# TFP growth, embeddedness, and Covid-19: a novel production model that allows estimating trade elasticities *

André Carrascal

Luis Orea

January 19, 2023

## Abstract

The main contribution of this paper is the proposal of a new method to estimate trade elasticities based on a production model where trade elasticities and technological parameters are estimated simultaneously. Our empirical model, inspired by the theoretical framework introduced by Caliendo et al (2018) to study the propagation of productivity shocks, also permits assessing whether their central equation aimed at understanding the sources of productivity change, is supported by the data. Furthermore, using econometric techniques, our paper examines trade-related productivity effects that have rarely been examined in the literature on productivity growth decomposition. The proposed model provides a common analytical framework for an empirical examination of several issues that both traditionally and more recently have attracted the interest of many academics and policy/makers, namely TFP growth, embeddedness, and Covid-19. We use the World Input-Output Database (WIOD) for the period 2000-2014 to compute most of the relevant variables employed in these applications.

JEL codes: F47, O47, C68

**Keywords:** Total factor productivity, embeddedness, trade elasticities, Covid-19.

* This paper began as part of the Spanish research project “Inter-sectoral and regional effects of institutional responses to the COVID-19 epidemic” (Project PID2020-113076GB-I00). Both authors wish to acknowledge Joanna Bashford, assistant researcher of the research project INNJOBMAD-CM, for editing the text. We also wish to acknowledge helpful suggestions from Alan Wall. We would like to thank conference participants at EWEPA 2022 in Porto, the Spanish Workshop on Efficiency and Productivity Analysis 2022 in Badajoz, and ERSA Congress 2022 in Pécs for their valuable comments on an earlier version of this paper.

## 1. Introduction

This paper examines several issues - some of them classical in the literature and others more recent- that have long been of interest to academics and policy/makers. Productivity is a key driver for economic growth and a key source of large cross-country income differentials. The pursuit of total factor productivity (TFP) growth requires an understanding of its factors. Much of the literature on productivity growth decomposition (see e.g. Sickles and Zelenyuk, 2019) focuses on the adoption of more productive technologies (technical change), the existence of diffusion and learning limitations that prevent firms from adopting such technologies (catching-up effect or efficiency change), the misallocation of resources across firms and sectors, as well as the aggregation of low-level (industries or firms) productivity growth measures. Another traditional strand of the literature (see, e.g. Kitsos et al., 2022) examines the relationship between the spatial embeddedness of industrial structures, understood as the share of intermediate (business to business) economic activity taking place within a specific region, and regional economic resilience. Interestingly, the related theory is inconclusive as to whether these intra-regional, inter-sectoral input-output (IO) linkages could generate both positive or negative externalities for local firms during growth (or recessions) periods (Diodato and Weterings, 2015). In addition, there is an emerging and rapidly growing literature (see e.g. Brodeur et al., 2021) on the economic and financial impacts of the Covid-19 pandemic, the socioeconomic consequences of lockdowns, and the governmental response to the pandemic.

This paper aims to shed light on the above-mentioned issues using a common framework inspired by the theoretical model introduced by Caliendo et al. (2018) for studying the propagation of sectoral and regional productivity shocks to the rest of the US economy. Our principal contributions are the following. The first contribution is to provide a novel production-based approach for estimating trade elasticities. Second, our empirical model allows testing Caliendo et al. (2018)'s central equation, thereby aiming to understand the sources of change in sectoral productivity. The third contribution of our paper is to measure the productivity effects associated to the benefits of international trade; an effect that has rarely been examined econometrically based on a structural TFP decomposition.

The main results are as follows. First, despite using a very simple specification of our production model in order to focus our empirical analysis on trade elasticities, our estimated trade elasticities are in the range of those estimated in the literature using gravity equations. Moreover, the estimated trade elasticities reveal that TFP increases with trade openness, in line with other papers examining the productivity impact of openness and trade liberalization. Second, we find that the improvement in fundamental productivity is the most important TFP driver. However, the changes in international trade explain a significant proportion of the variations in measured TFP growth across countries and sectors. Third, our results also indicate that most of the variations in the degree of embeddedness across countries and sectors are explained by differences in own fundamental productivity changes, which we associate with the existence of local economies of agglomeration and/or local knowledge spillovers. We finally find that the Covid-19 pandemic has reduced countries' gross output by 14.42% on average. Although most of this effect can be attributed to shortages in intermediate inputs and reductions in labour supply, our results also indicate the existence of non-negligible effects on countries' output through a deterioration in the benefits of international trade due to the Covid-19 pandemic.

Our first contribution is to link Caliendo et al. (2018)'s theoretical TFP decomposition with the estimation of trade elasticities, where trade elasticities and technological parameters are estimated simultaneously. Indeed, they show that sectoral total factor productivity (TFP) not only depends on what they labelled as the 'fundamental' productivity level, the latter referring to how much value added can be produced in the absence of trade, but also on a country's share of its own intermediate goods, a measure of embeddedness. Once we insert their theoretical decomposition of measured TFP into an empirical production model, we immediately realize that the coefficient of their trade-related productivity driver is (the inverse) of a trade elasticity, which can thus be estimated econometrically. Caliendo and Parro (2015), among others, estimate the trade elasticities using gravity equations based on bilateral trade variables. Instead of using a gravity model, we propose estimating the sectoral trade elasticities using a production model. The key difference with previous methods is the data used to identify the trade elasticities. Like Caliendo and Parro (2015), our method does not involve the estimation of unobservable trade barriers as we use trade data to calculate the trade elasticities. However, as our target productivity driver is the country's share of its own intermediate goods (i.e. one minus the sum of *all* country's bilateral trade shares), we do not need to drop observations with zeros as occurs in Caliendo and Parro (2015) and previous papers using bilateral trade flows. In contrast, we need production data to estimate our trade elasticities. In this sense, our methodology can be used as a complementary approach to estimating sectoral trade elasticities.

