Globalization in the time of COVID-19*

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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 the 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, implying an average 12.9% drop in GDP across countries. Moreover, we show that global production linkages have a clear role in explaining the observed magnitude. Finally, we show that the economic effects of the COVID-19 shock would have been marginally worse in a closer economy, with an average drop of GDP of 13% across countries. Our results contribute to the recent debate on the renationalization of global production. We show that renationalization would not help countries mitigate the impact of global pandemic shocks and would itself imply enormous GDP losses.

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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]

This is the first paper to study the role of global production linkages in the transmission of a pandemic shock across countries. We exploit an unprecedented disruption in production in recent world history, namely the global spread of the COVID-19 virus, 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 the 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 recent world history: with around 73.646.001 cases, 1.639.061 deaths and millions of people in quarantine around the world to date[2], the spread of the COVID-19 is the largest pandemic ever experienced in the globalised world.[3] Second, the COVID-19 shock is not an economic shock in its nature, hence its origin and diffusion are independent from the fundamentals of the economy. Third, differently from any other non-economic shock experienced before, it is of global nature. Indeed, while the majority of natural disasters or epidemics have a local dimension, the spread of COVID-19 has been confined to the Chinese province of Hubei only for a few weeks, to then spread across the entire world.

[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 16th of December 2020

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

Understanding the effects of a global production disruption induced by a pandemic is complex. We build on the work by Caliendo and Parro (2015) and 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 shock. We extend the framework by introducing a role for policy intervention in deterring production. In our set-up, the policy maker can use the instrument of lockdown as a policy response to deter the virus diffusion. The policy intervention of lockdown translates into a production barrier that increases the production costs for intermediates and final goods for the internal market as well as for the exporting market.[4] We construct a measure of lockdown using three 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 lockdown to heterogeneously affect every 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).Third, we account for the average duration of lockdown in each region and sector using the information in the CoronaNet database. Moreover, we account for the geographic distribution of industries in every region and country to have a complete picture of the heterogeneous impact of the shock. Our measure of the shock proxies 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 test the fit of our shock using OECD and Eurostat data and calibrate it to match the average change in Industrial Production for the available countries in our sample. The model performs well in matching the aggregate pattern in the drop of Industrial Production across countries.

Two considerations are in order: first, the COVID-19 shock is global. Lockdown policies have

[4] 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. 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). 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.

been implemented in almost all countries around the world. Accounting for the contemporaneous lockdown policies in each country is essential to correctly measure the economic impact of COVID-19 in a general equilibrium framework.[5] Second, the lockdown policies across the globe were region and sector specific. Capturing the regional variation in the lockdown policies allows to approximate the actual policies implemented in each country as accurately as possible, minimizing potential measurement error.

We solve the model in relative changes to identify the welfare effect of the COVID-19 shock. We perform two different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 shock and an indirect effect coming from the global shock affecting other countries. We perform the two 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 latter counterfactual exercise aims to contribute to the ongoing policy debate on whether countries should renationalize their production and become more protectionist. We construct a counterfactual economy with a partial trade closure instead of a full autarky for two reasons: first, it provides a more realistic picture of the potential effect of a partial renationalization of production, a policy discussed by some of the leaders around the world today. Second, in a world with complete autarky, the COVID-19 shock might not have crossed country borders and diffused to the entire world at the same pace, thus making the analysis of a counterfactual scenario with the same COVID-19 shock as in an open economy unrealistic.

The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region, stringency and duration of the

[5] Not accounting for the contemporaneous shock in different countries could lead to trade diversion due to asymmetric shocks.

lock-down policies implemented in each region-sector-country and degree of *teleworkability* of each occupation. We calibrate a 43 countries 50 sectors economy and evaluate the welfare effects of the COVID-19 shock 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. We observe an average income drop of 12.9%, with the most pronounced falls for Slovenia and Poland. 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 drop in value added is partially driven by the geography of production in each country combined with the regional diffusion of the shock – regional variation in lockdown policies – and by the inter-sectoral linkages across countries, but also by the heterogeneity in the degree of *teleworkability* across sectors.

The role of the global production linkages in transmitting 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 observed total income drop, on average 30% of the total across the countries in our sample. At the same time, global value chains mitigate the severity of the lockdowns policies. Indeed, to deeply 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 extremely interesting results. When we raise trade costs to proxy a closer economy, the impact of the COVID-19 shock is extremely similar – up to the first decimal point – to the impact of the COVID-19 shock in an open economy for all countries in our sample. In fact, we estimate an average drop in GDP due to the COVID-19 in a closer economy of 13%, compared to an average drop of 12.9% in an open economy. Trade has two different effects in our model: on 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 lockdown, and it allows firms to export and import final and intermediate inputs. On the other hand, it transmits the shock through global value chains. Which of the two effects dominates – leading to a smaller or a bigger impact of the COVID-19 shock in a closer economy – depends on the relative size of the domestic COVID-19 shock in each country compared to the other countries, and on the production structure of each economy in our sample. Our counterfactual exercise clearly shows that an increase in trade costs marginally worsen the impact of the COVID-19 shock across countries. However, increasing trade barriers would itself imply an additional drop in real income between 14% and 33% across countries. All in all, our results suggest that higher trade barriers would have not alleviated the effects of a global pandemic.

Our paper is closely related to a growing literature that studies 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 most of the countries across the world to understand the response of the economy under different production barrier scenarios in free trade and a less integrated world. Moreover, our exercise contributes to the recent debate on the economic effect of the return to protectionism, highlighted in the recent papers by Fajgelbaum et al. (2019), Amiti et al. (2019) and T. Fetzer (2020).

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 COVID-19 abroad.[7]

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

[7] A growing literature in economics extends the SIER model to study the economic consequences of the diffusion of the pandemic under different policy scenarios and in different set-up (see for example Atkeson (2020), Berger (2020), Eichenbaum et al. (2020), P. Fajgelbaum (2020)). We are the first to study the diffusion of the COVID-19 shock through GVCs. Baldwin and di Mauro (2020) were the first to highlight the importance of GVC in the transmission of the COVID-19 pandemics. In the meanwhile, several papers emerged that study a similar question. Bonadio et al. (2020), a paper developed contemporaneously to ours, study a similar question using a global network model of production and trade. We differentiate from their work by parsimoniously incorporating regional variation in the lockdown policy as well as in the geographical distribution of economic activity to precisely capture the effect of the COVID-19 shock on

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

2 Theoretical Framework

In this section we model the COVID-19 shock into a Ricardian framework (Caliendo and Parro (2015)).

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 but immobile across countries, and all markets are perfectly competitive.

Households. In each country there are L_n representative households that maximise utility over final goods consumption C_n. The preferences are given by

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

with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$. Income I_n is generated through the labor supplied L_n which generates wages w_n, and through lump-sum transfers (i.e. tariffs).

Production. Labor and composite intermediates goods (materials) are used to produce a continuum of intermediate goods ω^j. Producers differ in the efficiency of production $z_n^j(\omega^j)$, which varies across sectors and countries. The production technology of a good ω^j is

economic outcomes across countries. Moreover, Antràs et al. (2020) develop a model of human interaction to analyze the relationship between globalization and pandemics.

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

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. The parameter $\gamma_n^{k,j} \geq 0$ is the share of materials from sector k used in the production of the intermediate good ω^j, with $\sum_{k=1}^J \gamma_n^{k,j} = 1 - \gamma_n^j$. The parameter $\gamma_n^j \geq 0$ is the share of value added and varies across sectors and countries.

