermediate and final trade, sectoral output and value-added information, consumer and producer prices. With this data, one can construct bilateral input-output tables, intermediate consumption and expenditure levels for 43 countries and a rest of the world aggregate (ROW) (Timmer et al., 2015). In total each country consists of 56 sectors, which we aggregate into 50 industries (see table A4) in the Appendix. This aggregation concerns mostly services; we keep the sectoral detail in the manufacturing and agricultural industries. Data on bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB). The parameter for the productivity dispersion, hence the trade cost elasticity is taken from Caliendo and Parro (2015).

To construct the shocks, as detailed in equation 1 and 2, we need the following data:

COVID-19 cases. We exploit information on the number of corona cases in each country c_i and region from multiple sources. We use data from the Johns Hopkins Coronavirus Resource Center and combine them with information from national statistical offices for Italy, Germany, Spain and Portugal. This provides us with COVID-19 cases as of April 16th in each of the 43 countries of our data set, with regional disaggregation for the US, Italy, China, Germany, Spain and Portugal.[30] Figure A1 shows 4 selected country maps with regional variation in the number of COVID-19 cases. The data of COVID-19 cases on regional level is then merged with the regional, sector level employment data. This way, we can construct a measure that accounts for the severity of a sector being hit by the COVID-19 pandemic. Concrete, the severity of the effect in a sector depends on the geographical distribution of the sector across.

[30] The regional dimension will be updated for every country as soon as this information becomes available.

Table A1: Change in value added (in %) - Open Economy

Panel B: Shock 1 - Open Economy

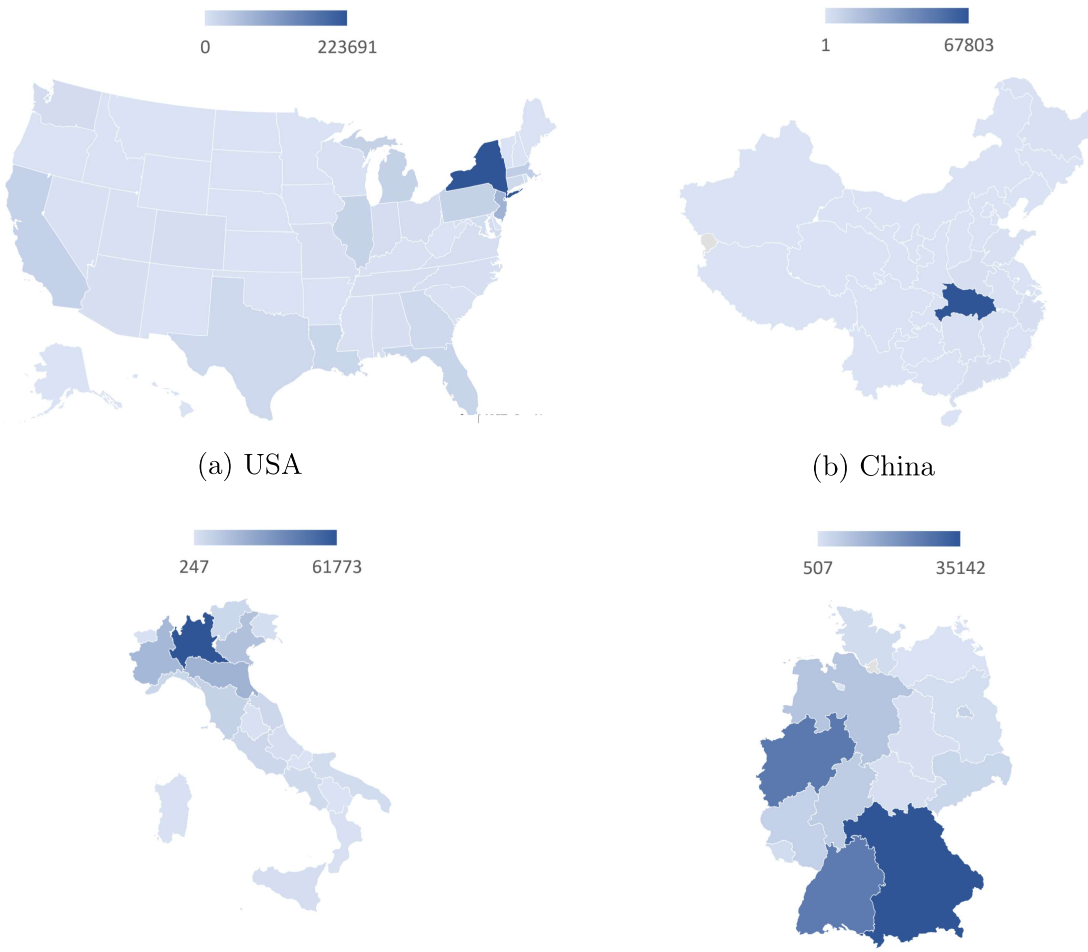
Sector	Italy in %	Germany in %	USA in %	China in %	EU28 in %	Rest of World in %
Agriculture	-1.98	-0.98	-1.30	-0.15	-1.38	-0.55
Food, Beverages, Tabacco	-1.93	-0.99	-1.26	-0.18	-1.37	-0.46
Mining, Quarrying	-2.10	-1.05	-1.30	-0.15	-1.13	-0.67
Textiles	-2.28	-0.98	-1.21	-0.05	-1.63	-0.45
Electrical Equipment	-2.29	-1.01	-1.31	-0.01	-1.22	-0.40
Machinery, Equipment	-1.71	-1.01	-1.20	-0.26	-1.22	-0.57
Motor Vehicles	-1.53	-0.97	-1.11	-0.25	-1.05	-0.46
Intm. Resources Manufacturing	-2.00	-0.98	-1.26	-0.16	-1.28	-0.43
Manufacturing, nec.	-1.67	-0.95	-1.21	-0.29	-1.23	-0.50
Pharmaceuticals	-1.89	-1.05	-1.27	-0.24	-1.39	-0.69
Chemicals	-2.39	-0.99	-1.32	-0.12	-1.42	-0.41
Electricity, Water, Gas	-1.97	-0.97	-1.27	-0.16	-1.33	-0.62
Construction	-1.94	-0.97	-1.28	-0.19	-1.34	-0.48
Wholesale, Retail Trade	-1.98	-0.99	-1.28	-0.13	-1.37	-0.48
Transport	-2.01	-1.00	-1.29	-0.15	-1.37	-0.52
Accommodation and Food	-1.93	-0.98	-1.28	-0.18	-1.58	-0.47
Real Estate	-1.94	-0.97	-1.29	-0.18	-1.40	-0.47
Public Services	-1.95	-0.97	-1.28	-0.19	-1.36	-0.46
Social Services	-1.94	-0.96	-1.29	-0.19	-1.35	-0.46
Services, nec.	-1.97	-0.98	-1.29	-0.17	-1.36	-0.51