Another contribution of our paper is to draw the attention of researchers via the use of general equilibrium models (Hosoe et al., 2010) to the extent that it is possible to examine whether the data supports (part of) the foundational theoretical framework behind them by simply developing an empirical counterpart of one of their key equations. Indeed, although Caliendo et al. (2018) used their theoretical decomposition of sectoral TFP growth to simulate the propagation of disaggregated fundamental productivity changes, they did not test it empirically. Our empirical model allows sectoral TFP to depend on countries' share of expenditure on domestic goods, as predicted by Caliendo et al. (2018)'s model. This allows us to examine whether their central equation aimed at understanding the sources of change in sectoral productivity following a change in fundamental productivity, is supported by the data.

The third contribution of our paper is to link Caliendo et al. (2018)'s theoretical TFP decomposition with the empirical literature on TFP decomposition. A major contribution of these authors is to prove that the international trade of intermediate goods propagates productivity changes across sectors and countries by way of endogenous changes in the pattern of international trade through a so-called "selection process" that determines what types of goods are produced in which countries.[1] The productivity impact of their selection process, which can be associated with changes in the benefits of international trade in terms of cheaper intermediate inputs, has rarely been examined in the literature using a structural TFP decomposition. There are some notable exceptions. Diewert and Morrison (1986) point out that a decrease in import prices (relative to export prices) can be viewed as an increase in TFP. ten Raa and Mohnen (2002) treat the trade sector as a production sector, with multiple inputs (exports) and outputs (imports) and find that productivity goes up when the terms of trade improve. Shestalova (2001, 2019) also finds an effect of international trade on productivity that captures wedges between optimal and observed net export values, reflecting the gains of free trade. While these papers decompose TFP growth using non-parametric techniques, we propose examining trade-related productivity effects using econometric techniques. [2]

[1] Caliendo et al. (2018) abstracted from international trade because they focused their analysis on the US economy and, hence, their geographical units were regions, not countries.

[2] It should be highlighted that while the aforementioned literature relies on a structural decomposition of TFP, other authors have obtained trade-related productivity effects using a more parsimonious approach, i.e. by regressing countries' production or TFP on a set of underlying regressors (see e.g. Edwards, 1998; Miller and Upadhyay, 2000).

The proposed model provides an analytical framework for carrying out several simulation analyses that are not only of interest in their own right but also exemplify how the trade elasticities estimated in this paper, together with other parameters of the model, can be used to study a wide variety of phenomena. The World Input-Output Database (WIOD) (Timmer et al., 2015), for the period 2000-2014 is used to compute all the relevant variables in most of these applications.

Our first two simulation analyses emphasize that international trade linkages, and the fact that materials produced in one country are potentially used as inputs far away, are essential in propagating productivity changes spatially and across sectors. Mimicking partially the analyses carried out by Caliendo et al. (2018), we first examine the relative contribution of changes in both sectoral fundamental productivity and international trade to sectoral productivity. We next study the determinants of national embeddedness. The proposed model is used here to decompose countries' degree of embeddedness into two factors: the effect of changes in their own fundamental productivity, and the effect of changes in the fundamental productivity in other countries. We finally simulate the compound economic effects of the Covid-19 pandemic outbreak, based on our production model with input-output sectoral linkages. Previous papers (e.g. Liu and Sickles, 2021; and Liu and Cheng, 2021) have examined the economic effect of the Covid-19 pandemic through three channels: the shortage of intermediate inputs, reductions in labour supply, and reduced technology spillovers. Using Caliendo et al. (2018)'s theoretical framework, we show that the pandemic might also have impacted sectoral and country production by reducing the benefits of international trade.

The rest of the paper is organized as follows. Section 2 outlines the main features of the general equilibrium model developed by Caliendo and Parro (2015) and Caliendo et al. (2018) with trade in intermediate goods, sectoral heterogeneity, and input-output linkages. We show here how TFP can be decomposed into a traditional technological component and a trade-related effect that has been often ignored in the empirical literature. Section 3 introduces the econometric specification of our production model that decomposes sectoral TFP into its two main drivers: fundamental productivity and international trade of intermediate goods. Section 4 introduces the data sources and the definition of the variables used to estimate both the trade elasticities and carry out our applications. Section 5 presents both the parameter estimates and the computed trade elasticities. Section 6 includes the three applications of our model, aiming to examine sectoral productivity changes, changes in countries' degree of embeddedness, and the compound economic impact of the recent Covid-19 pandemic outbreak. Finally, Section 7 presents the conclusions.

## 2. Theoretical framework

Our empirical model is inspired by the static two/factor model with $N$ regions and $J$ sectors developed by Caliendo et al. (2018) to study the impact of intersectoral and interregional trade linkages in propagating disaggregated productivity changes to the rest of the US economy. In our empirical application the regions are the European countries.

### 2.1 *General characteristics of the CPRS model.*

This subsection summarizes the main features of the general equilibrium model with trade in intermediate goods, sectoral heterogeneity, and IO linkages first developed by Caliendo and Parro (2015) to quantify the welfare effects from tariff changes and used later in Caliendo et al. (2018) to examine the propagation of TFP shocks. They assumed an economy with two primary inputs (L and K), and a mixture of intermediate goods from all sectors that are used for production.[3] Producers demand intermediate goods (M) for production and supply goods not only for consumption but also for production in all sectors. Constant returns to scale (CRS) are assumed in order to comply with the identity between value added and the income from labour and capital. A given sector may be either tradable, in which case goods from that sector may be traded at a cost across regions, or non-tradable. While final goods in their model are non-tradable, the intermediate goods in tradable sectors are costly to trade. Global competitive markets for intermediate goods are assumed, e.g., producers purchase intermediate goods from the lowest cost suppliers across countries in their model, and the source from which goods are purchased is endogenously determined and can vary because of changes in trade costs.