Due to constant returns to scale and perfect competition, firms price at unit costs, where c_n^j is the cost of an input bundle defined as

$$c_n^j = \Upsilon_n^j w_n^{\gamma_n^j}\prod_{k=1}^{J} P_n^{k\gamma_n^{k,j}} \tag{2}$$

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

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 represente trade costs κ_{ni}^j when selling a product of sector j from country i to country n

$$\kappa_{in}^j = \underbrace{\left(1 + t_{in}^j\right)}_{\tilde{\tau}_{in}^j}\underbrace{D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}}_{d_{ni}^j} \tag{3}$$

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.[8]

Additionally, intermediate and final goods are now subject to barriers arising from domestic policy interventions due to the COVID-19 shock v_i^j, that can potentially deter production. COVID-19 is modelled as a barrier to production in the affected areas. We propose a new measure to quantify the intensity of the economic shock, leveraging on the diffusion of

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

COVID-19 across space, the geographical distribution of sectors in each country and a novel index for the stringency of the policy intervention in each country, sector and region.[9]

The COVID-19 shock v_i^j can be expressed as

$$v_i^j = 1 + \sum_{r=1}^{R} \left(\psi_{ir}^j * \frac{l_{ir}^j}{\sum_{r=1}^{R} l_{ir}^j} \right) \tag{4}$$

and

$$\psi_{ir}^j = IndexClosure_i * (1 - TW^j) * Duration_{ir}^j \tag{5}$$

where l_{ir}^j is the total employment of sector j in region r of country i, $\sum_{r=1}^{R} l_{ir} j$ is the sum of employed individuals in a sector j across all regions r of country i and ψ_i^j is a measure of the restrictiveness of the lockdown, comprising three different elements. $IndexClosure_i$ 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 5, $(1 - TW^j)$ 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. Moreover, we allow essential sectors to have a higher degree of *teleworkability*. Finally, to account for the average duration of lockdown in each region and sector, we use the information in the CoronaNet database. We use detailed information on the duration of lockdown in each country, region and sector contained in the CoronaNet database and map the lockdown policies implemented

[9]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.

in all regions and sectors of our sample. [10]

The first part of the formula ψ_{ir}^{j}, returns a measure of lockdown for each country, region 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. Crucially, we exploit the richness of information in the CoronaNet dataset (see Cheng and Messerschmidt (2020)) to construct a measure of the duration of the restrictions for each country, region and sector. The second term of the formula, $\frac{l_{ir}^{j}}{\sum_{r=1}^{R} l_{ir}j}$ is a measure of the geographic distribution of production across regions in the country, quantifying how much each sector is concentrated in a region compared to the rest of the country. The regional dimension in the duration of the restrictions and in the distribution of production in each country allow us to have a complete and precise picture of the impact of the the lockdown measures in each country across space.[11]

Under perfect competition and constant returns to scale, an intermediate or final product (trade and non-tradable) is available in country n at unit prices, which are subject to the production barrier v_i^j, trade costs κ_{ni}^j and 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

[10] A detailed description of the dataset can be found in Cheng and Messerschmidt (2020). In section 3 we provide details on the construction of each dataset used to create the variable ψ_{ir}^{j}

[11] It is important to highlight that the COVID-19 shock substantially differs from 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 lockdown 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 with the indirect effect coming from the global production linkages.

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

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

The price for a composite intermediate good is given by

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

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. 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.[12] Equation 7 also provides the price index of non-tradable goods, which can also be affected by the production barrier v_i^j. For non-tradable goods the price index is given by $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j v_n^j$.

Due to the interrelation of the sectors across countries, the existence of production barriers v_i^j has also an indirect effect on the other sectors across countries. A firm in country i can supply its output at price[13]

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

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

[13] c_i^j is the minimum cost of an input bundle (see equation 3), 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 equation 4 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 $\sum_{k=1}^{J} \gamma_i^{k,j} = 1$.

Under Cobb-Douglas preferences, the consumers can purchase goods at the consumption prices P_n, which are also dependent on production barriers υ_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.

$$P_n = \prod_{j=1}^{J} \left(P_n^j / a_n^j\right)^{a_n^j} \tag{9}$$

Expenditure Shares, Total expenditure and Trade Balance. 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.

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j \upsilon_i^j\right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^N \lambda_i^j \left[c_i^j \kappa_{in}^j \upsilon_i^j\right]^{\frac{-1}{\theta^j}}} \tag{10}$$

The bilateral trade shares are affected by the production barriers υ_i^j both directly and indirectly through the change in the cost of the input bundle c_i^j from equation 2, which contains all information from the IO-tables.

Total expenditure on a good j in country n, X_n^j, has to equal the total expenditures on the composite intermediate goods of firms and households[14]

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

To close the model, the value of total imports, trade surplus and domestic demand need to

[14] The national income is a function of labor income, tariff rebates R_i and the trade surplus D_i, hence $I_i = w_i L_i + R_i - D_i$. X_i^j is a country i's expenditure on sector j goods and services, $M_n^j = \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j$ a imports of country n in sector j good from a country i.

be equal to the value of domestic sales and exports

$$\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{ni}^{j}}{(1+\tau_{ni}^{j})}X_n^j + D_n = \sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{in}^{j}}{(1+\tau_{in}^{j})}X_i^j \tag{12}$$

Given the trade surplus D_n, labor l_n, the measure of absolute advantage λ_n^j and the trade costs d_{ni}^j, the equilibrium under the domestic production barriers is a wage vector $\mathbf{w}$ and prices $\left\{P_n^j\right\}_{j=1,n=1}^{J}, N$ that satisfy equilibrium conditions, as in Caliendo and Parro (2015).

Equilibrium in relative changes. We use the methodology introduced by Dekle et al. (2008) and define the equilibrium in relative changes. This procedure allows us to (i) have an exact mapping of the model to the data in a base year, (ii) identify the effect of a change in the the production cost $\hat{v}_i^j$, which is the main objective of the paper, and (iii) solve for the general equilibrium without the need of estimating all the set of parameters in the data.

Intuitively, the solution method is equivalent to a difference in difference estimation. Solving the model in relative changes allows departing from the estimation of the fundamentals of the model which remain unchanged after the shock hits the economy, which is equivalent to assuming parallel trends of a counterfactual economy where the shock does not happen. On the other hand, this solution method allows to precisely isolate the impact of a specific shock, in our case the production barriers induced by the diffusion of the COVID-19 pandemic, and to quantify its effect in a rich general equilibrium framework.

The solution method allows us to define an equilibrium of the model under the change of policy $v_i^{j\prime}$ relative to a world with no policy intervention that deter production. In our model, $\hat{c}_n^j$ is the change in the cost of input bundle, which itself depends on the change in wages $\hat{w}_n$, and the change in prices $\hat{P}_n^{k\gamma_n^{k,j}}$. These changes directly affect the sectoral price index P_n^j, and translate into changes in the unit costs (equation 14). X_n^j are the sectoral expenditure levels, while the prime income is given by $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^{J} X_n^{j\prime}(1 - F_n^{j\prime}) - S_n$, with $F_n^j \equiv \sum_{i=1}^{N}\frac{\pi_j^{in}}{(1+t_{in}^j)}$. L_n

is a country n's labor force, and D_n captures the trade surplus. The trade shares (equation 15) respond to changes in the production costs, unit costs, and prices. The productivity dispersion parameter θ^j determines the intensity of the reaction. Equation 16 ensures that the goods' market is clear and trade is balanced (equation 17).