Panel B: Shock 2 - Open Economy

Sector	Italy in %	Germany in %	USA in %	China in %	EU28 in %	Rest of World in %
Agriculture	-12.08	-10.69	-10.23	-13.55	-11.42	-12.61
Food, Beverages, Tabacco	-11.90	-10.91	-10.32	-13.47	-11.21	-11.82
Mining, Quarrying	-12.10	-9.69	-10.32	-13.47	-10.49	-12.27
Textiles	-12.36	-10.25	-10.75	-14.02	-11.92	-12.77
Electrical Equipment	-12.34	-10.27	-10.68	-13.99	-10.62	-10.97
Machinery, Equipment	-11.95	-11.45	-10.93	-12.89	-11.57	-11.52
Motor Vehicles	-12.24	-11.72	-10.62	-12.98	-11.49	-11.61
Intm. Resources Manufacturing	-12.11	-10.93	-10.47	-13.44	-11.23	-11.83
Manufacturing, nec.	-11.81	-11.63	-11.00	-13.22	-11.50	-11.65
Pharmaceuticals	-11.42	-12.16	-10.47	-13.24	-11.38	-10.96
Chemicals	-12.30	-9.90	-10.31	-13.63	-10.67	-12.03
Electricity, Water, Gas	-12.06	-11.03	-10.45	-13.46	-11.15	-12.04
Construction	-12.05	-11.19	-10.37	-13.33	-11.07	-11.83
Wholesale, Retail Trade	-12.05	-10.96	-10.35	-13.57	-11.08	-11.90
Transport	-12.06	-10.74	-10.33	-13.52	-11.00	-12.11
Accommodation and Food	-12.06	-11.10	-10.37	-13.38	-11.27	-11.57
Real Estate	-12.06	-11.17	-10.37	-13.37	-11.15	-11.35
Public Services	-12.04	-11.11	-10.37	-13.32	-11.12	-11.76
Social Services	-12.05	-11.24	-10.37	-13.32	-10.99	-11.15
Services, nec.	-12.06	-11.04	-10.36	-13.40	-10.89	-11.63

Note: The table shows the sectoral value added changes, in % for selected countries, Italy, Germany, USA, and China. The upper part of the table presents the results for shock 1 in an open economy. The second part presents the results in the case of shock 2 in an open economy. Column 6 presents the value added results (in %) for EU28, which are weighted by the initial value added by country. Column 7 shows the value added weighted results for all remaining countries. Further, sectors are aggregated into broader categories (see table A3 in the Appendix)).

Figure A1: COVID-cases by region in selected countries



(a) USA (b) China

(c) Italy (d) Germany

Note: The maps show the number of COVID-19 cases by region for the US (A1a), China (A1b), Italy (A1c), and Germany (A1d) until the 16th of April 2020. We chose this date to coincide with the data of the simulations. Since COVID-19 pandemics is still ongoing, we will update the data of COVID-cases in future versions of this paper.

Employment Data. Information on employment by country-region and sector is crucial to account for the geographical distribution of sectors across each country as well as for the COVID-19 shares over employment in a country-region.[31]

For the *EU*, we use the information contained in Eurostat. For the *US* we use IPUMScps to

[31] Data on employment at sector-region level are not available for some countries in the sample, we therefore construct a simpler version of equation 1. In this case, the formula does not capture the geographical distribution of sectors in the country, but accounts for the sectoral distribution of employment and for their labor intensity. This is the case for Australia, Brazil, Canada, India, Indonesia, Japan, Korea, Mexico, Russia, Taiwan, RoW.

construct employment by state(region) and sector of activity. To construct the employment shares across regions and sectors for *China*, we use two data sources: first, we use data from the National Bureau of Statistic of China for the year 2018 on employment by region and sector.[32] The second data source comes from the 2000 census. The National Bureau of Statistic of China provides the sector information for 19 sectors and 31 regions. Sectors consist of one agricultural sector, one mining sector, one manufacturing sector and 16 services sectors, hence a more aggregated sector level than provided in the paper. We therefore complement the available data with the employment shares by prefectures and sector from the 2000 census to construct the regional employment level for each of the WIOD sectors. The census data is used to retrieve the employment shares in each Chinese region and sector. We now have information for China divided into 340 prefectures and 151 sectors (SIC industry code), which is then aggregated to 31 Chinese regions and the 50 WIOD sectors.[33] We then redistribute the most recent available number of employment from the National Bureau of Statistic of China according to the shares from the 2000 census data (see figure A2).[34] This returns regional employment shares for each WIOD sector and region in China.

