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## Globalization in the Time of COVID-19

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# Globalization in the Time of COVID-19

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# Globalization in the Time of COVID-19

## Abstract

The economic effects of a pandemic crucially depend on the extend 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 our model to quantify the welfare effect of the disruption in production that started in China and then 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, 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.<sup>1</sup>

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 800.000 cases, 39.014 deaths and millions of people in quarantine around the world to date, the spread of COVID-19 disease is the largest pandemics ever experienced in the globalized world.<sup>2</sup> 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 (thankfully) 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 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 production barrier that increases the

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<sup>1</sup>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

<sup>2</sup>See Maffioli (2020) for a comparison of COVID-19 with other pandemics in the recent history.

production costs for intermediates and final goods produced for the internal market as well as for the exporting market. 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.<sup>3</sup> 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 under three different scenarios: (i) a *snap-shot* scenario based on the actual number of COVID-19 cases in each country, (ii) a quarantine scenario, imposing quarantine to a fraction of the labour force in some countries and (iii) a closed world scenario, that evaluates the effects of the COVID-19 shock in a less integrated world, hence with higher tariffs. The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region and the number of corona cases in each region or country. We calibrate a 40 countries 50 sector economy and incorporate the COVID-19 production 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, countries with a share of COVID-19 cases to the employed population above 0.05% impose a policy according to which up to 60% of the labor force is quarantined for one month; results show that most countries with quarantined labor force experience a drop in real income up to 14%, with the most pronounced drops for the China, Finland and the UK.<sup>4</sup>

The role of the global production linkages in magnifying the effect of the production shock is clear when we look at countries for which we do not impose the quarantine restriction under the quarantine scenario. For this group of countries, the quarantine of their trade partners increases the effect of the COVID-19 shock drastically from a an average 0.2% decrease in real income in the no quarantine scenario, to 3% drop in real income in the quarantine case. Moreover, we show that the centrality of a country in the global value chains is a key element in explaining the magnitude of the economic effect of the shock.

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<sup>3</sup>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).

<sup>4</sup>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.

We further decompose the economic impact of the COVID-19 shock by sectors and find that the income drop is widespread across all sectors. These results substantially differ from what Caliendo and Parro (2015) find for the decrease in tariffs due to the NAFTA agreement. Indeed, contrary to drops in tariffs that affect some sectors more than other, 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 real income is partially driven by the geography of production in each country combined with the geographic diffusion of the shock, and partially by the inter-sectoral linkages across countries. Finally, we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the current tariffs 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 with the actual tariffs, we find a mixed pattern. For some countries the shock in a less integrated world has a stronger effect, while for some other countries the shock has a marginally milder effect in a closer world. 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 through the trade linkages to other countries. Trade has a two different effects in our model: on the one hand, it smoothens 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. The balance between these two effects depends on the degree of integration of the country in the network of global production and on the sectoral specialization of each country.<sup>5</sup>

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.<sup>6</sup> Indeed, our paper is based on the work of Caliendo and Parro

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<sup>5</sup>Further analysis is needed to better understand the determinants of this pattern.

<sup>6</sup>See for example Dekle et al. (2008), Arkolakis et al. (2012)

(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 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.<sup>7</sup>

The paper is structured as follows. In section 2 we describe the COVID-19 shock and motivate the rationale of our modelling 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 March 26, 2020, the virus has affected nearly 500.000 people in 175 countries, causing 22.295 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

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<sup>7</sup>A growing literature in economics extends the SIER model to study the economic consequences of the diffusion of the pandemics under different policy scenarios (see for example Atkeson (2020), Berger (2020), Eichenbaum et al. (2020))



large shares of the population into quarantine.<sup>8</sup> Because of forced quarantine, there is wide consensus that the economic costs of the pandemic will be considerable, as factories, businesses, schools and country borders 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  $v_{ij}$  can be expressed as

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

where  $l_{ijr}$  is the total employment of sector  $j$  in region  $r$  of country  $i$ ,  $c_{ir}$  is the number of official cases of COVID-19 in region  $r$  of country  $i$ ,  $\gamma_i^j$  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. In our counterfactual exercise we substitute the share of corona cases over total employment  $\frac{c_{ir}}{\sum_{j=1}^J l_{ijr}}$  with a share of people under quarantine.<sup>9</sup> 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. Data on employment at sector-region level are not available for each country in our sample, and we construct a simpler version of equation 1<sup>10</sup>:

$$v_i^j = \frac{c_i}{\sum_{j=1}^J l_{ij}} * e^{\gamma_i^j}, \quad (2)$$

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.

Finally, it is important to highlight that the production barrier shock presented in equation 1 substantially differs from a natural disaster. A natural disaster is a geographically localized

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<sup>8</sup>To date, this has been the case in China, Italy, Spain, Germany, France, Australia, South Africa, India, Argentina, Saudi Arabia, some states of the US and many other countries.