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^{J} \hat{P}_n^{k\gamma_n^{k,j}} \tag{13}$$

$$\hat{P}_n^j = \left[\sum_{i=1}^{N} \pi_{in}^j [\hat{\kappa}_{in}^j \hat{\upsilon}_i^j \hat{c}_i^j]^{-1/\theta^j} \right]^{-\theta^j} \tag{14}$$

$$\hat{\pi}_{in}^j = \left[\frac{\hat{c}_i^j}{\hat{P}_n^j} \hat{\kappa}_{in}^j \hat{\upsilon}_i^j \right]^{-1/\theta^j} \tag{15}$$

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

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{k\prime}}{(1+\tau_{ni}^{k\prime})} X_n^{j\prime} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^{k\prime}}{(1+\tau_{in}^{k\prime})} X_i^{j\prime} \tag{17}$$

From equations 13 to 17, it is straightforward to see how the shock υ_i^j affects the economy, both domestically and through global production linkages. In the next section we describe the data used for the calibration of the model and for the construction of the shock.

3 Data and calibration

In this section we present the data used to calibrate the model and to construct our shock.

We use data from different sources 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 flows. Our quantification exercise requires a large number of data, which we gather combining different sources.[15]

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 as 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, regions and sectors. Indeed, our measure of the shock as detailed in equation 4 requires information on employment by country-region and sector. This data is crucial to account for the geographical distribution of sectors across each country and region. We combine different sources: (i) for alle the countries in the EU we use the information contained in Eurostat, (ii) for the US we use IPUMScps to construct employment by state(region) and sector of activity, (iii) while for Canada we use official data from the statistical office.

The construction of employment data by sector-province in China required two different data sources. We start from the information on employment by region and sector from the National Bureau of Statistics of China for the year 2018.[16] However, the National Bureau of Statistics of China provides aggregated sectoral statistics (1-digit). We use the employment shares from the Chinese Census to construct employment by sector-region consistent with the WIOD sectoral classification[17].

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

[16] 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.

[17] 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

Third, constructing the lockdown 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 lockdown in each region. 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.[18] Finally, we use detailed information on the duration of lockdown in each country, region and sector contained in the CoronaNet database and map the lockdown policies implemented in all regions and sectors in the sample. [19]

Accounting for regional and sectoral variation when measuring the stringency of lockdown policies across countries, as well as for the geographic distribution of sectors across regions in a country is crucial to capture the heterogeneous effect of the COVID-19 pandemics across countries and to have reliable estimates of the economic impact of the COVID-19 pandemics. In fact, not including these elements is equivalent to assuming a homogeneous distribution

of the region-sector employment shares for China is provided in the appendix. Data on employment at sector-region level are not available for some countries in our sample. 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.

[18]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 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).

[19]A detailed description of the dataset can be found in Cheng and Messerschmidt (2020).

of economic activity and diffusion of the COVID-19 disease across regions within a country as well as of lockdown policies. For explanation purposes, we illustrate the case of Italy. The bulk of manufacturing production in Italy is concentrated in the north of the country. The north of Italy has been hit much harder by the COVID-19 pandemics compared to the south, and it implemented stronger and immediate responses in terms of lock-down policy. In this case, our shock v_i^j from equation 5 is able to capture both elements: first, it accounts for the geographical distribution of production across regions with the term $\frac{l_{ir}^j}{\sum_{r=1}^R l_{irj}}$. Second, it captures the heterogeneity in the lockdown policy across regions with the term ψ_{ir}^j.

We use this extensive set of data to construct a measure for the COVID-19 shock as detailed in equation 4 that accounts for the regional variation in the duration as well as the restrictiveness of the lockdown policies implemented, for the degree of *teleworkability* of each occupation and for the geographic distribution of production across regions in the country. Intuitively, the COVID-19 shock described in equation 4 has a similar interpretation of an iceberg type trade cost. In fact, the shock v_i^j equals 1 when there is no restriction in place, hence it does not increase the cost of producing a good. On the contrary, v_i^j increases in the degree of the restriction and the duration of the lockdown, while it decreases in the degree of *teleworkability* of each occupation.

Fit of the shock

Our measure for the COVID-19 shock from equation 4 is meant to capture the production barriers each country experiences due to the lockdown policies in response to the diffusion of the pandemic. To check the fit of our specification for the shock, we perform a simple calibration exercise by targeting the drop in industrial production across countries. We collect data on Industrial Production (IP) across countries from OECD and Eurostat for the 9 months before the strike of the COVID-19 pandemics (pre period) and for the 4 months of the COVID-19 pandemics (post period) for 38 countries of our sample.[20] Figure 1 plots the average change in the IP index between the pre and the post period in the data on the y axis versus the change in manufacturing output predicted by the model on the x axis. The size of the circle is proportional to the GDP of each country. We find a clear positive correlation between the IP contraction predicted by our model and the average contraction observed in the data, with a correlation of 0.6. While figure 1 presents clear evidence of the correlation between the contraction of production predicted using our shock and real data, we do not reach a perfect fit. This is because of two main reasons: first, data on IP are only partially available – both in terms of countries and time coverage – and they present some unclear patterns that can be due to measurement error (see, for example, the case of Ireland where the OECD IP data reports a substantial increase of IP during the COVID-19 period).[21] Second, while we include one well specified exogenous shock in the model that accounts for several components – the severity of the lockdown policies, the degree of teleworkability of each occupation, the duration of the lockdown in each region and sector as well as for the geographical distribution of production across regions within a country – we miss a number of other shocks that might generate the data – for example, country policies to boost industrial production in the wake of the shock.

In section 4 we present the results of our counterfactual exercises.

[20]The sample includes data from June 2019 until June 2020. Using the data on the duration and the stringency of the restriction, we fix the month of March 2020 as the start of the pandemic period. A more accurate calibration exercise could be performed using the detailed information on the duration of the lockdown policy by country.

[21]We believe that new and additional data will be extremely valuable to achieve a better fit for the calibration exercise.

4 Results

The constructed shock v_i^j and the extensive set of data are used to instruct the model to perform counterfactual analysis. As described in section 2, 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 two different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the disruption in domestic production induced by the lock-down policies, and an indirect effect, from the global shock affecting other countries. We perform the two 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

In this section, we present the results of the change in welfare, sectoral value added and trade for each country in our sample. 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 are presented in table 1. 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 countries on average experience a drop in real income of 12.9%, with few exceptions, among which Sweden. Indeed, Sweden it's the only European country that did not implement any coercive and generalised restriction to the workforce.

In table 2, we further investigate the sectoral distribution of the economic impact of the COVID-19 shock. We find that the drop in the value added (in billion 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. In absolute terms, the strongest drops in value added are experienced in the service sectors, such as accommodation, food, real estate and public services.[22]

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 billion US Dollars in intermediate resource manufacturing, machinery equipment and textiles. Germany faces a decrease in exports especially pronounced 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 wholesale trade while China experiences the biggest drop in exports in the sectors of electrical equipment, intermediate resource manufacturing and textiles.

All 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.

[22] Table 2 provides the results for aggregated sectors. See table A2 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.

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 global production networks? To decompose the real income changes observed in table 1 we use the structural model and perform two counterfactual exercises: one in which we shock each country individually and one in which we shock all countries but one. 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 experiences through the shock of the global production network. We perform the following decomposition:

$$\forall i \neq j \; : \; \hat{W}_i = \underbrace{\left(\hat{W}_i^D(v_i) \right.}_{\text{Direct}} + \underbrace{\left. \sum_{j=1}^{J} \hat{W}_i^I(v_j) \right)}_{\text{Indirect}} + \underbrace{\left(1 - \hat{W}_i(v_{ALL}) \right)}_{\text{Global}} \tag{18}$$

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) but country i, $\hat{W}_i(v_{ALL})$ 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.

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 decrease 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 all other countries but Germany are shocked.

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 at the same time, the observed income drop marginally 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 to avoid quantification mistakes.

Figure 2 and table 4 show the results of the decomposition in open economy. 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. We find that the *indirect* effect on average accounts for 30% of the total drop in GDP across the countries in our sample.

It is important to clarify that this exercise is an accounting decomposition of the total drop in GDP in the two different components, the *direct* and the *indirect* effect. 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.