Quarantine Restrictiveness. For the construction of the quarantine index α_i^j we require information on the degree of restriction for each country ($IndexClosure_i$).

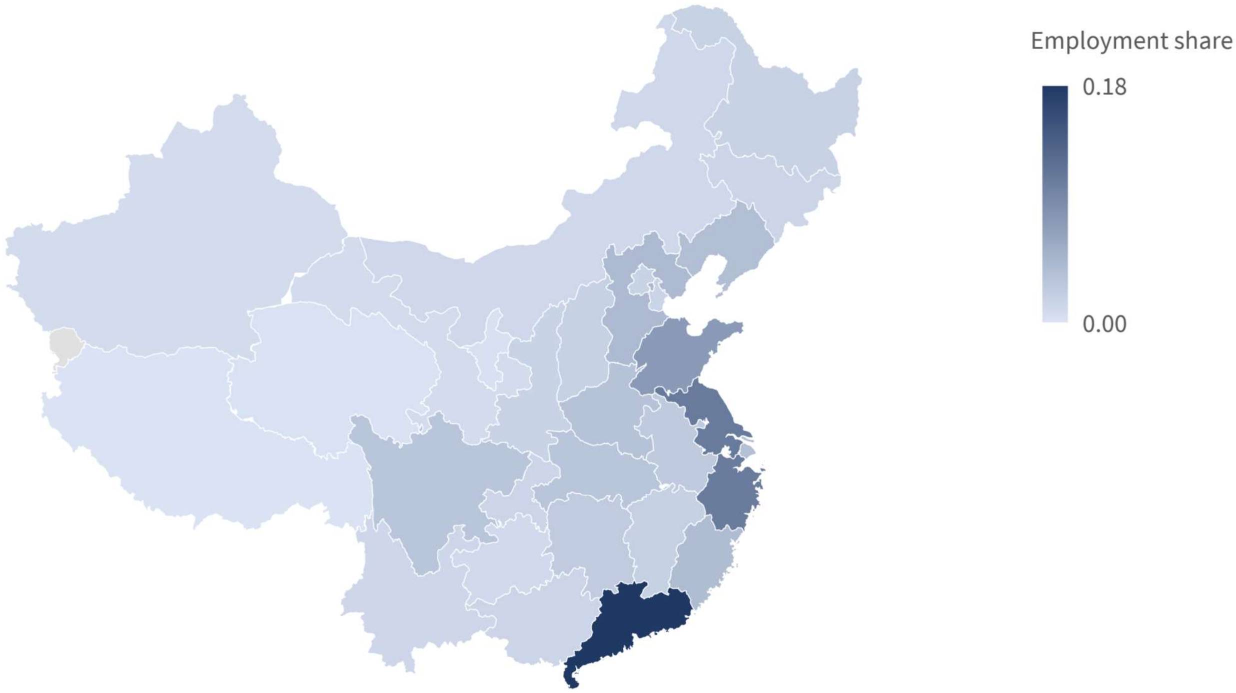
We use the index on government responses to the COVID-19 diffusion of the University of Oxford, where $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. Further, using the information contained in the data-set on government responses to the COVID-19 from the University of Oxford, we account for the average duration of strict quarantine, which we estimate to be of one month. COVID-pandemics is still ongoing, which is why we do not have the final number of quarantine days across countries.

[32] See `http://www.stats.gov.cn/english/` for a general overview of the data collected by the NBSC, and `http://data.stats.gov.cn/english/` for employment data at regional level.

[33] The concordance of SIC industry codes to WIOD can be retrieved from the authors. We aggregate the 340 Chinese prefectures to 31 regions, because the COVID-19 data is only available at the more aggregated, regional level.

[34] The correlation of the employment shares across regions of the census 2000 data and the data from the National Bureau of Statistics is 0.93.