<sup>9</sup>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

<sup>10</sup>The section 4 describes in detail the data sources that we use in this paper

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 modelled 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 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. In the model 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.<sup>11</sup>

**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  $\sum_j \alpha_n^j = 1$ .

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<sup>11</sup>We are currently working on a version of the model that does not allow mobility across countries and sectors. Caliendo et al. (2019) develop a dynamic version of this model with spatially distinct labor markets and labor mobility across regions, while Caliendo et al. (2017) build a multi-country dynamic general equilibrium model to study and quantify the economic effects of trade and labor market integration in the context of the 2004 European Union enlargement.

$$u(C_n) = \prod_{j=1}^J C_n^j \alpha_n^j \quad (3)$$

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  $\omega^j$  and producers differ in the efficiency  $z_n^j(\omega^j)$  to produce output. The production technology of a good  $\omega^j$  is

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

with labor  $l_n^j(\omega^j)$  and composite intermediate goods  $m_n^{k,j}(\omega^j)$  from sector  $k$  used in the production of the intermediate good  $\omega^j$ .  $\gamma_n^{k,j} \geq 0$  are the share of materials from sector  $k$  used in the production of the intermediate good  $\omega^j$ . 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.<sup>12</sup>

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

$$c_n^j = Y_j w_n^{\gamma_n^j} \prod_{k=1}^J P_n^{k,j \gamma_n^{k,j}}, \quad (4)$$

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

**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  $\kappa_{ni}^j$  when selling a product of sector  $j$  from country  $i$  to  $n$

$$\kappa_{in}^j = \underbrace{(1 + t_{in}^j)}_{\tilde{\tau}_{in}^j} \underbrace{D_{in}^{\rho_j} e^{\delta^j \mathbf{Z}_{in}}}_{d_{ni}^j} \quad (5)$$

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.<sup>13</sup>

<sup>12</sup>In our autarky scenario, we do not allow for cross border trade, hence cut the cross country IO-linkages. Intermediate goods used for production can only be sourced within countries and across sectors. This gives  $\gamma_n^j = 1 - \sum_{j=1}^J \gamma_n^j$ .

<sup>13</sup>Iceberg type trade cost in the formulation of Samuelson (1954) are captured by the term  $\mathbf{Z}_{in}$

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 modelled 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  $v_i^j$ ,  $\kappa_{ni}^j$  and depend on the efficiency parameter  $z_i^j(\omega^j)$ .

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

$$p_n^j(\omega^j) = \min_i \left\{ \frac{c_i^j \kappa_{ni}^j v_i^j}{z_i^j(\omega^j)} \right\}. \quad (6)$$

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  $p_n^j(\omega^j) = c_n^j v_n^j / z_n^j(\omega^j)$ .

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

$$P_n^j = A^j \left( \sum_{i=1}^N \lambda_i^j (c_i^j \kappa_{in}^j v_i^j)^{\frac{-1}{\theta^j}} \right)^{-\theta^j} \quad (7)$$

where  $A^j = \Gamma [1 + \theta^j(1 - \eta^j)]^{\frac{1}{1-\eta^j}}$  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.<sup>14</sup> 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  $\theta^j$  that varies by sector and captures comparative advantage.<sup>15</sup> Equation 7 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  $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j v_n^j$ .

**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

<sup>14</sup>see Caliendo and Parro (2015) for more details.

<sup>15</sup>Convergence requires  $1 + \theta^j > \eta^j$ .

firm in country  $i$  can supply its output at price,<sup>16</sup>

$$p_{in}^j(\omega^j) = v_i^j \kappa_{in}^j \frac{c_i^j}{z_i^j(\omega^j)} \quad (8)$$

**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.

$$P_n = \prod_{j=1}^J (P_n^j / \alpha_n^j)^{\alpha_n^j}. \quad (9)$$

**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.

$$\pi_{in}^j = \frac{\lambda_i^j [c_i^j \kappa_{in}^j v_i^j]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^N \lambda_i^j [c_i^j \kappa_{in}^j v_i^j]^{\frac{-1}{\theta^j}}}, \quad (10)$$

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 expenditure of the households.

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<sup>16</sup> $c_i^j$  is the minimum cost of an input bundle (see equation 5), where  $Y_i^j$  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 1 and 2 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  $\sum_{k=1}^J \gamma_i^{k,j} = 1$ .

The goods market clearing condition is given by

$$X_n^j = \sum_{k=1}^J \gamma_n^{j,k} \sum_{i=1}^N X_i^k \frac{\pi_{in}^k}{(1 + \tau_{in}^k)} + \alpha_i^j I_i, \quad (11)$$

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  $Y_n$ :

$$\sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{ni}^j}{(1 + \tau_{ni}^j)} X_n^j + S_n = \sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{in}^j}{(1 + \tau_{in}^j)} X_i^j = \sum_{j=1}^J Y_n^j \equiv Y_n \quad (12)$$