4.2 Less Integrated World

In this section we quantify the real income effect of the COVID-19 shock in a less integrated world, where we increase the trade costs in each country and sector up to 100 percentage points. To do so, we solve for a counterfactual economy where we increase trade cost up to 100 percentage points and we shock the economy with the same COVID-19 shock as in the open economy described in section 4.1. The choice of solving for a counterfactual economy where we increase trade cost up to 100 percentage points is motivated by the interest in answering a substantial policy question: what would have been the effect of the COVID-19 shock in a less integrated world? Answering this question implies assuming higher frictions to trade across countries, but not a complete absence of trade. On the contrary, a complete autarky scenario would mimic a world where countries do not trade at all; event though this is an extremely interesting research question, it is not a realistic representation of the policies debated and proposed by some of todays countries' leaders.

First and unsurprisingly, a less integrated world itself implies enormous income losses for all countries in our sample. Table 5 shows the real income changes for all countries in the sample in a less integrated world. Column 2 and 7 of table 5 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 real income changes due to the COVID-19 shocks in the open economy (as in table 1). Finally, columns 5 and 10 (Δ) present the difference between the real income drop due to the COVID-19 shocks in a less integrated vs. open economy.

In a less integrated world countries experience an enormous reduction in real income due to the increase in trade costs, to which we add the negative effect 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.

The impact of the COVID-19 shock is marginally higher for most countries in a less integrated economy than in an open one, with an average drop in real income of 13% compared to an average of 12.9% in an open economy. Figure 3 graphically illustrate the impact of COVID-19 in an open economy (dark grey bars) and in a less integrated world (light grey bars). It is straightforward to notice that the difference in the impact of the COVID-19 shock across the two different economies is marginal, with the biggest (negative) differences observed for China and Luxembourg. For both countries, the impact on COVID-19 shock would have been higher in a closed economy for completely different reasons; in fact, while China is an exporting hub for the entire world, Luxembourg relies almost entirely on manufactured imports from abroad, being extremely specialized in service production. An increase in trade barriers would magnify the impact of the COVID-19 shock in both cases, by reducing total exports for China and by increasing the cost of imports for Luxembourg. Trade has two different effects in our model: on the one hand, it mitigates 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 lockdown, and allows firms to export and import final and intermediate inputs. On the other hand, it transmits the shock through global value chains. Which of the two effects dominates – leading to a smaller or a bigger impact of the COVID-19 shock in a closer economy – depends on the relative size of the domestic COVID-19 shock in each country compared to the other countries, and on the production structure of each economy in our sample. The results in table 5 and figure 3 show that trade on average mitigates the effect of the COVID-19 shock. This is because in the absence of trade, each country increases the reliance on domestic production, which is itself disrupted due to the lockdown policies in response to the COVID-19 shock. In other words, trade allows countries to implement more stringent lockdown policies to counteract the negative impact of the COVID-19 pandemics. Our counterfactual exercise clearly shows that an increase in trade costs would marginally worsen the impact of the COVID-19 shock across countries. However, increasing trade barriers implies an additional drop in real income between 14%

and 33% across countries. All in all, our results suggest that higher trade barriers would have not alleviated the effects of a global pandemics.

5 Conclusions

This study uses a general equilibrium framework to evaluate the economic impact of the COVID-19 shock and its diffusion through global value chains. 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 modelling choice of the shock accounts for the geography of the diffusion of the COVID-19 shock across regions and countries, the intensity of the policy of lockdown across sectors, regions and countries and the geographical distribution of sectors across regions in each country 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 two different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 shock, and an indirect effect coming from the global shock affecting other countries. We perform the two 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 43 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, with an average drop of 12.9% across countries, 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. We decompose the COVID-19 total income change into a *direct* component due to the domestic production shock and an *indirect* component due to global linkages. We show that linkages between countries account for a substantial share – on average 30% – of the total income drop observed.

Finally, we construct a counterfactual economy in which we increase trade cost up to 100 percentage points and examine the effect of the COVID-19 shock in a less integrated world. We find that the impact of the COVID-19 shock in a closer economy would have been very similar to the impact it has on the economy as of today. In fact, we estimate an average drop in GDP due to the COVID-19 shock in a closer economy of 13%, compared to an average drop of 12.9% in an open economy. These results contributes to the recent policy debate on the renationalization of global supply chains. While many governments recently called for the renationalization of production to better cope with global shocks, like the COVID-19 pandemic, we show that higher trade barriers would have not alleviated the effects of a global pandemic. All in all, higher trade barriers would have instead magnified the economic impact of COVID-19 for most countries in our sample.

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. 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 modelled 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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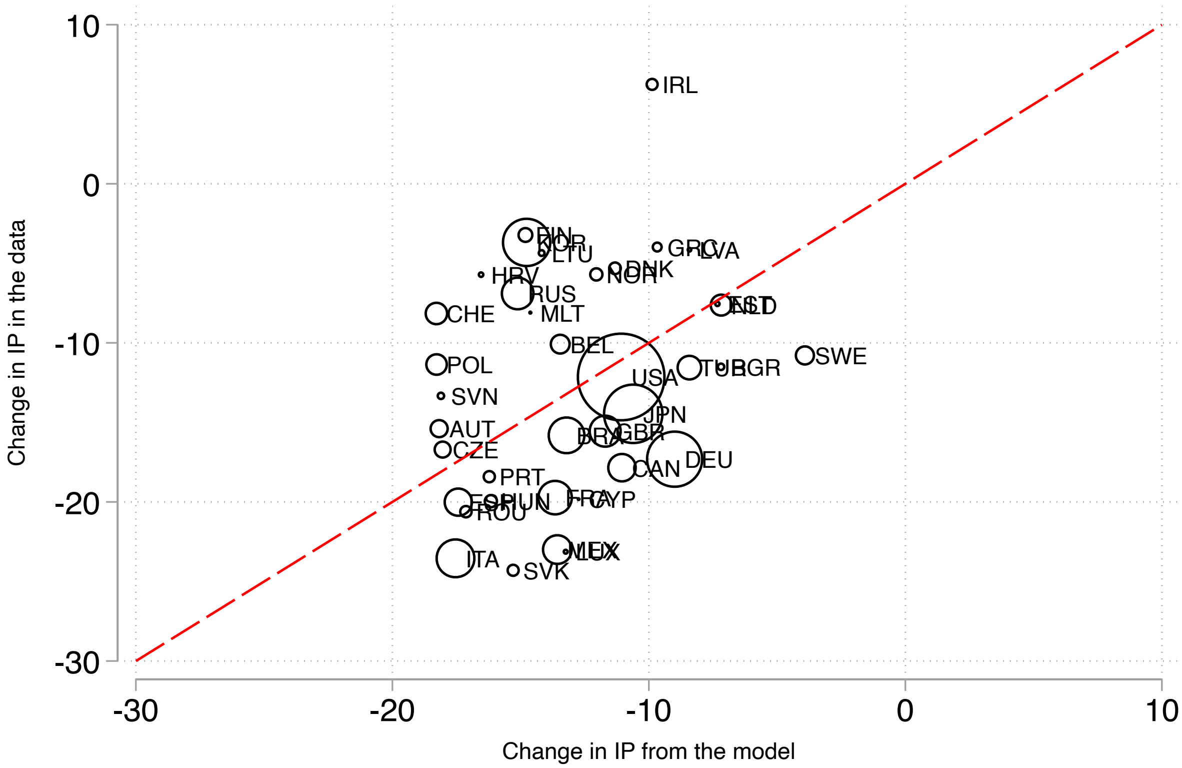
Figures

Figure 1: Calibration of the shock



Note: This figure presents the correlation between changes (in %) in industrial production (IP) from OECD and Eurostat data – the change is calculated as the difference between the average IP in the 6 months before and the 6 months after COVID-19 – and the change (in %) in industrial production from the model. The red dashed line represents the 45 degree line. The correlation is 0.6.