Caliendo et al. (2018) allow productivities to differ by both sectors and firms. Productivity differences across individual firms in a sector are introduced in the same way as in Eaton and Kortum (2002). They assume that representative firms located in region $n = 1, \dots, N$ and operating in sector $j = 1, \dots, J$ produce a continuum of varieties of intermediate goods that differ in their idiosyncratic productivity level, $z_n^j$. In each region and sector, this productivity level is assumed to be a random variable that follows a Fréchet distribution with shape parameter $\theta^j$, which in a trade context can be interpreted as the (negative of the) elasticity of trade with respect to trade costs. On the other hand, the productivity of all firms in country $n$ and sector $j$ is also determined by the so-called 'fundamental productivity', $T_n^j$, that refers to how much value added can be produced in the absence of trade. In their model, $T_n^j$ affects the productivity of value added as in Acemoglu et al. (2012).

In summary, while the productivity of all firms within the industry is determined by a deterministic or 'fundamental' productivity level, the dispersion of within-industry productivities is modelled using the industry-specific parameter, $\theta^j$. A lower $\theta^j$ implies a larger dispersion of productivity across firms. In the context of their model, a higher fundamental productivity makes the average productivity in a sector higher, a notion of absolute advantage, whereas a smaller value of $\theta^j$ generating more heterogeneity means that comparative advantage exerts a stronger force for trade against the resistance imposed by the trade costs.

Caliendo et al. (2018) use the above-mentioned assumptions governing the distribution of idiosyncratic productivities to derive: i) the distribution of prices across countries; ii) the probability that one country provides a good at the lowest price in another country, and iii) the share of countries' total expenditures purchased abroad. In particular, using the properties of the Fréchet distribution, the share of country $n$'s total expenditures on sector $j$'s goods purchased from any country $i$ is:

$$\pi_{ni}^j = \frac{\left[x_i^j \kappa_{ni}^j\right]^{-\theta^j} \left(T_i^j\right)^{\theta^j \gamma_i^j}}{\sum_{i=1}^{N} \left[x_i^j \kappa_{ni}^j\right]^{-\theta^j} \left(T_i^j\right)^{\theta^j \gamma_i^j}} \tag{1}$$

where $x_n^j$ is the cost of the input bundle used to produce goods in region $n$ and sector $j$, $\kappa_{ni}^j$ is the cost of delivering a unit from country $i$ to country $n$ (trade costs or geographic barriers), and $\gamma_i^j$ is the share of value added in gross output. Country $n$'s embeddedness can be measured using its own trade share:

[3] In should be pointed out that Caliendo et al. (2018) used a composite factor comprising land and structures that we associate with capital.

$$\pi_{nn}^{j} = 1 - \sum_{i \neq n}^{N} \pi_{ni}^{j} = \frac{\left[x_n^j \kappa_{nn}^j\right]^{-\theta^j} \left(T_n^j\right)^{\theta^j \gamma_n^j}}{\sum_{i=1}^{N} \left[x_i^j \kappa_{ni}^j\right]^{-\theta^j} \left(T_i^j\right)^{\theta^j \gamma_i^j}} \tag{2}$$

Notice that while the own trade share ($\pi_{nn}^{j}$) increases when this country-sector experiences an increase in its fundamental productivity, it decreases when the fundamental productivity of this sector in other countries increases.[4] Finally, it increases when the trade costs or the barriers to import goods from other regions increase.

### 2.2 *Measured TFP and trade.*

This sub-section shows that measures of industry total factor productivity (TFP) can be decomposed into a traditional technological component and a trade-related effect that has been completely ignored in the empirical literature.

As customary, Caliendo et al. (2018) measure the TFP in region $n$ and sector $j$ as:

$$lnA_n^j = lnY_n^j - (1 - \beta_n^j)\gamma_n^j lnL_n^j - \beta_n^j \gamma_n^j lnK_n^j - \sum_{k=1}^{J} \gamma_n^{jk} lnM_n^{jk} \tag{3}$$

where $Y_n^j$ is a measure of real gross production in region-sector pair $(n, j)$, $K_n^j$ and $L_n^j$ denote the demand for capital and labour respectively, $\beta_n^j$ is the share of capital in value added, $M_n^{jk}$ is the demand for material inputs by firms in sector $j$ from sector $k$, and $\gamma_n^{jk} \geq 0$ is the share of sector $j$ goods spent on materials from sector $k$. By rearranging the terms of the above TFP definition, we find that the technology of each sector can be represented by a Cobb-Douglas production function.[5] As is customary, we next assume that the technology of each sector has constant returns to scale, namely that $\gamma_n^j = 1 - \sum_{k=1}^{J} \gamma_n^{jk}$.

Caliendo et al. (2018) show that the economy-wide competitive equilibrium allows interpreting $A_n^j$ as the ratio of the cost of the input bundle ($x_n^j$) to the price of the final good ($P_n^j$) in the same fashion as Jorgenson and Grilliches (1967). Therefore, $A_n^j$ can be viewed as either a primal or dual measure of TFP. Assuming a globally competitive market for intermediate goods, and having solved for the distribution of prices, Caliendo et al. (2018) find that measured sectoral TFP in region $n$ and sector $j$ can be written as:[6]

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[4] In particular, the elasticity of trade shares as referring to the respective changes in $T_n^j$ and $T_i^j$, $\forall i \neq n$ are:

$$\partial ln\pi_{nn}^j / \partial lnT_n^j = \theta^j \gamma_n^j (1 - \pi_{nn}^j)$$

$$\partial ln\pi_{nn}^j / \partial lnT_i^j = -\theta^j \gamma_i^j \pi_{ni}^j$$

Therefore, changes in sector $j$'s fundamental productivities impact trade shares according to $\theta^j$. A similar comment can be made regarding the changes in trade costs, $\kappa_{ni}^j$, or in the cost of an input bundle, $x_n^j$. It should be recognized, however, that the above elasticities are *conditional* on the cost of an input bundle, $x_n^j$. Therefore, they only allow us to obtain the *direct* elasticities of trade shares with respect to changes in own and foreign fundamental productivity.