Substituting equation 11 into 12 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  $v'$ . 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:

$$\hat{c}_n^j = \hat{w}_n^{Y_n^j} \prod_{k=1}^J P_n^{k Y_n^{k,j}}, \quad (13)$$

$$\hat{p}_n^j = \left( \sum_{i=1}^N \pi_{in}^j [\hat{\kappa}_{in}^j \hat{c}_i^j \hat{c}_i^j]^{-1/\theta^j} \right)^{-\theta^j}, \quad (14)$$

$$\hat{\pi}_{in}^j = \left( \frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \hat{v}_i^j \right)^{-1/\theta^j}, \quad (15)$$

$$X_n^{j'} = \sum_{k=1}^J \gamma_n^{j,k} \sum_{i=1}^N X_i^k \frac{\pi_{in}^{k'}}{(1 + \tau_{in}^{k'})} + \alpha_i^j I_i', \quad (16)$$

$$\frac{1}{B} \sum_{j=1}^J F_n^{j'} X_n^{j'} + s_n = \frac{1}{B} \sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{ni}^{j'}}{1 + t_{ni}^{j'}} X_i^{j'}, \quad (17)$$

where  $\hat{w}_n$  are wage changes,  $X_n^j$  are sectoral expenditure levels,  $F_n^j \equiv \sum_{i=1}^N \frac{\pi_i^{in}}{(1+t_{in}^j)}$ ,  $I_n^j = \hat{w}_n w_n L_n + \sum_{j=1}^J X_n^j (1 - F_n^j) - S_n$ ,  $L_n$  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 (13).

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 14). The trade shares in equation 15 respond to change in the production costs, unit costs, and prices, and the productivity dispersion parameter  $\theta^j$  governs the intensity of the reaction. Equation 16 ensures goods market clearing in the new equilibrium and the balanced trade condition is given by equation 17.

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.<sup>17</sup> 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.

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

In this subsection we evaluate the welfare effects from the increase in the production barrier caused by the spread of COVID-19. The base year for our analysis is 2016, the last available year for the majority of the data used in the analysis. 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 maximise the number of countries covered in our sample conditional on having reliable information on tariffs, production and trade flow data.

Our main data source is 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

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<sup>17</sup>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.

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).<sup>18</sup>

A crucial element for the quantification exercise is to measure the intensity of the COVID-19 shock across countries as detailed in equation 2. For this end, we use information on the number of corona cases in each country  $c_i$  from the Johns Hopkins Coronavirus Resource Center<sup>19</sup> and the employment level by sector and country contained in the WIOD database. For China and Italy, the two countries with the highest number of corona cases at the date of writing, we collect additional information on the geographical distribution of sectors across the country. Indeed, equation 1 requires information on the employment level in each sector and region (province in China). For the case of Italy, we collect information on employment by sector and region ( $l_{ijr}$ ) for the year 2018 from the National Statistical Office (ISTAT). The construction of employment by sector 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<sup>20</sup>. 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 retrieve the employment level of manufacturing and services<sup>21</sup>. This procedure returns employment shares by region and sector for 50 sectors and each province in China in 2018.

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 under four different scenarios: (i) a *snap-shot* scenario based on the actual number of COVID-19 cases in each country, (ii) a quarantine scenario, imposing quarantine to a fraction of the labour force in some countries, (iii) a *snap-shot* scenario a closer world, that evaluates the effects of the COVID-19 shock in a less integrated world, hence with higher tariffs and (iv) a quarantine scenario in a a closer world.

The aggregated results of the *snap-shot* and the quarantine scenario by country are presented in table 1. In column 2 and 6 we present the real income drops from the *snap-shot* scenario,

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<sup>18</sup>As tariffs are not available for every year and every pair within our time frame, we interpolate tariff levels forward and backward.

<sup>19</sup>For further details, visit the following website: <https://coronavirus.jhu.edu/>

<sup>20</sup>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.

<sup>21</sup>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.



assuming no quarantine for any country in the world.<sup>22</sup> In this case, we find real income drops up to almost 1.4% 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.

It is crucial to note that the number of corona cases as well as the countries that implement quarantine is in continuous evolution, hence the point estimates of this scenario might change drastically as the spread of the COVID-19 disease affects more countries and more people. Moreover, the focus of this paper is to highlight 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.<sup>23</sup>

In our quarantine scenario in table 1, countries with a share of COVID-19 cases to the employed population above 0.005% impose a policy according to which up to 60% of the labor force is quarantined for one month. In absence of real time data on the policy adopted by each country in the world, both in terms of the decision on the quarantine and on the share of population in quarantine, we made a conservative choice by exploiting the available information on the policy adopted by some countries to back-up a threshold of COVID-19 cases over employed population that leads countries or regions to adopt quarantine. We then choose to impose a *real* quarantine to 60% of the employed population, driven by the fact that a share of workers in the service sector would be able to work from home and manufacturing production have been reduced partially in most cases.<sup>24</sup> Results in table 1 show that most countries with quarantined labor force experience a drop in real income around 13%, with the most pronounced drops for the China, Finland and UK.<sup>25</sup>

Figure 2 shows the correlation between a very simple measure of country openness ( $Export+Import$ )/GDP, and change in value added under the *snap-shot* scenario (i) in open economy. Strikingly, countries that are more central in the global production networks as

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<sup>22</sup>It is important to highlight that this scenario would however imply a tremendous cost in terms of human lives in the medium run that our model does not account for.

<sup>23</sup>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.