Figure 2: Decomposition of real income changes - Open Economy

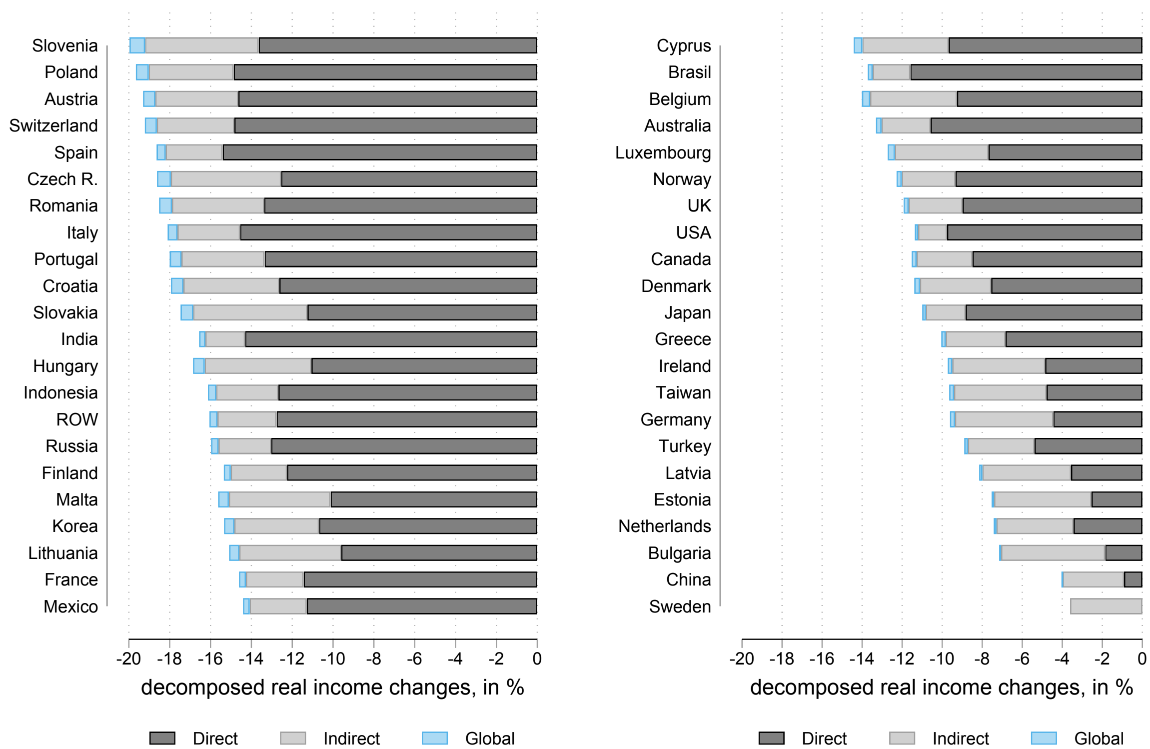
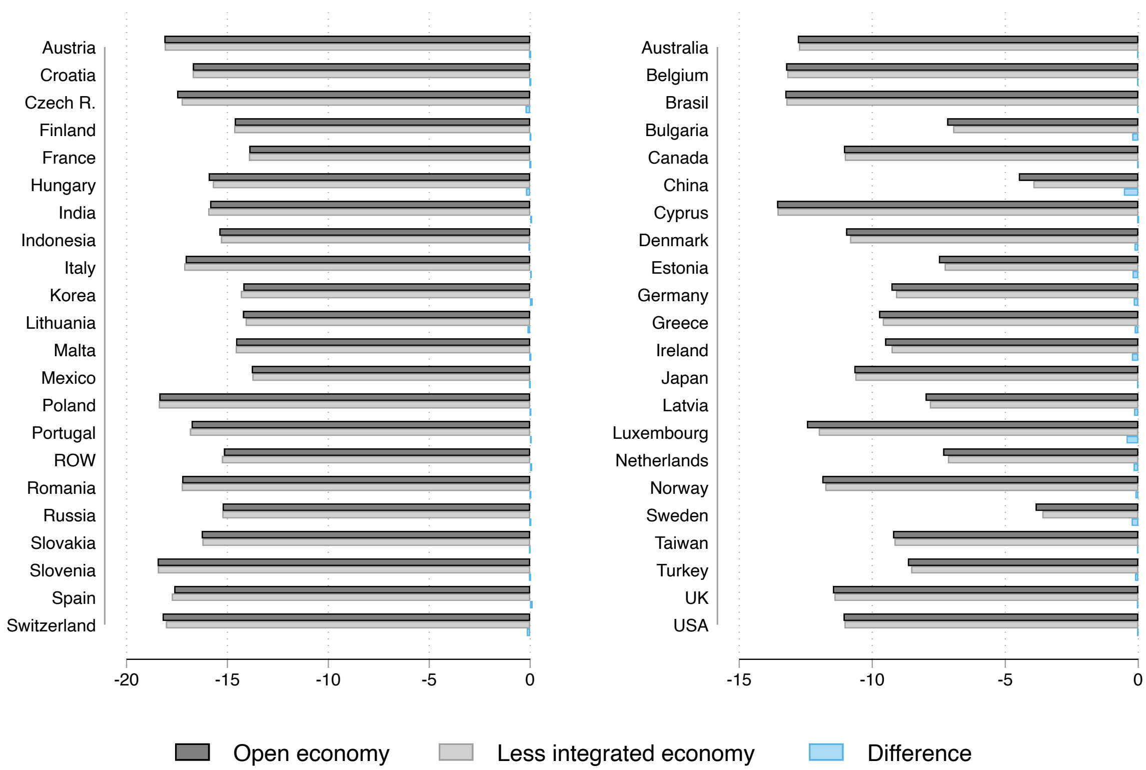


Figure 3: Real income changes: open economy vs less integrated economy (in %)



Tables

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

Country	Δ in %	Country	Δ in %
Australia	-12.76	Ireland	-9.27
Austria	-18.11	Italy	-17.15
Belgium	-13.20	Japan	-10.64
Bulgaria	-6.96	Korea	-14.34
Brasil	-13.23	Latvia	-7.84
Canada	-11.04	Lithuania	-14.10
Switzerland	-18.05	Luxembourg	-12.01
China	-3.95	Malta	-14.59
Cyprus	-13.56	Mexico	-13.76
Czech R.	-17.27	Netherlands	-7.16
Germany	-9.11	Norway	-11.77
Denmark	-10.84	Poland	-18.40
Spain	-17.76	Portugal	-16.86
Estonia	-7.28	ROW	-15.27
Finland	-14.67	Romania	-17.27
France	-13.93	Russia	-15.25
UK	-11.43	Slovakia	-16.24
Greece	-9.61	Slovenia	-18.45
Croatia	-16.72	Sweden	-3.61
Hungary	-15.73	Taiwan	-9.17
Indonesia	-15.32	Turkey	-8.54
India	-15.95	USA	-11.05

Note: The table presents the aggregated real income changes in % for every country.