Figure A2: Employment shares across Chinese regions

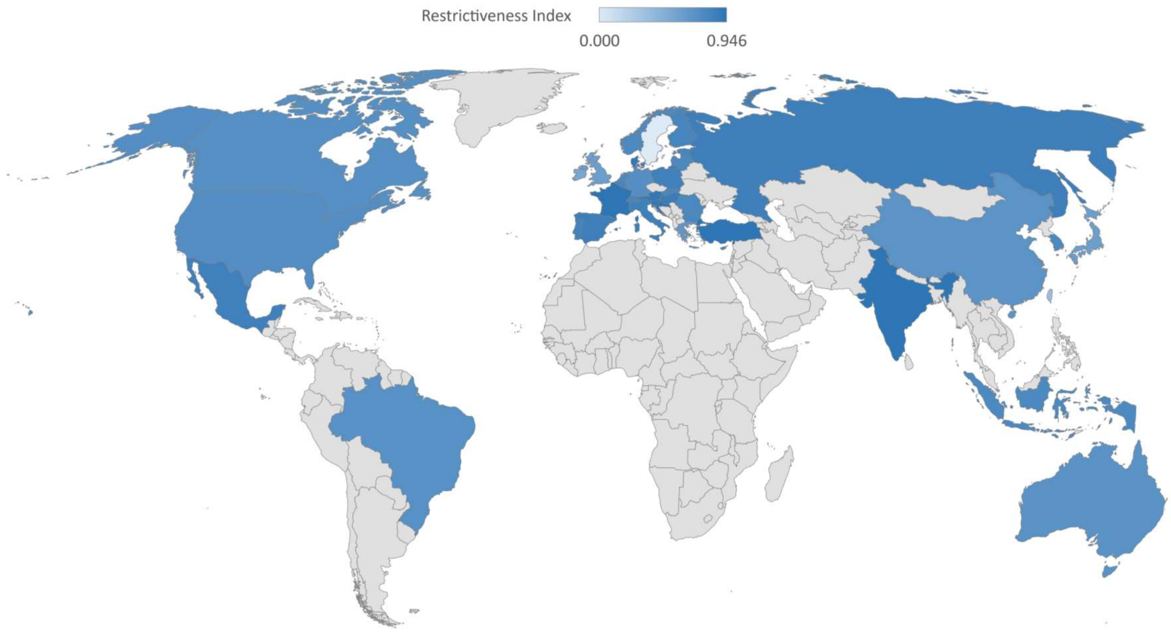


Note: The map shows the regional employment over total Chinese employment, which is crucial to construct the geographical distribution of the extent of the shock. We further have data on the within regional sector distribution needed to construct the shock 1.

Teleworkability. We follow Dingel and Neiman (2020) to construct a measure of the degree of *teleworkability* of each occupation. The information contained in the Occupational Information Network (O*NET) surveys is used to construct a measure of feasibility of working from home for each sector. The information on O*NET is provided as NAICS classification, for which we provide a concordance to match the WIOD sector classification (see table A2). The policy interventions implemented due to COVID-19 explicitly exempt the sensitive sectors from all restrictive measures, which is the reason why we increase the share of teleworkable employment for such sensitive sectors to 0.8. Precisely, the sensitive sectors are still producing their goods and services without a complete shutdown. The list of sensitive sectors includes (ISIC rev 3 sectoral classification): Agriculture (sector 1), Fishing (sector 3), Electricity and gas (sector 23), Water supply (sector 24), Sewage and Waste (sector 25), Postal and courier (sector 34), Human health and social work (sector 49).

Construction of the shocks. Using all the data described above we can construct the two shocks (see equations 1 and 1). Figures A4 and A5 show maps of the two shocks for all countries of the sample. Figure A6 zooms into the EU and shows the size of the two shocks

Figure A3: Restrictiveness Index across countries



Note: The map reports the restrictiveness index for all countries in our sample. An index equal to zero means no restrictions (i.e. in Sweden), while an index equal 100 means that the entire economy is set under a complete shutdown (i.e. France it is 0.97. No information is available for countries shaded in gray.

for the EU countries.

A.2 Additional results

A.2.1 Additional less integrated economy scenarios

In this subsection, we present scenarios that gradually close the openness of the economy. Concrete, we increase the trade costs from 10 percentage points to 100 percentage points.[35] For both shocks, the additional increases in trade costs by 10 percentage points on average decreases the size of the real income drops by 0.02 for Germany and China, 0.18 for Italy, 0.013 for the USA, and by 0.03 across all countries.

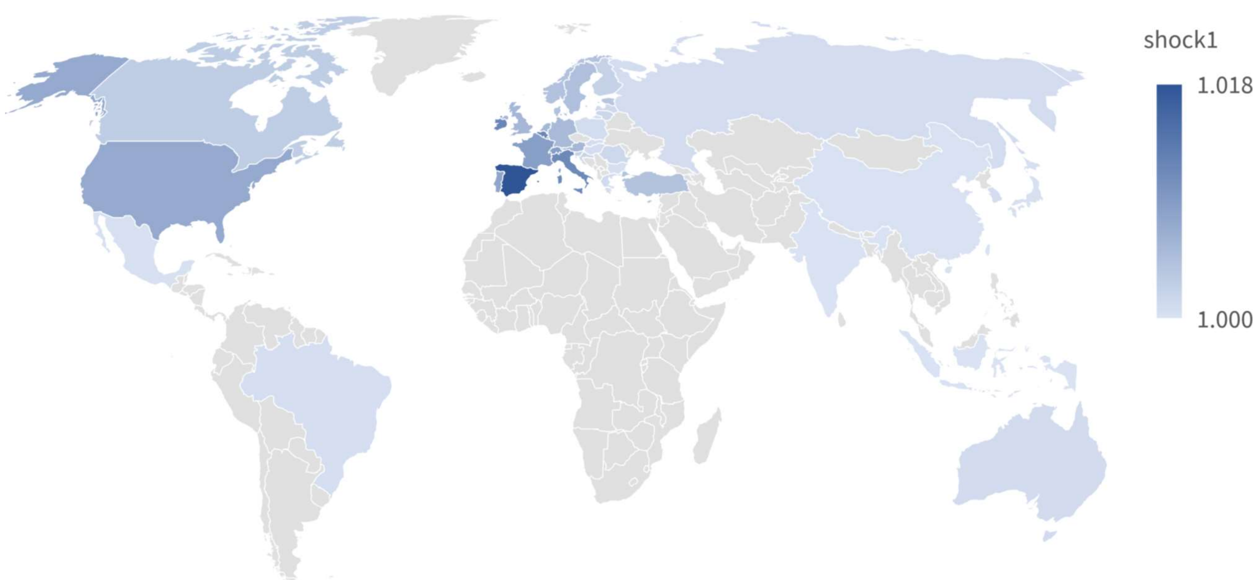
[35]The main body of the text presents the results for a less integrated world with an increase of trade costs by a hundred percentage points.