[5] Notice that we can derive a primal representation of the sectoral production function from the aforementioned TFP definition if we rewrite it as follows:

$$Y_n^j = A_n^j \left[ \left(K_n^j\right)^{\beta_n^j} \left(L_n^j\right)^{1-\beta_n^j} \right]^{\gamma_n^j} \prod_{k=1}^{J} \left(M_n^{jk}\right)^{\gamma_n^{jk}}$$

[6] They express this relationship using rates of growth in their equation (16).

$$lnA_n^j = \gamma_n^j lnT_n^j - \frac{1}{\theta^j} ln\pi_{nn}^j \quad (4)$$

The first term measures the (attenuated) effect of changes in fundamental productivity on measured TFP. Changes in measured TFP are identical to changes in fundamental productivity if the share of value added in gross output is equal to one ($\gamma_n^j = 1$). This exact relationship between $T_n^j$ and $A_n^j$ no longer holds once either trade ($\pi_{nn}^j < 1$) or sectoral linkages ($\gamma_n^j < 1$) are operative.

The second term in equation (4) is a trade-related productivity effect that depends on the degree of embeddedness of country $n$, $\pi_{nn}^j$. Recall that the own trade share ($\pi_{nn}^j$) increases when this country-sector experiences an increase in its fundamental productivity. Hence, since $\theta^j > 0$, trade reduces the effect of a fundamental productivity increase on measured productivity in that country-sector while, at the same time, raising measured productivity in another country's sector $j$. If trade is non-operative, the share of traded intermediate goods vanishes (i.e., $\sum_{i \neq n}^{N} \pi_{ni}^j = 0$) and hence $\pi_{nn}^j$ is equal to unity in every country. Therefore, this equation indicates that, with no trade, a country and sector-specific productivity change has no effect on the measured productivity of any other country or sector.

A major contribution of Caliendo et al (2018) is to prove that the competition for intermediate inputs in a globalized world propagates productivity changes across sectors and regions. They show that, if trade is operative, productivity changes are propagated across sectors and regions by way of the following selection process, which is captured entirely in equation (4) by the country's share of its own intermediate goods, $\pi_{nn}^j$. The country-sector that experienced a fundamental productivity increase exploits its advantage by selling a wider range of goods. However, the new varieties of intermediate goods, since not being initially produced, are associated with idiosyncratic productivities that are relatively worse than those of varieties produced before the change. Therefore, this negative selection effect for country $n$ and sector $j$ partially offsets the positive consequences of the fundamental productivity change, relative to an economy with no trade, in that country-sector pair.[7]

We can associate the last term in equation (4) with a deterioration (recuperation) of the benefits of international trade for intermediate goods because, in the Caliendo et al (2018) framework, international trade (transport cost) tends to reduce (increase) the price of both intermediate and final goods in each country.[8] As the above trade-related effect also has to do with the Ricardian notions of absolute and comparative advantage of other countries as suppliers in the globalized intermediate goods market, we can view the last term in equation (4) as a *Ricardian* effect or a trade-related spillover effect.

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[7] In other country-sector pairs, the opposite effect takes place yielding higher measured productivity in those locations.

[8] The price of good $j$ is given by the following function:

$$P_n^j = A^j \left[ \sum_{i=1}^{N} \left[ x_i^j \kappa_{ni}^j \right]^{-\theta^j} \left( T_i^j \right)^{\theta^j \gamma_i^j} \right]^{-1/\theta^j}$$

This function summarizes how worldwide states of technology, input costs around the world, and trade costs govern prices in each country $n$. This equation suggests that international trade tends to reduce final good prices in each country if trade costs are not prohibitive ($\kappa_{ni}^j \neq \infty$, for $i \neq n$), this being due to an expansion of each country's effective state of technology with technology available from other countries, discounted by input costs and trade costs.

Last, but not least, it is germane to recall that the key parameters for the propagation of productivity shocks across sectors and regions in Caliendo et al (2018)'s model are the trade elasticities $\theta^j$. Caliendo and Parro (2015) used a gravity equation to estimate the dispersion of productivities. Notice, however, that equation (4) provides an alternative (new) method to estimate the dispersion parameter $\theta^j$ based on the estimation of industry production functions that allow the productivity level to depend on the region's share of expenditure on domestic goods, $\pi_{nn}^j$. Instead of using a gravity equation, we estimate the dispersion of productivity parameters together with the technological parameters of our production model.

## 3. Econometric specification

This section introduces the econometric specification of equation (4) that decomposes sectoral TFP into its two main drivers: fundamental productivity and the international trade of intermediate goods. From this equation, and after adding a time subscript to both dependent and independent variables, we can express the logarithm of measured sectoral TFP as:

$$lnA_{nt}^j = \gamma_n^j lnT_{nt}^j - \frac{1}{\theta^j} ln\pi_{nnt}^j \tag{5}$$

As the value-added share $\gamma_n^j$ can be computed using the information available in the World Input–Output Database (WIOD), we next normalize equation (5) using this share. After adding a traditional noise term, this yields the following expression:

$$\left(\frac{lnA_{nt}^j}{\gamma_n^j}\right) = lnT_{nt}^j - \frac{1}{\theta^j} \cdot \left(\frac{ln\pi_{nnt}^j}{\gamma_n^j}\right) + v_{nt}^j \tag{6}$$

where $v_{nt}^j$ is a symmetric but likely heteroskedastic noise term that captures unobserved industry-specific productivity shocks. The unique parameters to be estimated here are the set of trade elasticities ($\theta^j$) and the parameters used to model $lnT_{nt}^j$.