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

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-7.47	-2.23	-23.86	-33.42	-38.69	-267.85
Food, Beverages, Tabacco	-5.80	-5.44	-26.78	-15.46	-46.74	-91.30
Mining, Quarrying	-1.51	-0.43	-50.23	-19.60	-14.33	-327.96
Textiles	-5.89	-0.62	-3.00	-5.20	-14.18	-36.99
Electrical Equipment	-4.89	-7.72	-36.26	-6.73	-32.21	-86.12
Machinery, Equipment	-9.11	-14.77	-19.33	-13.10	-51.03	-43.49
Motor Vehicles	-2.30	-15.66	-15.66	-11.67	-32.49	-49.60
Intm. Resources Manufacturing	-17.69	-18.61	-69.89	-36.82	-103.38	-212.13
Manufacturing, nec.	-3.77	-4.99	-26.54	-8.65	-25.64	-37.65
Pharmaceuticals	-1.97	-3.60	-10.76	-3.65	-18.60	-19.77
Chemicals	-3.10	-3.82	-29.48	-6.56	-22.27	-46.55
Electricity, Water, Gas	-8.98	-9.34	-35.91	-8.36	-64.36	-136.60
Construction	-16.82	-14.86	-73.54	-27.57	-120.10	-265.33
Wholesale, Retail Trade	-37.97	-28.92	-233.13	-29.84	-241.07	-542.96
Transport	-19.14	-13.20	-49.80	-15.02	-105.96	-219.82
Accommodation and Food	-12.24	-4.87	-53.85	-7.52	-68.51	-86.96
Real Estate	-47.06	-35.52	-227.43	-21.90	-242.61	-296.87
Public Services	-33.75	-35.89	-325.71	-18.09	-232.70	-381.68
Social Services	-21.73	-25.12	-135.61	-7.38	-158.88	-147.36
Services, nec.	-84.19	-77.39	-473.31	-67.34	-561.44	-803.48

Note: The table presents the sectoral value added changes, in bn USD for selected countries, Italy, Germany, USA, and China. 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 A2 in the Appendix).

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

Panel A: 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	-0.90	-1.94	-5.83	-2.07	-16.04	-29.47
Food, Beverages, Tabacco	-2.82	-11.98	-8.76	-9.55	-50.14	-40.87
Mining, Quarrying	-0.18	-1.70	-5.46	-1.85	-12.68	-186.58
Textiles	-6.26	-4.21	-1.60	-45.14	-22.51	-41.80
Electrical Equipment	-4.68	-23.13	-18.02	-107.89	-65.86	-101.04
Machinery, Equipment	-4.72	-31.94	-13.32	-38.41	-66.04	-26.71
Motor Vehicles	-2.29	-43.87	-11.58	-13.42	-77.53	-54.45
Intm. Resources Manufacturing	-12.34	-38.80	-35.69	-56.59	-140.21	-160.39
Manufacturing, nec.	-2.12	-13.74	-20.44	-30.22	-40.64	-33.67
Pharmaceuticals	-1.83	-7.72	-5.94	-4.10	-30.65	-9.64
Chemicals	-3.76	-19.07	-14.30	-13.01	-58.36	-52.01
Electricity, Water, Gas	-0.47	-3.85	-2.59	-0.76	-14.04	-6.83
Construction	-0.29	-0.42	-0.02	-2.53	-7.65	-3.48
Wholesale, Retail Trade	-3.19	-12.43	-29.68	-30.95	-76.02	-58.54
Transport	-2.17	-7.80	-15.25	-13.87	-57.80	-53.49
Accommodation and Food	-0.01	-1.62	-0.22	-1.54	-6.20	-18.33
Real Estate	-0.32	-0.36	-0.41	0.00	-1.90	-1.16
Public Services	-1.44	-2.04	-8.69	-0.59	-27.38	-25.43
Social Services	-0.18	-0.12	-0.27	-0.12	-1.71	-1.99
Services, nec.	-4.04	-19.98	-45.63	-14.03	-132.57	-73.05

Panel B: 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	-3.01	-3.08	-6.12	-2.04	-20.77	-27.28
Food, Beverages, Tabacco	-7.03	-4.54	-9.15	1.00	-48.09	-60.87
Mining, Quarrying	-7.26	-4.23	-26.56	-8.68	-50.28	-123.62
Textiles	-6.33	-4.29	-18.34	0.01	-35.45	-64.53
Electrical Equipment	-7.54	-12.58	-40.30	-6.48	-76.98	-175.68
Machinery, Equipment	-6.39	-4.83	-15.47	4.21	-45.69	-90.43
Motor Vehicles	-6.55	-6.16	-29.83	3.75	-57.37	-79.19
Intm. Resources Manufacturing	-16.72	-17.81	-40.65	-2.68	-131.66	-228.40
Manufacturing, nec.	-3.81	-4.85	-14.62	2.58	-36.45	-79.98
Pharmaceuticals	-3.93	-1.90	-5.42	0.77	-24.29	-21.85
Chemicals	-7.26	-7.89	-15.92	-4.10	-52.41	-68.99
Electricity, Water, Gas	-1.95	-1.63	-1.76	-0.07	-13.44	-8.95
Construction	-0.59	-0.91	-0.33	-0.06	-5.14	-8.16
Wholesale, Retail Trade	-6.47	-6.77	-7.22	-0.99	-49.89	-137.10
Transport	-4.30	-4.24	-5.28	-1.31	-37.32	-96.49
Accommodation and Food	-0.76	-0.71	-0.75	-0.37	-6.91	-18.27
Real Estate	-0.20	-0.05	-0.04	-0.00	-1.32	-2.11
Public Services	-2.55	-1.50	-12.79	-0.26	-28.43	-20.60
Social Services	-0.07	-0.07	-0.55	-0.04	-1.21	-2.30
Services, nec.	-7.58	-12.51	-18.32	-2.31	-87.96	-156.70

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 in the open economy.

Table 4: Decomposition of real income changes - Open Economy

Country	Direct Effect in %	GVC Effect in %	GE Effect in %	Country	Direct Effect in %	GVC Effect in %	GE Effect in %
Australia	-10.58	-2.45	-0.28	Korea	-10.69	-4.15	-0.50
Austria	-14.64	-4.07	-0.59	Latvia	-3.56	-4.43	-0.16
Belgium	-9.26	-4.34	-0.40	Lithuania	-9.60	-4.99	-0.49
Brasil	-11.60	-1.88	-0.24	Luxembourg	-7.68	-4.68	-0.35
Bulgaria	-1.86	-5.19	-0.10	Malta	-10.12	-4.98	-0.51
Canada	-8.49	-2.79	-0.24	Mexico	-11.29	-2.80	-0.32
China	-0.91	-3.07	-0.03	Netherlands	-3.44	-3.85	-0.13
Croatia	-12.63	-4.70	-0.61	Norway	-9.34	-2.69	-0.26
Cyprus	-9.68	-4.32	-0.43	Poland	-14.87	-4.16	-0.63
Czech R.	-12.55	-5.40	-0.67	Portugal	-13.36	-4.07	-0.57
Denmark	-7.55	-3.56	-0.28	ROW	-12.77	-2.90	-0.39
Estonia	-2.54	-4.86	-0.13	Romania	-13.38	-4.51	-0.62
Finland	-12.25	-2.76	-0.34	Russia	-13.03	-2.58	-0.36
France	-11.44	-2.83	-0.34	Slovakia	-11.25	-5.60	-0.61
Germany	-4.45	-4.91	-0.25	Slovenia	-13.65	-5.56	-0.76
Greece	-6.84	-2.99	-0.22	Spain	-15.41	-2.79	-0.44
Hungary	-11.06	-5.23	-0.56	Sweden	0.00	-3.61	0.00
India	-14.31	-1.94	-0.30	Switzerland	-14.83	-3.80	-0.59
Indonesia	-12.67	-3.05	-0.40	Taiwan	-4.79	-4.62	-0.24
Ireland	-4.86	-4.64	-0.22	Turkey	-5.39	-3.33	-0.18
Italy	-14.56	-3.06	-0.47	UK	-8.98	-2.69	-0.25
Japan	-8.83	-1.99	-0.18	USA	-9.76	-1.44	-0.16

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: Real income changes (in %) - Less integrated vs. Open Economy