Table A2: Teleworkability by sector

NAICS sec-id	WIOD sec-id	Sector Description	sec-id	Teleworkability sec-id	NAICS Description	WIOD	Sector
11	1	Crops, Animals	0.08	23	26	Construction	0.19
11	2	Forestry, Logging	0.08	42	27	Trade, Repair of Motor Vehicles	0.52
11	3	Fishing, Aquaculture	0.08	42	28	Wholesale Trade	0.52
21	4	Mining, Quarrying	0.25	44-45	29	Retail Trade	0.14
11	5	Food, Beverages, Tobacco	0.08	48-49	30	Land Transport	0.19
31-33	6	Textiles, Apparel,Leather	0.22	48-49	31	Water Transport	0.19
31-33	7	Wood, Cork	0.22	48-49	32	Air Transport	0.19
31-33	8	Paper	0.22	48-49	33	Aux. Transportation Services	0.19
31-33	9	Recorded Media Reproduction	0.22	48-49	34	Postal and Courier	0.19
31-33	10	Coke, Refined Petroleum	0.22	72	35	Accommodation and Food	0.04
31-33	11	Chemicals	0.22	51	36	Publishing	0.72
31-33	12	Pharmaceuticals	0.22	51	37	Media Services	0.72
31-33	13	Rubber, Plastics	0.22	51	38	Telecommunications	0.72
31-33	14	Other non-Metallic Mineral	0.22	55	39	Computer, Information Services	0.79
31-33	15	Basic Metals	0.22	52	40	Financial Services	0.76
31-33	16	Fabricated Metal	0.22	52	41	Insurance	0.76
31-33	17	Electronics, Optical Products	0.22	53	42	Real Estate	0.42
31-33	18	Electrical Equipment	0.22	54	43	Legal and Accounting	0.80
31-33	19	Machinery, Equipment	0.22	54	44	Business Services	0.80
31-33	20	Motor Vehicles	0.22	54	45	Research and Development	0.80
31-33	21	Other Transport Equipment	0.22	56	46	Admin., Support Services	0.31
31-33	22	Furniture, Other Manufacturing	0.22	99	47	Public, Social Services	0.41
22	23	Electricity, Gas	0.37	61	48	Education	0.83
22	24	Water Supply	0.37	62	49	Human Health and Social Work	0.25
22	25	Sewerage, Waste	0.37	71	50	Other Services, Households	0.30

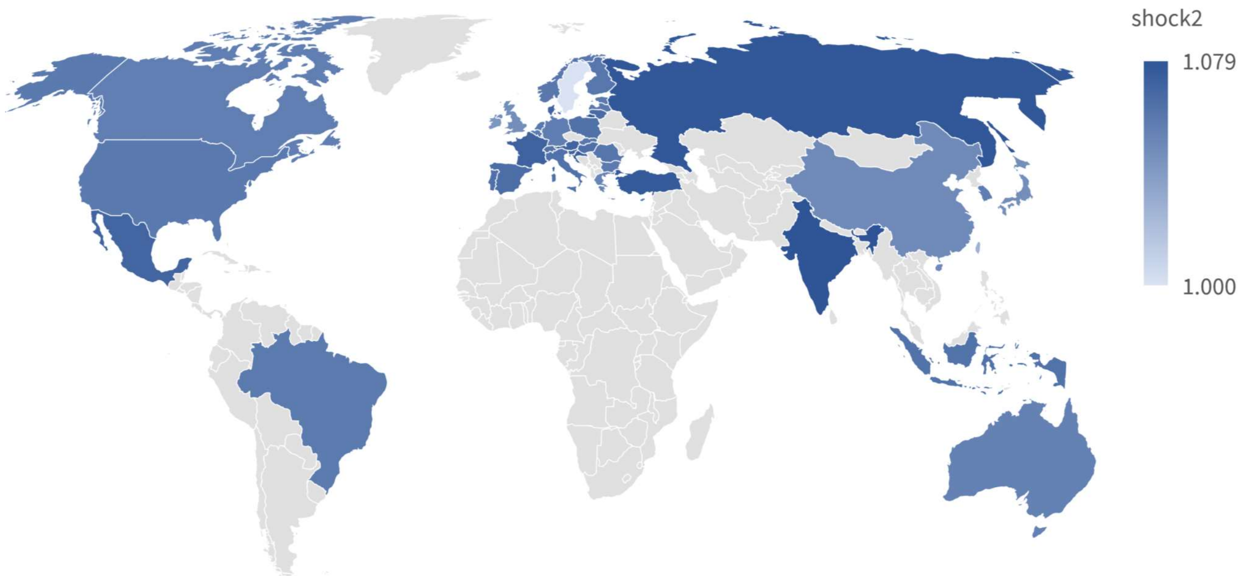
Note: The table shows the degree of teleworkability of each WIOD sector. Zero would indicate that work cannot be done from home, while teleworkability equal to 1 indicates that the entire work is independent of the location.