Liu and Sickles (2021) argue in their application to the Covid-19 pandemic that sectoral heterogeneity should be considered in productivity growth analyses using industry-level data, as such heterogeneity is intrinsic due to the techno-economical features of each distinct sector. These authors addressed this issue by allowing for industry-specific time trends in their production models. We do not need to extend our model in this fashion because fundamental productivity in (4) is scaled down by the share of value added in gross output. As these shares vary across regions and industries, we are already controlling for the parameter heterogeneity issue discussed by Liu and Sickles (2021) when modelling the technology of each industry.

We next propose a very simple specification of $lnT_{nt}^j$ to focus our empirical analysis on trade elasticities. In particular, we assume that fundamental productivity can be modelled empirically as follows:

$$lnT_{nt}^j = \alpha_n + \alpha^j + \delta_1 t + \delta_2 t^2 \tag{7}$$

The industry and country-specific intercepts in equation (7) allow us to control for persistent differences in unobserved sectoral production conditions. We next use a time polynomial of degree two to capture exogenous technological progress or technical change.[9] If the trade elasticities are treated as an additional parameter of the model, they can be estimated using a non-parametric approach. Alternatively, we can use a parametric approach and

[9] Disentangling $lnT_{nt}^j$ into several sources, such as technical change, changes in sectoral technical inefficiency and the effect of knowledge or spatial spillovers is left for future research.

parameterize the trade elasticities as a function of a set of covariates. If trade elasticities are treated as an additional parameter of the model, the model can be written as follows:

$$\left(\frac{lnA_{nt}^{j}}{\gamma_n^j}\right) = \alpha_n + \alpha^j + \delta_1 t + \delta_2 t^2 + \tau^j \left(\frac{ln\pi_{nnt}^{j}}{\gamma_n^j}\right) + v_{nt}^j \tag{8}$$

where $\tau^j = -1/\theta^j$ is a parameter that is estimated for each tradable *and* non-tradable sector. A more restricted specification of this model can be obtained if we assume that $\tau^j$ is common to all sectors (i.e., $\tau^j = \tau$ for all $j = 1, \dots, J$). We can then use this common parameter to test statistically whether countries' measured TFP does depend on their own trade share of intermediates, as predicted by Caliendo et al. (2018)'s model.

Caliendo and Parro (2015) treat the construction sector and the whole set of service sectors as fully non-*tradable* sectors and trade elasticities are not estimated for these sectors. If we want to estimate trade elasticities for only *tradable* sectors as in Caliendo and Parro (2015), the model to be estimated can be written as:

$$\left(\frac{lnA_{nt}^{j}}{\gamma_n^j}\right) = \alpha_n + \alpha^j + \delta_1 t + \delta_2 t^2 + \tau^j \left(\frac{ln\pi_{nnt}^{j}}{\gamma_n^j}\right) TR^j + v_{nt}^j \tag{9}$$

where the new variable $TR^j$ identifies *tradable* sectors, and a specific elasticity parameter is only estimated for sectors with $TR^j = 1$.

An alternative specification is proposed based on the relationship between countries' own trade shares of intermediates and sectoral trade elasticities. If we abstract from material input use so that $\gamma_n^j = 1$, the own trade share of one country can be written in the case of two countries as:

$$\pi_{11}^j = \frac{1}{1+\left(h_2^j/h_1^j\right)^{\theta^j}} \quad , \quad h_i^j = T_i^j/x_i^j \kappa_{1i}^j \tag{10}$$

Notice that the variance of $\pi_{11}^j$ depends on the variance of $\left(h_2^j/h_1^j\right)$ if $\theta^j > 0$. Moreover, if $\theta^j = 0$, $\pi_{11}^j$ is a constant term, and hence $var(\pi_{11}^j) = 0$. We take advantage that the *observed* variance of the own trade shares is likely correlated with the underlying but *unobserved* sectoral trade elasticities to parameterize $\tau^j$ as a function of a set of covariates:

$$\tau^j = \tau_0 + \tau_1 SD^j + \tau_2 TR^j \tag{11}$$

where $SD^j$ is the standard deviation of the logged own trade shares in sector $j$. The model to be estimated now can be written as:

$$\left(\frac{lnA_{nt}^{j}}{\gamma_n^j}\right) = \alpha_n + \alpha^j + \delta_1 t + \delta_2 t^2 + \left(\tau_0 + \tau_1 SD^j + \tau_2 TR^j\right) \left(\frac{ln\pi_{nnt}^{j}}{\gamma_n^j}\right) + v_{nt}^j \tag{12}$$

## 4. Data

To perform the analysis and calibrate the model described in previous sections, our main data source is the World Input-Output Database (WIOD) (Timmer et al., 2015). This database in its last release for 2016 gives us detailed industry-level information about 28 EU countries (as of July 1st, 2013) and 15 other major countries worldwide[10] from 2000 to 2014. In particular, WIOD contains data about 56 different sectors, 21 of which are manufacturing sectors, 29 service sectors, 3 primary sectors, 2 mining and energy-related and one for the

[10] In our analysis we classified these countries into 31 European and 10 non-European countries, excluding Japan and Taiwan that contained missing values for some essential information on value added.

construction sector. The list of countries and sectors can be found in the Appendix. We also provide the correspondence between the WIOD sectors, the International Standard Industrial Classification (ISIC Rev. 4) and the aggregation of the 20 sectors we use in our applications to facilitate computations.

WIOD offers data on a set of national input-output tables that are interconnected via bilateral international trade flows (Timmer et al., 2016). This information on both domestic and international flows of goods and services allows us to analyse global production networks, and grants an insight as to the starting and end point of said flows. The main advantages of using the information contained in WIOD rely on the construction methodology[11] of the database. The input-output tables from WIOD are constructed by exploiting a time series of national accounts data (following the 2008 version of the System of National Accounts), additionally employing bilateral international trade statistics to disaggregate imports by country of origin and use category. The tables are consistent over time and space since they are all derived applying the same set of principles and accounting identities. Some examples where WIOD has been used are, for instance, in the analysis of trade and global value chains (Antras and Chor, 2018; Antras and de Gortari, 2020; Los, Timmer and de Vries, 2015 and 2016), environmental issues (Wiedmann and Lenzen, 2018; Shapiro and Walker, 2018), and many other topics such as international inflation spillovers (Auer et al., 2019) or sectoral productivities (Duarte and Restuccia, 2020), among others.