Country	Less integrated Economy		Open Economy	Δ	Country	Less integrated Economy		Open Economy	Δ
	Trade Costs	Shock	Shock	Shock		Trade Costs	Shock	Shock	Shock
Australia	-18.36	-12.80	-12.76	-0.04	Korea	-21.77	-14.21	-14.34	0.13
Austria	-22.59	-18.12	-18.11	-0.01	Latvia	-30.80	-8.00	-7.84	-0.16
Belgium	-27.05	-13.24	-13.20	-0.04	Lithuania	-30.00	-14.23	-14.10	-0.13
Brasil	-13.98	-13.27	-13.23	-0.04	Luxembourg	-29.65	-12.46	-12.01	-0.44
Bulgaria	-33.50	-7.18	-6.96	-0.23	Malta	-34.43	-14.57	-14.59	0.02
Canada	-20.02	-11.07	-11.04	-0.03	Mexico	-17.38	-13.79	-13.76	-0.03
China	-17.12	-4.49	-3.95	-0.54	Netherlands	-19.99	-7.33	-7.16	-0.17
Croatia	-27.89	-16.71	-16.72	0.01	Norway	-19.55	-11.88	-11.77	-0.11
Cyprus	-31.14	-13.58	-13.56	-0.01	Poland	-23.09	-18.37	-18.40	0.03
Czech R.	-21.68	-17.49	-17.27	-0.22	Portugal	-24.12	-16.78	-16.86	0.08
Denmark	-19.91	-10.98	-10.84	-0.15	ROW	-29.33	-15.17	-15.27	0.10
Estonia	-31.87	-7.50	-7.28	-0.22	Romania	-27.35	-17.24	-17.27	0.02
Finland	-22.12	-14.64	-14.67	0.03	Russia	-20.91	-15.24	-15.25	0.01
France	-18.87	-13.92	-13.93	0.02	Slovakia	-25.90	-16.28	-16.24	-0.04
Germany	-19.44	-9.28	-9.11	-0.17	Slovenia	-26.58	-18.46	-18.45	-0.02
Greece	-24.02	-9.74	-9.61	-0.14	Spain	-18.31	-17.63	-17.76	0.13
Hungary	-22.13	-15.93	-15.73	-0.20	Sweden	-22.61	-3.86	-3.61	-0.25
India	-13.84	-15.86	-15.95	0.10	Switzerland	-19.72	-18.22	-18.05	-0.17
Indonesia	-18.60	-15.40	-15.32	-0.08	Taiwan	-24.39	-9.22	-9.17	-0.05
Ireland	-21.57	-9.52	-9.27	-0.24	Turkey	-18.55	-8.66	-8.54	-0.13
Italy	-16.61	-17.07	-17.15	0.07	UK	-20.38	-11.48	-11.43	-0.06
Japan	-14.63	-10.68	-10.64	-0.04	USA	-13.06	-11.08	-11.05	-0.03

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.

A Appendix: Data Sources and Description

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

Calibration of the baseline economy. We use data from the 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 A3) 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).

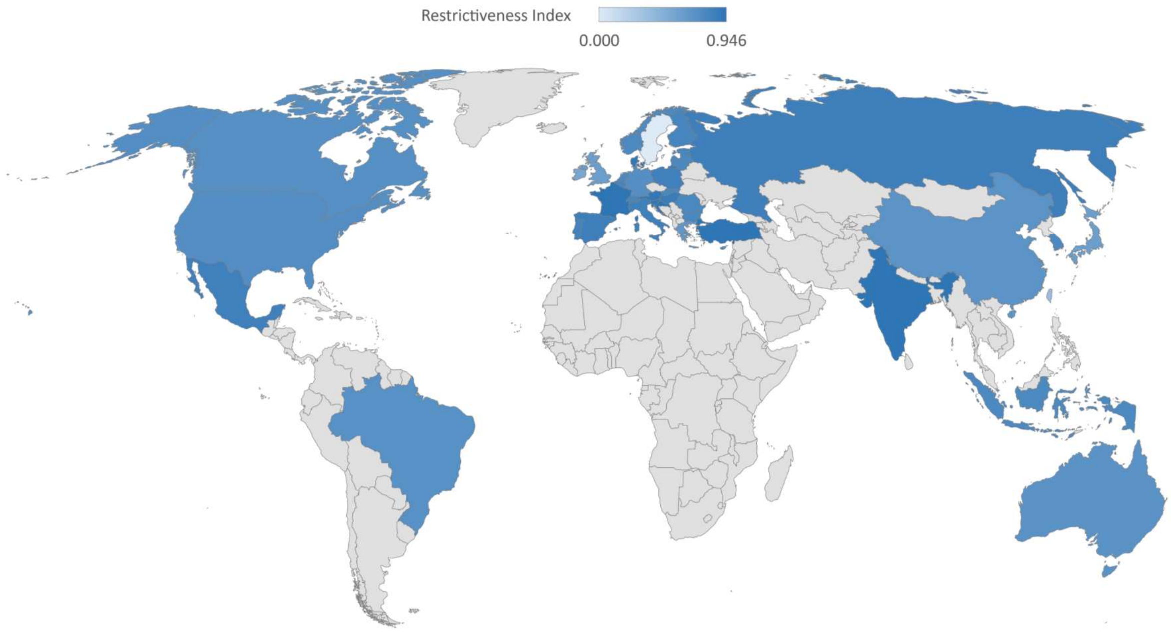
Construction of the shock As described in the main body of the paper, we construct a simple measure that quantifies the intensity of the economic shock. To construct the shock, as detailed in equation 4, we need employment data across countries, regions and sectors, the duration of the policy interventions on regional and national level, data on the severity of the policy interventions, and information on teleworkability of the sectors.

Duration of the policy interventions To construct our measure of the policy intervention ψ_i^j, we need data on the lock-down duration by country-region-sector. We exploit the data from national ministries (e.g. Estonia, Germany, France) and the Corona Net project database, which is a joint project of the TU Munich and partner universities. They collect real time data on the regulations with which governments and public authorities at the national and sub-national levels have reacted to the COVID-19 pandemic. The project has so far identified over 15 thousand different COVID-19 related interventions in 195 countries, which provides us with the largest, most comprehensive source of information on governmental action related to the COVID-19 crisis. Most importantly, the database distinguishes between different types of national and sub-national policies and the duration.(Cheng et al., 2020). This provides us with a regional variation in the duration of each policy intervention. Having reliable information on the regional duration of the policy intervention by sector is crucial to correctly map the COVID-19 shock in our set-up. Data on the regional restrictiveness of the policy interventions are not available for four European member states (France, Belgium, Sweden, and Lithuania). Hence, we use a different source for the construction of the restrictiveness index for these countries, namely the Oxford University data (Hale (2020)) and construct the duration of the lock-down policies at country level.

Data on COVID-19 policy interventions. Another crucial element to construct ψ_i^j is the information on the degree of restriction in 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.

Employment. Information on employment by country-region and sector is crucial to account for the geographical distribution of sectors across each country. In Italy, for example, COVID-19 hit the region Lombardy the worst, which led to a longer shutdown of specific businesses compared to other regions in the country. A sector that is solely located in Lom-

Figure A1: 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.

bardy will therefore be hit more than a sector that is only located in another region, such as Molise.[23]

For the *EU*, we use the information contained in the Eurostat. For the *US* we use IPUMScps to 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 Statistics of China for the year 2018 on employment by region and sector.[24] The second data source comes from the 2000 census. The National Bureau of Statistics of China provides the sector information for 19 sectors and 31 regions. Sectors con-

[23]Data on employment at sector-region level are not available for some countries in the sample, we therefore construct a simpler version of equation 4. 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.

[24]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.