<sup>24</sup>Detailed data on the quarantine policy adopted by each country and on the share of workers in quarantine in each region (and ideally in each sector) would allow us to perform a more detailed exercise.

<sup>25</sup>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.

Table 1: Welfare Change across Countries, in Percent

Country	(i)	(ii)	$\Delta$	Country	(i)	(ii)	$\Delta$
Austria*	-0.65%	-13.80%	-13.15%	Australia	-0.17%	-1.67%	-1.50%
Belgium*	-0.72%	-13.68%	-12.96%	Brasil	-0.06%	-1.16%	-1.10%
China*	-0.10%	-16.26%	-16.16%	Bulgaria	-0.19%	-3.37%	-3.19%
Croatia*	-0.27%	-13.92%	-13.66%	Canada	-0.17%	-2.74%	-2.56%
Cyprus*	-0.30%	-13.68%	-13.38%	Greece	-0.19%	-2.31%	-2.12%
Czech R.*	-0.26%	-13.77%	-13.51%	Hungary	-0.15%	-4.21%	-4.06%
Denmark*	-0.34%	-13.70%	-13.36%	India	-0.04%	-1.31%	-1.27%
Estonia*	-0.38%	-13.60%	-13.22%	Indonesia	-0.06%	-1.75%	-1.68%
Finland*	-0.23%	-14.13%	-13.90%	Japan	-0.05%	-1.55%	-1.50%
France*	-0.53%	-13.87%	-13.34%	Korea	-0.20%	-3.20%	-3.00%
Germany*	-0.46%	-13.69%	-13.23%	Latvia	-0.22%	-3.14%	-2.92%
Ireland*	-0.42%	-13.22%	-12.80%	Lithuania	-0.22%	-3.70%	-3.48%
Italy*	-0.97%	-13.78%	-12.81%	Mexico	-0.07%	-2.41%	-2.34%
Luxembourg*	-1.05%	-13.14%	-12.10%	Poland	-0.15%	-3.66%	-3.51%
Malta*	-0.38%	-14.31%	-13.93%	ROW	-0.35%	-3.30%	-2.95%
Netherlands*	-0.38%	-13.52%	-13.14%	Romania	-0.18%	-3.15%	-2.97%
Norway*	-0.47%	-13.87%	-13.40%	Russia	-0.08%	-2.58%	-2.50%
Portugal*	-0.54%	-14.18%	-13.64%	Slovakia	-0.16%	-3.96%	-3.80%
Slovenia*	-0.33%	-13.80%	-13.47%	Taiwan	-0.11%	-2.35%	-2.24%
Spain*	-1.35%	-13.84%	-12.48%	Turkey	-0.17%	-2.63%	-2.46%
Sweden*	-0.31%	-13.94%	-13.63%	UK*	-0.28%	-14.08%	-13.80%
Switzerland*	-0.84%	-13.83%	-12.99%	USA*	-0.33%	-13.66%	-13.33%

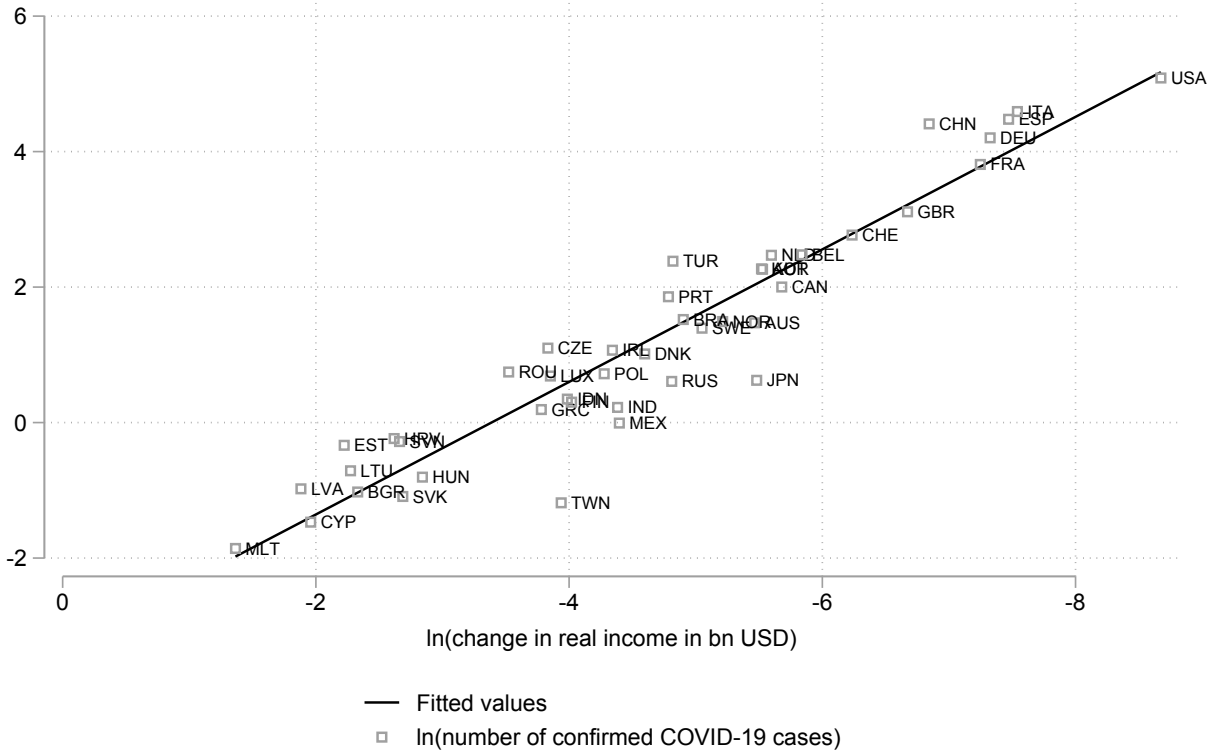
**Note:** The \* indicates that the country belong to the quarantine group in scenario (ii). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated.