Making use of the information available from the Socio-Economic Accounts included in the WIOD, we obtain Industry-level data on total employment ($L$), capital stocks ($K$), intermediate inputs ($M$), gross output ($Y$) and value-added ($V$) at current and constant prices, in millions of local currencies. The industry classification is consistent with the world input-output tables. To transform these variables into constant prices, we deflate them using the information on gross output prices (for gross output), price levels of intermediate inputs (for intermediate inputs) and price levels of gross value added (for the rest of the variables). Finally, WIOD also offers information on exchange rates for translating local currencies(millions) into dollars.

From the information contained in the input-output tables on intercountry trade flows, we can compute some of the parameters needed for our decomposition such as bilateral trade shares and regional trade surpluses, as in Caliendo et al. (2018). Additionally, we also obtain the shares of value-added and intermediate inputs in gross output by sector and country. These parameters are used to carry out our decomposition of measured TFP. Tables 1 and 2 show the sector and country aggregate measures[12] of the countries' share of their own intermediate goods ($\pi_{nn}^{j}$) and the share of value added in gross output ($\gamma_{n}^{j}$).

[Insert Table 1 here]

As can be seen in Table 1, $\pi_{nn}^{j}$ reflects the different trade dependencies of the countries considered in the analysis. Those that are smaller, more specialized and, therefore, more open to trade, are the ones with lower shares of their own intermediate goods. Examples of these are Ireland, Luxembourg, Hungary, Malta, Slovakia, Slovenia and Belgium, all with shares below 0.75. This is expected and in line with previous studies such as, for example, McQuinn and Varthalitis (2018) which explains how Ireland moved from a non-tradable economy prior to 2007 to a mostly export-driven country. Likewise, Guerrieri and Caffarelli (2012) analyses the level of openness of the European Union countries from 2000 to 2009 using different trade

[11] See Timmer et al. (2015) for a full description of the construction method.

[12] Since measured TFP is calculated based on gross output, we use gross output shares to aggregate these variables into country and sectoral measures.

measures. In contrast, larger and more diversified countries (depending less on other countries) such as the United States, China or Brazil have shares above 0.95. On average, we observe that European countries are more open in terms of intermediate inputs (for some, due to being members of the EU free trade agreement) while non-European countries tend to be larger with a high share of own intermediate inputs. Hence, European countries are more integrated into international supply chains but at the same time prove more vulnerable in terms of possible disruptions or shortages.

Table 1 also shows how European countries have a higher share of intermediate inputs in gross output as compared to the rest of the World countries. This is partly explained by the sectoral specialization of each country, this information being well complemented with the information contained in Table 2.

[Insert Table 2 here]

Table 2 shows the values of those same parameters but for sectors. It is clear to see that the share of own intermediate inputs is usually larger for service sectors (traditionally considered as non-tradable sectors (Jensen et al., 2005)). They are normally locally produced and, consequently, less reliant on foreign inputs. Manufacturing, and, in general, tradable sectors, have lower $\pi_{nn}^{j}$ but also, at the same time, these values are accompanied by larger standard deviations (more variability), especially for textiles, chemicals, metals, and electronics.

With regards to the value of $1-\gamma_{n}^{j}$, the share of intermediate inputs is related to the nature of the sector. Some of the sectors need more intermediate inputs for producing their goods or services than others. This is the case for manufacturing products in contrast with the lower value of this share for service sectors in general. In particular, this parameter is especially low for public administration, real estate, and wholesale and retail trade activities. In contrast, food products, textiles, metals, and transport equipment have a high share of intermediate inputs, meaning that they require more materials in their production.

## 5. Parameter estimates and trade elasticities

The parameter estimates of our production model together with the countries' own trade shares in equation (6) are shown in Table 3. All models are estimated using a set of country and sector-specific dummy variables to control for unobserved country and sector heterogeneity. Technical change (fundamental productivity) is modelled in a very simple fashion, i.e. using a time trend and its squared value. Similar results are obtained if we replace the time polynomial of degree two with a set of time dummies to capture better any common technological shocks that shift the technological production function over time. Notice also that the time polynomial function is common to all industries, an assumption that might be quite strong. The assumption of identical technical progress in all industries is lifted in Liu and Sickles (2021) by allowing for industry-specific time trends. For robustness analysis, we have re-estimated all the models allowing for sector-specific coefficients for both the time trend and its squared value. The performed F-tests are shown at the bottom of Table 3. They all indicate that we cannot reject the null hypothesis that the "fundamental" technical change is common to all industries. Finally, it is worth mentioning that very similar trade elasticities are also obtained if we use WIOD to compute the fundamental productivity level of each industry and replace $T_{nt}^{j}$ in equation (6) with its observed counterpart.[13] This suggests that our trade

[13] In this alternative specification of our model, $T_{nt}^{j}$ is computed using the value-added and the shares of labour and capital in value-added than can be obtained from WIOD as follows:

elasticities are robust to estimating simultaneously the parameters governing changes in fundamental productivity.