Figure A4: Shock 1 across all countries



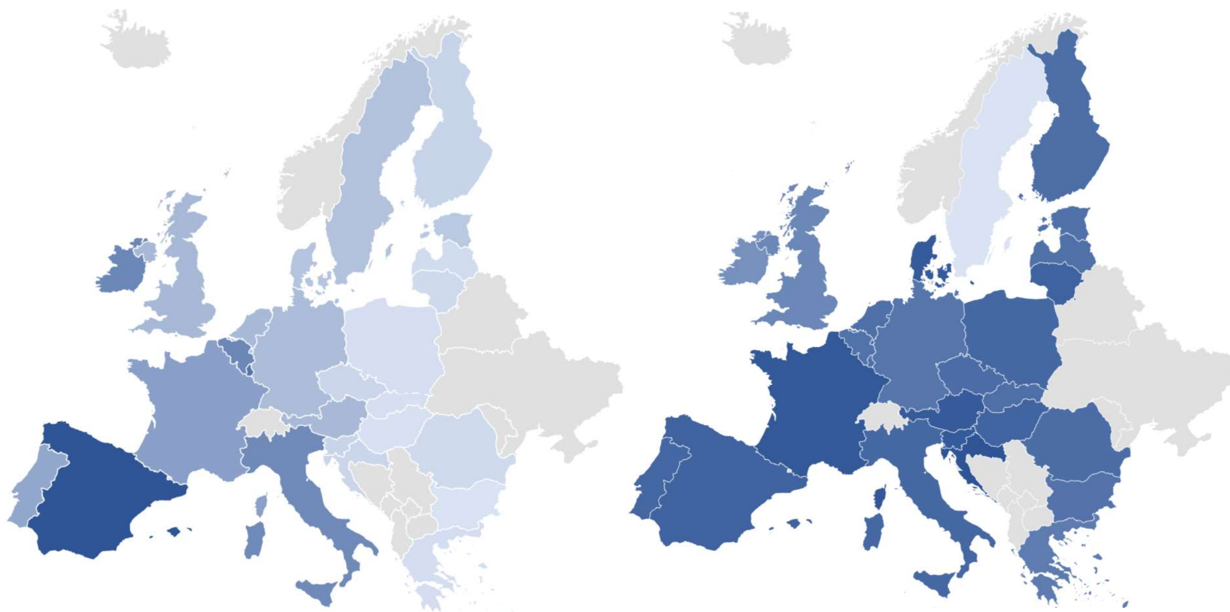
Note: The map reports the intensity of the snap-shot shocks (1) imputed into the model for all countries in our sample. A shock equal to 1 means no changes from the baseline, while a shock of 2 would imply an increase in the production barrier by a hundred percent. See equation 1 for the precise construction of the shock.

Figure A5: Shock 2 across all countries



Note: The map reports the size of the quarantine shocks (2) imputed into the model for all countries in our sample. A shock equal to 1 means no changes from the baseline, while a shock of 2 would imply an increase in the production barrier by a hundred percent. See equation 2 for the precise construction of the shock.

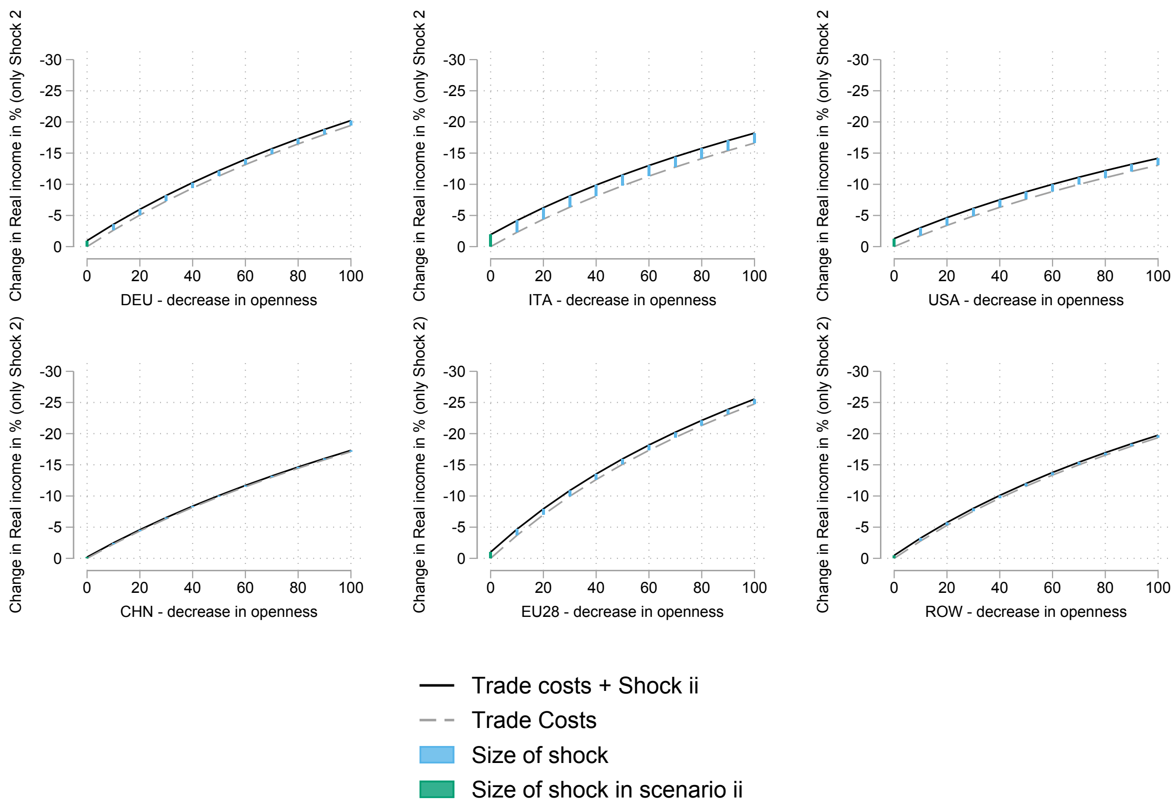
Figure A6: Size of the Shocks across EU28 member states