proxied by our simple measure of country openness experience higher drops in value added.<sup>26</sup>

The role of the global production linkages in magnifying the effect of the production shock is even clearer when we look at countries for which we do not impose the quarantine restriction under the quarantine scenario. For this group of countries, the quarantine of their trade partners increases the effect of the COVID-19 shock drastically, from average 0.2% decrease in real income in the no quarantine scenario, to around 3% drop in real income in the quarantine case (column 7 of table 1). Moreover, we show that the centrality of a country in the global value chains is a key element in explaining the magnitude of economic effect of the shock. Figure 3 provides a graphical representation of the change in real income for countries in quarantine (solid line, group 1 in the graph) and countries that do not implement

<sup>26</sup>See Baldwin and di Mauro (2020) for a further discussion on the importance of global value chains in understanding the impact of the COVID-19 shock across countries.

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.

the quarantine (dotted line, group 2 in the graph) in scenario (ii) vs our simple measure of country openness  $(Export+Import)/GDP$ . The figure reveals a clear pattern. The degree of openness does not play a crucial role in explaining the size of the shock on real income for the countries that are hit by the quarantine regime and hence experience a drastic negative shock on their home production (group 1). However, non-quarantined countries seem to face a bigger shock the more their economy relies on the global production network.

Figure 2: Country openness and change in value added in an open economy (scenario i)