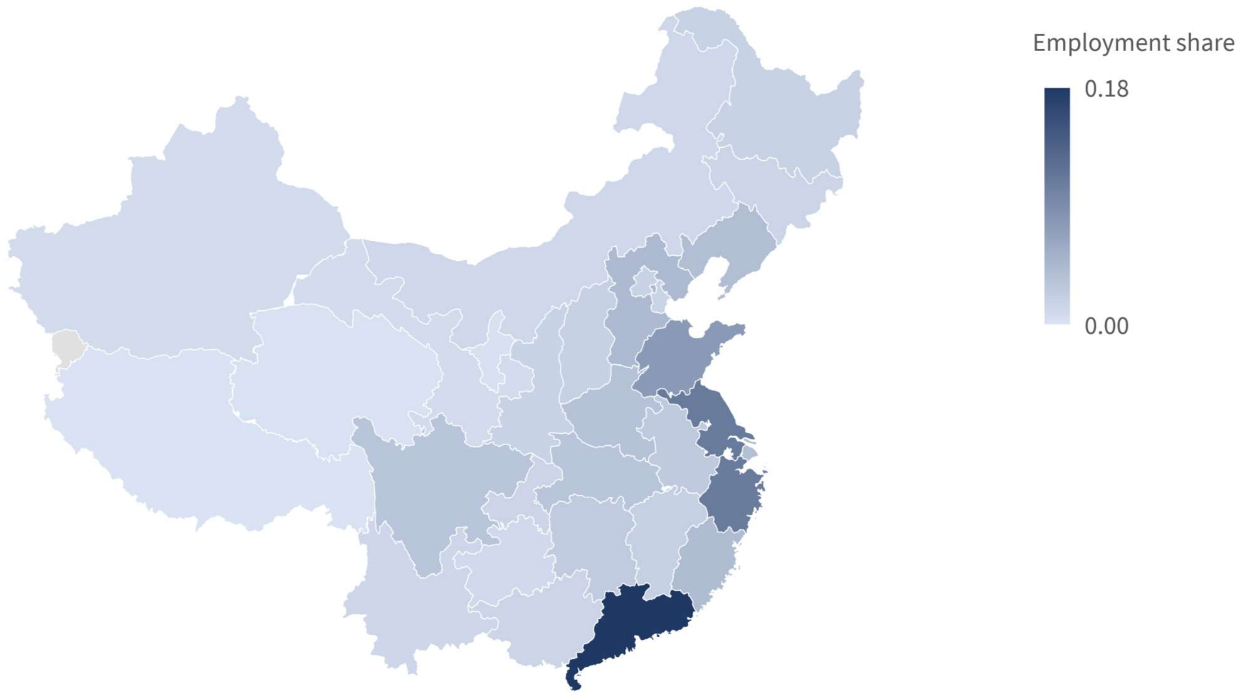
sist of one agricultural sector, one mining sector, one manufacturing sector and 16 services sectors, hence it is a more aggregated sector level than the WIOD data used to calibrate the baseline economy. We therefore complement the available data with the employment shares by prefectures and sectors 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 end up having information for 340 prefectures and 151 sectors (SIC industry code) in China, which is then aggregated to 31 Chinese regions and the 50 WIOD sectors.[25] We then redistribute the most recent available number of employment from the National Bureau of Statistics of China according to the shares from the 2000 census data (see figure A2).[26] This returns regional employment shares for each WIOD sector and region in China.

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 A1). 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

[25] 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.

[26] 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.

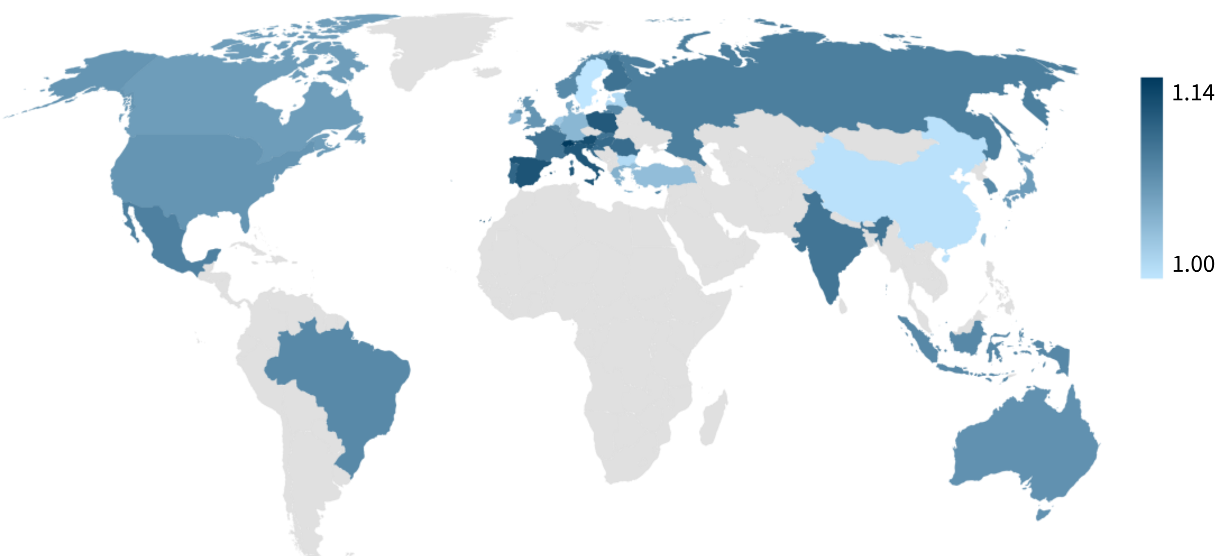
(sector 25), Postal and courier (sector 34), Human health and social work (sector 49).

Table A1: 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

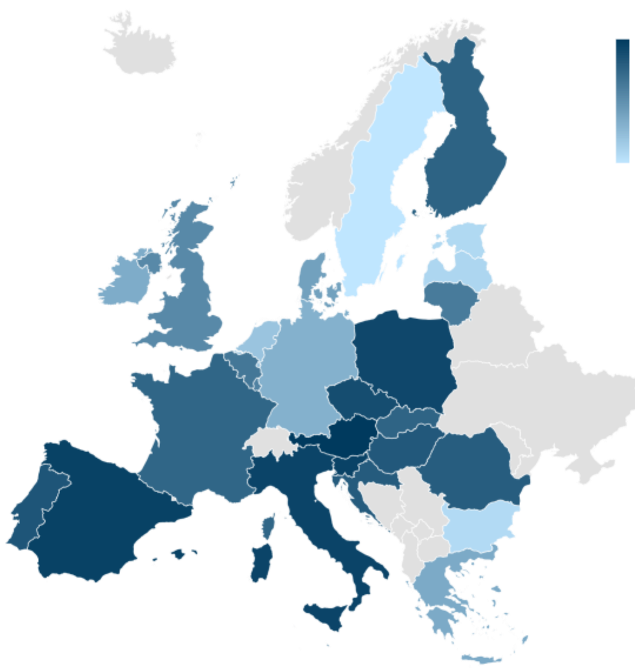
Note: The table shows the degree of teleworkability of each WIOD sector. Zero would indicate that work cannot be done from home, while teleworkability equal to 1 indicates that the entire work is independent of the location.

Figure A3: Size of Shock across all countries



Note: The map reports the intensity of the shocks 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 4 for the precise construction of the shock.

Figure A4: Size of the Shock for EU28 member states



Note: The map for the EU28 shows the size of the shock, 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 equation 4 for the precise construction of the shock. The darker the shade of blue, the higher is the size of the effect. The scale goes from 1, the least restrictive country (Sweden) to 1.12, the most restrictive country (i.e. Spain).

Table A2: 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 A3: 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