(a) Shock 1 (b) Shock 2

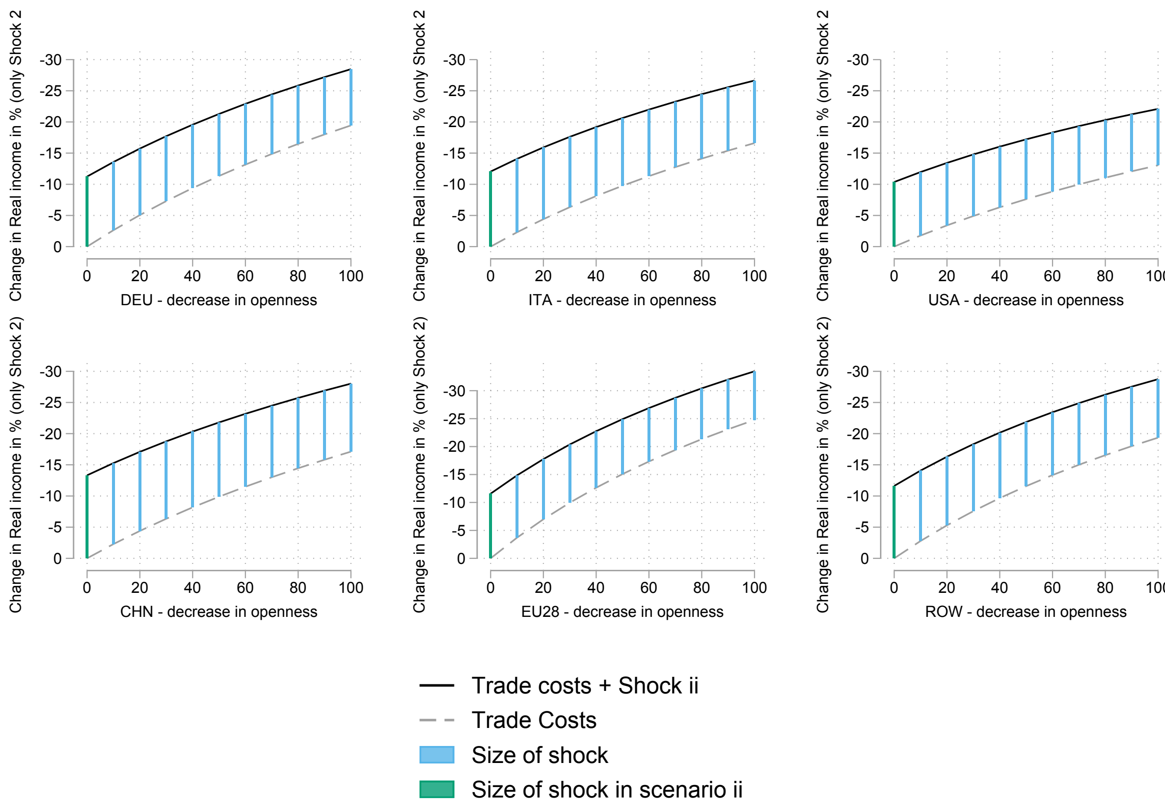
Note: The maps show the size of the snap-shot shocks (1) and the quarantine shock (2), which are imputed into the model for the EU28 member states. A shock equal to 1 means no changes from the baseline, while a shock of 2 would imply an increase in the production barrier by a hundred percent for an entire year. See equations 1 and 2 for the precise construction of the shock. The darker the shade of blue, the higher is the size of the effect. The scale of subfigure A6a goes from 1 (e.g. Bulgaria) to 1.018 (Spain). The scale of subfigure A6b goes from 1, the least restrictive country (Sweden) to 1.072, the most restrictive country (i.e. France).