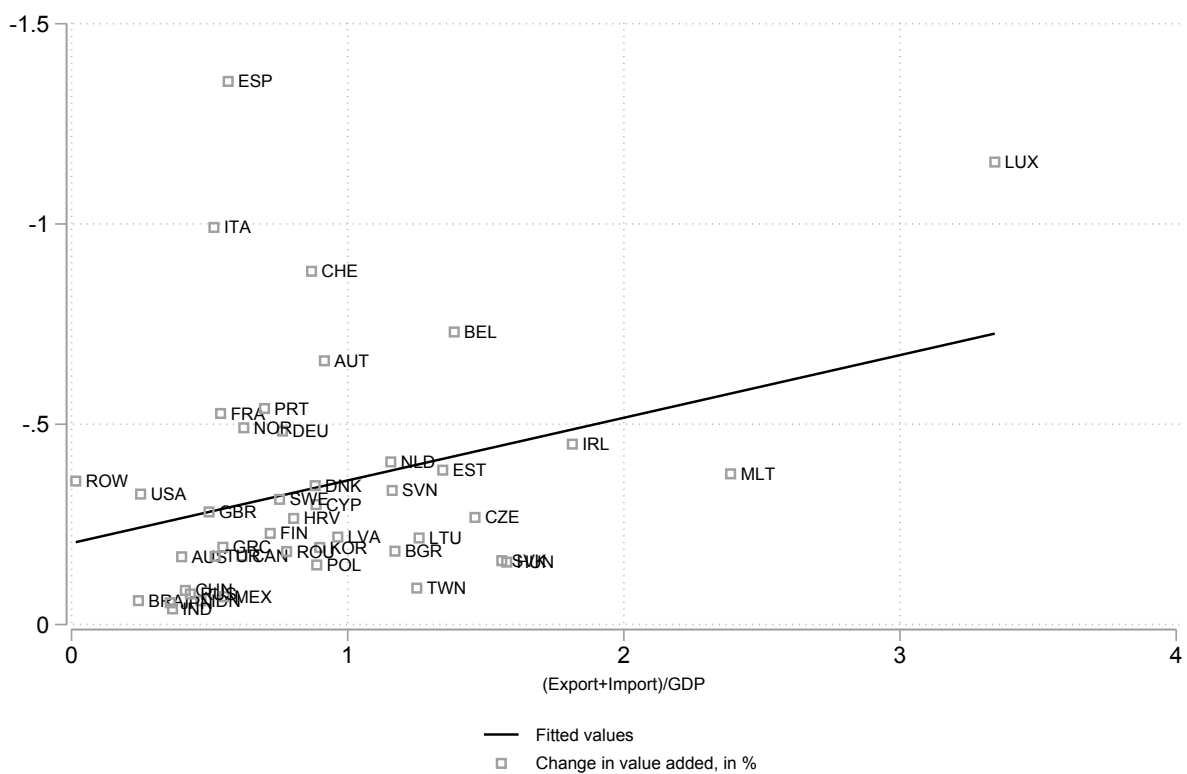
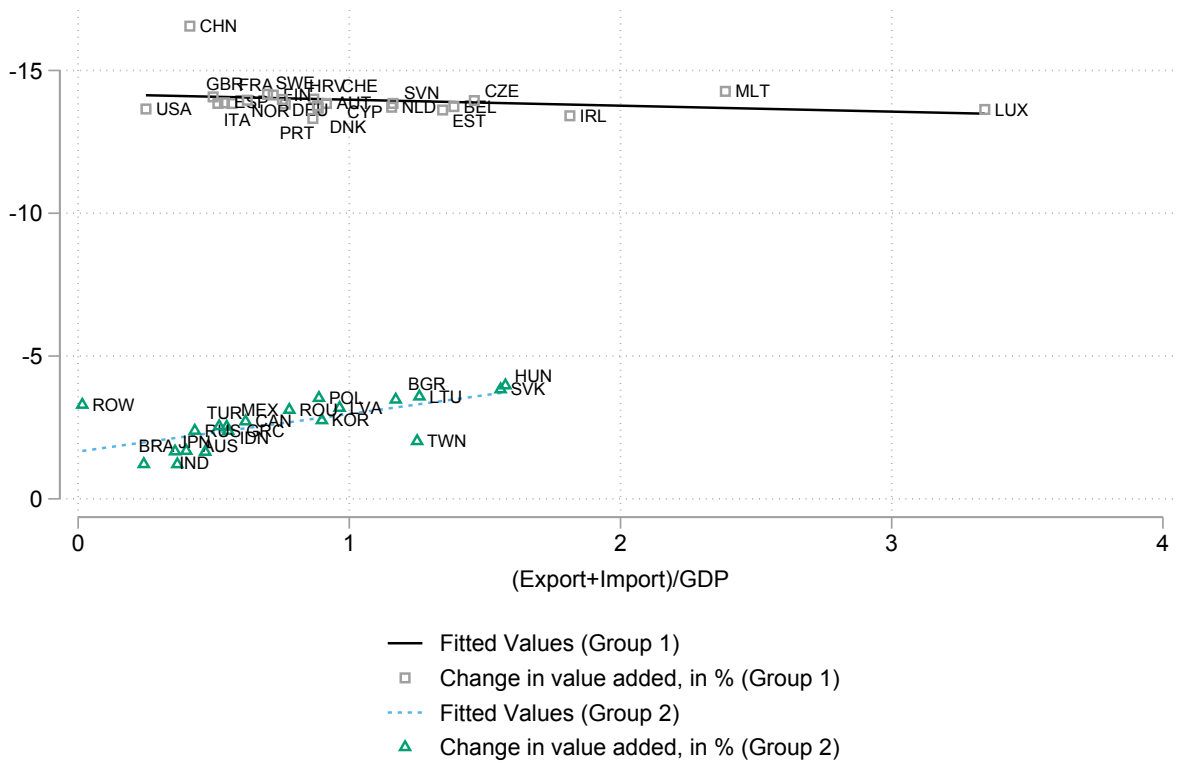


Figure 3: Country openness and Change in Value Added in an open economy with quarantine(scenario ii)



Note: Group 1 includes all the countries that belong to the quarantine group in scenario (iv). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated (Group 2)

We further decompose the economic impact of the COVID-19 shock by sectors in tables 2 and 3 and find that the income drop is widespread across all sectors. These results substantially differ from what Caliendo and Parro (2015) find for the decrease of tariffs due to the NAFTA agreement. Indeed, contrary to drops in tariffs that affect some sectors more than other, 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 real income is partially driven by the geography of production in each country combined with the geographic diffusion of the shock, and partially by the inter-sectoral linkages across countries.

Table 2: Change in sectoral value added - Scenario (i)

Sector	Italy	Germany	USA	China	Treated	Untreated
Agriculture	-1.00%	-0.48%	-0.33%	-0.08%	-0.61%	-0.22%
Chemicals	-1.24%	-0.54%	-0.33%	-0.07%	-0.62%	-0.16%
Construction	-0.98%	-0.47%	-0.33%	-0.10%	-0.55%	-0.18%
Electrical Equipment	-1.19%	-0.53%	-0.33%	-0.03%	-0.59%	-0.14%
Electricity, Water, Gas	-1.00%	-0.48%	-0.32%	-0.08%	-0.57%	-0.24%
Food, Beverages, Tobacco	-0.97%	-0.48%	-0.32%	-0.09%	-0.59%	-0.17%
Intm. Resources Manufacturing	-1.01%	-0.50%	-0.32%	-0.08%	-0.57%	-0.16%
Machinery, Equipment	-0.86%	-0.50%	-0.33%	-0.13%	-0.54%	-0.22%
Manufacturing, nec.	-0.82%	-0.45%	-0.32%	-0.13%	-0.51%	-0.19%
Mining, Quarrying	-1.07%	-0.55%	-0.33%	-0.08%	-0.46%	-0.27%
Motor Vehicles	-0.75%	-0.47%	-0.31%	-0.12%	-0.49%	-0.19%
Pharmaceuticals	-0.93%	-0.47%	-0.35%	-0.12%	-0.58%	-0.21%
Services, nec.	-0.99%	-0.48%	-0.33%	-0.09%	-0.55%	-0.18%
Textiles	-1.17%	-0.52%	-0.31%	-0.04%	-0.64%	-0.17%
Transport	-1.02%	-0.50%	-0.33%	-0.08%	-0.58%	-0.19%
Wholesale, Retail Trade	-1.00%	-0.49%	-0.33%	-0.08%	-0.58%	-0.17%