We have estimated all models by OLS for several reasons. One feature shared by OLS and the general equilibrium model introduced by Caliendo et al. (2018) is that they are static. As they do not indicate anything about the adjustment path from one equilibrium (year) to the next equilibrium (year), the comparative-static framework developed by Caliendo et al. (2018) tends to measure *final* or long-run effects[14] on measured productivity and our OLS estimator tends to yield medium-to-long run trade elasticities.[15] A possible objection to using OLS is that, although its predictions conform to Caliendo et al. (2018)'s theoretical framework, our empirical model might be underspecified due to both measured TFP and own trade shares depending on *own* sectors' fundamental productivity, and hence the (normalized) own trade share variable in equation (6) may be an endogenous variable. Notice, however, that Caliendo et al. (2018, p. 2052) assumed that sectors' fundamental productivity is deterministic. Our specification of fundamental productivity in equation (7) is also deterministic as it only depends on sector and country-specific fixed effects and a polynomial function of time. Moreover, if instead the unobserved but time-invariant sector and country-specific variables were random in nature and correlated with the own trade share variable, we would already be controlling for such correlation because we are using a fixed-type estimator. We recognize that addressing the endogeneity issue completely, where applicable, would require using a first-differences or within transformation of the variables to control for the correlation with time-invariant unobserved variables, as well as a set of instrumental variables to control for the correlation with time-varying unobserved sector and country-specific variables. This approach, however, would only allow us to estimate short-run trade elasticities and may hence underestimate the real long-run trade elasticities.[16] In this sense, Gallaway et al., (2003) points out "long-run estimates are more appropriate for most trade-policy analysis".[17]

[Insert Table 3 here]

While the first three models treat the trade elasticities as parameters that can be estimated, the last two models parameterize the trade elasticities as a function of a set of covariates. The simplest specification is provided by Model 1, where a common trade elasticity is estimated for all industries. Model 2 extends the previous one by allowing different trade elasticities for the tradable industries. As in Caliendo and Parro (2015), this specification imposes zero trade elasticities for the non-tradable sectors. Model 3 does not consider the construction sector and the whole set of service sectors as being *fully* non-tradable sectors, and

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$$T_{nt}^{j} = VA_{nt}^{j}/\left(K_{n}^{j}\right)^{\beta_{n}^{j}}\left(L_{n}^{j}\right)^{1-\beta_{n}^{j}}$$

[14] Since it includes, somehow, changes in prices through the cost of the input bundle. In contrast, economy wide models based solely on the traditional Input-Output demand relationships capture short-run effects due to the lack of substitution, crowding out or crowding in effects, and effects on prices (Chen et al, 2016).

[15] Baltagi and Griffin (1984) show that time series data tend to yield short run responses while cross sections tend to yield long run responses. As the OLS estimator uses both the cross-sectional and temporal information of the data, the estimated trade elasticities can be interpreted as falling in between short and long-run elasticities.

[16] To confirm this conjecture, we have also estimated equation (6) by GMM using, on the one hand, a first-differences transformation of our preferred specification (Model 4 in Table 3) and using, on the other hand, the fundamental productivity of other countries as well as its squared values and interactions as instruments. The computed GMM trade elasticities were highly correlated with the OLS elasticities (the coefficient of correlation was 98.5%). As expected, the average GMM trade elasticities (.59) are far smaller than the OLS elasticities (1.88). This seems to indicate that the long-run trade elasticity is about three times short-run trade elasticity.

[17] See also Boehm et al., (2022) for a discussion regarding the trade elasticity at various horizons and the different estimation methods.

hence it also estimates a trade elasticity for these industries. Obviously, we expect smaller elasticities for these industries than for the previous ones. Although the goodness-of-fit of these non-parametric models will be larger than their parametric counterparts, they might yield unsound (i.e. negative) trade elasticities. Model 4 parameterizes the trade elasticities using equation (11), i.e. as a function of the standard deviation of the own trade shares and the dummy variable indicating whether an industry is tradable or non-tradable. The last model in Table 3 again imposes zero trade elasticities for the non-tradable sectors, but now using a parametric specification for the trade elasticities.

We find large positive coefficients for the time trend in all estimated models, implying significant improvements in sectoral fundamental productivity. The small but negative coefficient found for the square value of the time trend indicates that the estimated rate of technical change decreases over time. Recall that, although the time polynomial function is common to all industries, the fundamental productivity term is scaled down by the share of value added in gross output in equation (6), and hence the final effect of technical change on measured TFP varies across industries and regions in our model.

Notice also that the coefficient of the country's share of its own intermediate goods is negative and statistically significant in Model 1. This result seems to corroborate the theoretical framework developed by Caliendo et al. (2018) that predicts a negative productivity effect associated with the degree of countries' embeddedness. We thus provide empirical evidence supporting the so-called *selection process* introduced by these authors to justify the propagation of local productivity shocks across sectors and regions.[18] We also find a negative and statistically significant coefficient for this variable in Model 4 that uses a parametric specification for the trade elasticities. As expected again, we do find a positive and statistically significant coefficient for the interaction of $SD^j$ and the (normalized) own trade elasticity ($ln\pi_{nn}^j$). This result also corroborates Caliendo et al. (2018)'s theoretical framework because their definition of $\pi_{nn}^j$ suggests the existence of larger trade elasticities $\theta^j$ (and hence smaller negative values for $\tau^j = -1/\theta^j$) when the variance of the own trade shares increases. Finally, it is worth noting that a positive and statistically significant coefficient is also found for the interaction of the tradable-sector dummy variable ($TR^j$), and the own trade elasticity ($ln\pi_{nn}^j$). This result confirms that the construction sector and the whole set of services sectors (i.e. the non-tradable sectors), do have significantly smaller trade elasticities than other more tradable sectors.