Figure A7: Real Income Changes with different openness degrees of the economy - Shock 1



Note: The 6 sub-figures show the real income changes for the four selected countries, Italy, Germany, USA, and China and the regions EU28, ROW. The x-axis presents the scenarios with different trade cost increases. At the point 0, the real income changes are identical to the changes of shock 1 shown in table 1. 50 equals the increase in trade costs for every country by 50 percentage points. 100 is identical to our less integrated economy scenario shown in the main body. The black solid lines indicate the decrease in real income due to the increase in trade costs plus the shock (1) under different degrees of openness of the economy. The gray dashed line shows the drop in real income that solely comes from the trade cost increases. The clue bars show the decrease in real income due to the shock (2). The green bar (at x-axis 0 - no trade costs) shows the decrease in real income that stems from the shock. It is identical to the decreases shown in table 1.

Figure A8: Real Income Changes with different openness degrees of the economy - Shock 2



Note: The six figures show the real income changes for the four selected countries, Italy, Germany, USA, and China and the regions EU28, ROW. The x-axis presents the scenarios with different trade cost increases. At the point 0, the real income changes are identical to the changes of shock 2 shown in table 1. 50 equals the increase in trade costs for every country by 50 percentage points. 100 is identical to our less integrated economy scenario shown in the main body. The black solid lines indicate the decrease in real income due to the increase in trade costs plus the shock (2) under different degrees of openness of the economy. The gray dashed line shows the drop in real income that solely comes from the trade cost increases. The clue bars show the decrease in real income due to the shock (2). The green bar (at x-axis 0 - no trade costs) shows the decrease in real income that stems from the shock. It is identical to the decreases shown in table 1.

Table A3: WIOD Sector Aggregation

WIOD sec-id	Sector Description	WIOD sec-id	Sector Description
	Agriculture	23	Electricity, Gas
2	Forestry, Logging	24	Water Supply
1	Crops, Animals		**Construction**
3	Fishing, Aquaculture	26	Construction
	Food, Beverages, Tobacco		**Wholesale and Retail Trade**
5	Food, Beverages, Tobacco	29	Retail Trade
	Mining, Quarrying	28	Wholesale Trade
4	Mining, Quarrying	27	Trade, Repair of Motor Vehicles
	Textiles		**Transport**
6	Textiles, Apparel,Leather	30	Land Transport
	Electrical Equipment	33	Aux. Transportation Services
18	Electrical Equipment		**Transport**
17	Electronics, Optical Products	32	Air Transport
	Machinery, Equipment	31	Water Transport
19	Machinery, Equipment		**Accommodation and Food**
	Motor Vehicles	35	Accommodation and Food
20	Motor Vehicles		**Real Estate**
	Intm. Resources Manufacturing	42	Real Estate
9	Recorded Media Reproduction		**Public Services**
8	Paper	46	Admin., Support Services
10	Coke, Refined Petroleum	47	Public, Social Services
16	Fabricated Metal		**Social Services**
13	Rubber, Plastics	49	Human Health and Social Work
7	Wood, Cork		**Services, nec.**
15	Basic Metals	37	Media Services
14	Other non-Metallic Mineral	40	Financial Services
	Manufacturing, nec.	36	Publishing
22	Furniture, Other Manufacturing	45	Research and Development
21	Other Transport Equipment	50	Other Services, Households
	Pharmaceuticals	44	Business Services
12	Pharmaceuticals	48	Education
	Chemicals	38	Telecommunications
11	Chemicals	34	Postal and Courier
	Electricity, Water, Gas	41	Insurance
25	Sewerage, Waste	43	Legal and Accounting
		39	Computer, Information Services

Note: The sectors written in bold indicate the broad categories each WIOD sector belongs to.

Table A4: Concordance WIOD Sectors - ISIC Rev. 4

WIOD		ISIC Rev. 4	WIOD		ISIC Rev. 4
ID	Description		ID	Description	
1	Crops & Animals	A01	26	Construction	F
2	Forestry & Logging	A02	27	Trade & Repair of Motor Vehicles	G45
3	Fishing & Aquaculture	A03	28	Wholesale Trade	G46
4	Mining & Quarrying	B	29	Retail Trade	G47
5	Food, Beverages & Tabacco	C10-C12	30	Land Transport	H49
6	Textiles, Apparel,Leather	C13-C15	31	Water Transport	H50
7	Wood & Cork	C16	32	Air Transport	H51
8	Paper	C17	33	Aux. Transportation Services	H52
9	Recorded Media Reproduction	C18	34	Postal and Courier	H53
10	Coke, Refined Petroleum	C19	35	Accommodation and Food	I
11	Chemicals	C20	36	Publishing	J58
12	Pharmaceuticals	C21	37	Media Services	J59_J60
13	Rubber & Plastics	C22	38	Telecommunications	J61
14	Other non-Metallic Mineral	C23	39	Computer & Information Services	J62_J63
15	Basic Metals	C24	40	Financial Services	K64
16	Fabricated Metal	C25	41	Insurance	K65_K66
17	Electronics & Optical Products	C26	42	Real Estate	L68
18	Electrical Equipment	C27	43	Legal and Accounting	M69_M70
19	Machinery & Equipment	C28,C33	44	Business Services	M71,M73-M75
20	Motor Vehicles	C29	45	Research and Development	M72
21	Other Transport Equipment	C30	46	Admin. & Support Services	N
22	Furniture & Other Manufacturing	C31_C32	47	Public & Social Services	O84
23	Electricity & Gas	D35	48	Education	P85
24	Water Supply	E36	49	Human Health and Social Work	Q
25	Sewerage & Waste	E37-E39	50	Other Services, Households	R-U