**Note:** The \* indicates that the country belongs to the quarantine group in scenario (ii). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated. In column Treated and Untreated we take the weighted average of the change in sectoral value added across all countries in the treated(untreated) group.

Finally, we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the current tariffs 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.<sup>27</sup> Focusing on the economic impact of the COVID-19 shock in a less integrated world compared to a world with the actual tariffs, we find a mixed pattern. For some countries the shock in a less integrated world has a stronger effect, while for some other countries the shock has a marginally milder effect in a closer world. This finding highlights the importance of inter-sectoral linkages in the transmission

<sup>27</sup>The effects of the tariff increase are not the focus of this paper. The results will be provided in an upcoming version containing a detailed Appendix.

Table 3: Change in sectoral value added in - Scenario (ii)

Sector	Italy	Germany	USA	China	Treated	Untreated
Agriculture	-13.69%	-13.54%	-13.46%	-16.63%	-13.68%	-2.50%
Chemicals	-14.96%	-14.72%	-13.94%	-17.00%	-14.38%	-1.44%
Construction	-13.80%	-13.74%	-13.66%	-16.28%	-13.90%	-2.40%
Electrical Equipment	-14.80%	-14.54%	-14.18%	-17.94%	-14.44%	-0.96%
Electricity, Water, Gas	-13.84%	-13.80%	-13.60%	-16.56%	-13.87%	-2.75%
Food, Beverages, Tobacco	-13.42%	-13.39%	-13.30%	-16.38%	-13.45%	-2.85%
Intm. Resources Manufacturing	-13.93%	-13.93%	-13.60%	-16.51%	-13.91%	-2.46%
Machinery, Equipment	-13.63%	-13.97%	-13.56%	-15.42%	-13.81%	-4.88%
Manufacturing, nec.	-13.01%	-13.48%	-13.38%	-15.31%	-13.55%	-4.08%
Mining, Quarrying	-14.08%	-14.66%	-13.78%	-16.55%	-14.13%	-2.17%
Motor Vehicles	-12.50%	-13.33%	-12.15%	-15.42%	-12.55%	-3.94%
Pharmaceuticals	-13.28%	-13.76%	-13.42%	-15.93%	-13.67%	-3.98%
Services, nec.	-13.84%	-13.78%	-13.66%	-16.41%	-13.93%	-2.36%
Textiles	-14.84%	-14.84%	-13.63%	-17.66%	-14.43%	-2.48%
Transport	-13.92%	-13.92%	-13.63%	-16.74%	-14.01%	-2.41%
Wholesale, Retail Trade	-13.88%	-13.85%	-13.69%	-16.96%	-13.93%	-2.41%

**Note:** The \* indicates that the country belongs to the quarantine group in scenario (ii). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated. In column Treated and Untreated we take the weighted average of the change in sectoral value added across all countries in the treated(untreated) group.

of the shock: a higher degree of integration in the global production network implies that a shock in one country directly diffuses through the trade linkages to other countries. Trade has a two different effects in our model: on the one hand, it smoothens 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. The balance between these two effects depends on the degree of integration of the country in the network of global production and on the sectoral specialization of each country.<sup>28</sup>

<sup>28</sup>Further analysis is needed to better understand the determinants of this pattern.

Table 4: Welfare Change across Countries Closed vs. Open Economy - Shock 1

Country	(i) Open Economy	(iii) Closed Economy	$\Delta$	Country	(i) Open Economy	(iii) Closed Economy	$\Delta$
Austria*	-0.65%	-0.65%	0.002	Australia	-0.17%	-0.17%	0.001
Belgium*	-0.72%	-0.72%	-0.000	Brasil	-0.06%	-0.06%	-0.001
China*	-0.10%	-0.13%	-0.028	Bulgaria	-0.19%	-0.19%	-0.002
Croatia*	-0.27%	-0.27%	-0.006	Canada	-0.17%	-0.17%	0.002
Cyprus*	-0.30%	-0.30%	-0.002	Greece	-0.19%	-0.19%	-0.006
Czech R.*	-0.26%	-0.25%	0.008	Hungary	-0.15%	-0.14%	0.005
Denmark*	-0.34%	-0.34%	0.003	India	-0.04%	-0.04%	-0.004
Estonia*	-0.38%	-0.39%	-0.001	Indonesia	-0.06%	-0.07%	-0.007
Finland*	-0.23%	-0.23%	-0.003	Japan	-0.05%	-0.05%	0.002
France*	-0.53%	-0.53%	-0.003	Korea	-0.20%	-0.23%	-0.026
Germany*	-0.46%	-0.43%	0.038	Latvia	-0.22%	-0.22%	-0.001
Ireland*	-0.42%	-0.42%	-0.004	Lithuania	-0.22%	-0.22%	0.002
Italy*	-0.97%	-0.97%	-0.000	Mexico	-0.07%	-0.07%	-0.006
Luxembourg*	-1.05%	-1.04%	0.002	Poland	-0.15%	-0.14%	0.004
Malta*	-0.38%	-0.38%	0.000	ROW	-0.35%	-0.35%	0.000
Netherlands*	-0.38%	-0.37%	0.008	Romania	-0.18%	-0.18%	0.001
Norway*	-0.47%	-0.24%	0.229	Russia	-0.08%	-0.09%	-0.010
Portugal*	-0.54%	-0.54%	-0.002	Slovakia	-0.16%	-0.16%	-0.005
Slovenia*	-0.33%	-0.32%	0.008	Taiwan	-0.11%	-0.14%	-0.025
Spain*	-1.35%	-1.36%	-0.010	Turkey	-0.17%	-0.17%	-0.002
Sweden*	-0.31%	-0.31%	0.004	UK*	-0.28%	-0.28%	-0.001
Switzerland*	-0.84%	-0.83%	0.009	USA*	-0.33%	-0.33%	0.000

**Note:** The \* indicates that the country belongs to the quarantine group in scenario (ii). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated.



Table 5: Welfare Change across Countries Closed vs. Open Economy - Shock 2

Country	(ii) Open Economy	(iv) Closed Economy	$\Delta$	Country	(ii) Open Economy	(iv) Closed Economy	$\Delta$
Austria*	-13.80%	-13.71%	0.091	Australia	-1.67%	-1.78%	-0.113
Belgium*	-13.68%	-13.62%	0.067	Brasil	-1.16%	-1.20%	-0.037
China*	-16.26%	-15.68%	0.576	Bulgaria	-3.37%	-3.41%	-0.034
Croatia*	-13.92%	-13.93%	-0.008	Canada	-2.74%	-2.74%	0.001
Cyprus*	-13.68%	-13.68%	-0.006	Greece	-2.31%	-2.35%	-0.042
Czech R.*	-13.77%	-13.55%	0.220	Hungary	-4.21%	-3.99%	0.217
Denmark*	-13.70%	-13.60%	0.104	India	-1.31%	-1.24%	0.069
Estonia*	-13.60%	-13.59%	0.009	Indonesia	-1.75%	-1.89%	-0.141
Finland*	-14.13%	-14.13%	-0.009	Japan	-1.55%	-1.54%	0.013
France*	-13.87%	-13.88%	-0.013	Korea	-3.20%	-3.64%	-0.432
Germany*	-13.69%	-13.23%	0.466	Latvia	-3.14%	-3.15%	-0.018
Ireland*	-13.22%	-13.04%	0.180	Lithuania	-3.70%	-3.64%	0.064
Italy*	-13.78%	-13.73%	0.054	Mexico	-2.41%	-2.37%	0.044
Luxembourg*	-13.14%	-12.95%	0.197	Poland	-3.66%	-3.49%	0.168
Malta*	-14.31%	-14.28%	0.037	ROW	-3.30%	-3.29%	0.015
Netherlands*	-13.52%	-13.27%	0.250	Romania	-3.15%	-3.03%	0.125
Norway*	-13.87%	-12.28%	1.590	Russia	-2.58%	-2.94%	-0.366
Portugal*	-14.18%	-14.21%	-0.025	Slovakia	-3.96%	-3.77%	0.188
Slovenia*	-13.80%	-13.62%	0.182	Taiwan	-2.35%	-2.83%	-0.477
Spain*	-13.84%	-13.85%	-0.015	Turkey	-2.63%	-2.67%	-0.038
Sweden*	-13.94%	-13.86%	0.082	UK*	-14.08%	-14.08%	0.001
Switzerland*	-13.83%	-13.68%	0.152	USA*	-13.66%	-13.64%	0.016

**Note:** The \* indicates that the country belongs to the quarantine group in scenario (ii). We refer to this group of countries as treated, while countries that do not implement the quarantine regime in scenario (ii) are called untreated.

## 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 use the model to evaluate the effect of the COVID-19 shock under three different scenarios, (i) a *snap-shot* scenario based on the actual number of COVID-19 cases in each country, (ii) a quarantine scenario, imposing quarantine to a fraction of the labour force in some countries and (iii) a closed world scenario, that evaluates the effects of the COVID-19 shock in a less integrated world, hence with higher tariffs. 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 abstracts from many other aspects related to the diffusion of the COVID-19 disease which are the topic of study of epidemiologists, medical doctors and statisticians. However, understanding how COVID-19 virus disease spreads across regions is outside the scope of this paper. In our framework, the spread of COVID-19 disease is 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 modelling and including sectoral interrelations to quantify the economic impact of the COVID-19 shock.

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