Moreover, the negative value of the coefficient for the degree of embeddedness also suggests that TFP is positively associated with openness. In this case, this measure of embeddedness can be also understood as (the inverse) of a relative openness indicator. The larger the value of embeddedness, the lower the engagement of the country/sector in trade activities (since they rely more on their own intermediate goods). This important result represents further confirmation that the framework proposed in this paper is in line with previous studies on this issue. Isaksson (2007) finds in his survey on TFP determinants that, in general, the macro-based literature shows a clear positive and significant effect of trade openness on productivity, as in our case. Even though we use a relatively new measure of

[18] Notice that, in our specification where $T_{nt}^j$ is replaced with its observed counterpart, we can subtract $lnT_{nt}^j$ from the normalized productivity measure if, following Caliendo et al. (2018)'s model, the effect of $lnT_{nt}^j$ on $lnA_{nt}^j/\gamma_n^j$ is equal to unity. Therefore, another empirical strategy to examine whether the data supports (some of) Caliendo et al. (2018)'s theoretical predictions is to estimate equation (6) using the computed value of $T_{nt}^j$ as another explanatory variable and test whether the estimated coefficient of this variable is equal to unity. As we were not able to reject this hypothesis using this specification of the model, we again provide empirical evidence supporting the theoretical framework developed by Caliendo et al. (2018).

openness, the estimated coefficient for trade has the expected sign. This is in line with Edwards (1998), who used many different definitions of openness and trade policies (revealing a robust relation between the two variables).

Table 4 shows the sector-specific trade elasticities that have been estimated (computed) using our non-parametric (parametric) specifications for the trade elasticities. The simplest model provides a common trade elasticity for all tradable and non-tradable industries equal to 3.16. Model 3 (Model 2) aims to examine whether the magnitude of the trade elasticity estimates varies considerably across (manufacturing) sectors. As in Caliendo and Parro (2015) and previous papers, we do find large heterogeneity in trade elasticities when they are treated as sector-specific parameters. Moreover, like these authors, some of our estimated trade elasticities have an incorrect sign when we allow for different coefficients using a non-parametric specification for the trade elasticities. For instance, we find negative values for $\theta^j$ not only in tradable sectors such as the manufacture of food products or the manufacture of chemicals and pharmaceutical products, but also in non-tradable sectors such as accommodation and food services, scientific and technical professional activities, or public services. It is also worth mentioning that noteworthy differences are often found in the estimated trade elasticities for the tradeable sectors when we restrict the model to estimate the trade elasticities of these sectors.

[Insert Table 4 here]

Despite these issues, the magnitudes of the sectoral trade elasticities found here are in the range of the trade elasticities estimated in the literature. For instance, Eaton and Kortum (2002)'s estimates ranged between 3.60 and 12.86, and their preferred estimate is 8.28. The average trade elasticity for our manufacturing sectors is 8.82. Using data on tradable sectors only, Caliendo and Parro (2015) obtain smaller elasticity estimates than Eaton and Kortum (2002), as they range from 3.29 to 4.55. Other studies obtain (slightly) larger trade elasticities in the manufacturing sector than in our paper,[19] a disparity caused not only by methodological differences (or by the nature of data used, e.g. bilateral vs own trade shares) but also because the estimated elasticities tend to increase with the goods disaggregation (see Broda and Weinstein, 2006; and Imbs and Méjean, 2017).

Models 4 and 5 estimate parametrically the sector-specific trade elasticities. As the parametric approach attenuates the sectoral heterogeneity in trade elasticities, the estimated elasticities are smaller on average than before. For instance, if we only estimate trade elasticities for the tradable sectors, the average trade elasticity is now 3.43, which is less than the elasticity found using a non-parametric approach, 8.82. In this sense, our parametric estimates can be interpreted as a lower bound of the underlying but unobserved trade elasticities. It should be highlighted that the negative trade elasticities found using a non-parametric approach vanish when we model them as a parametric function of a set of covariates. For this reason, the parametric models are our preferred ones.

Comparing our results with the Armington elasticities (Armington, 1969) traditionally used as trade elasticities in Computable General Equilibrium (CGE) models[20], the values are in line with the ones of the well-known Global Trade Analysis Project (GTAP) (Hertel, 1997), based on the previous estimations done for the SALTER model (Jomini et al., 1991). The

[19] See, for instance, the references cited in Caliendo and Parro (2015, footnote #44).

[20] In CGE models, it is necessary to distinguish between goods that are domestically produced and those that are imported, or between goods that are domestically consumed and those that are exported in order to avoid cross-hauling problems (two-way trade). The smaller the elasticity of substitution (inelastic), the higher the difference is between these goods. This assumption about imperfect substitution between imports and domestic goods is called Armington's assumption (Armington, 1969).

country level results obtained by GTAP present trade elasticities characterized by a larger value for the sectors of manufacturing of motor vehicles and other transport equipment (5.20 in the GTAP estimations), manufacturing of textiles, furs and leather (3.29), and manufacturing of machinery and other equipment (2.99). On average, manufacturing sectors have trade elasticities around the value of 2.80 (very similar to our 2.87 average result in model 4). Another issue that is worth discussing is whether we should consider the construction sector and the whole set of service sectors as *fully* non-tradable sectors, as in Caliendo and Parro (2015) and Caliendo et al. (2018). They are highly non-tradable but not totally non-tradable for two reasons. First, we find significant $\tau^j$ coefficients for these sectors when the trade elasticities are estimated non-parametrically. Second, as we are using a two-digit level of goods disaggregation, countries' share of their own intermediate goods in these sectors is often far from unity, indicating that some of the goods produced in these sectors, in fact, have been the subject of international trade and hence can be considered as tradable goods.

In summary, for the aforementioned reasons, the parametric model that treats, to some extent, all sectors as tradable sectors (i.e. Model 4) is the model we use to compute the trade elasticities that feed the simulation analyses of Section 6.

## 6. Applications

The proposed model provides an analytical framework for examining several issues empirically. We first examine whether changes in sectoral fundamental productivity and changes in the benefits of international trade have contributed to improving (or worsening) sectoral productivity. We next study the determinants of regional embeddedness, understood as the share of intermediate economic activity taking place within a specific country or region. We finally insert our decomposition of countries' embeddedness into the theoretical framework introduced by Caliendo et al (2018) to simulate the compound economic effects of the Covid-19 pandemic outbreak. We use the World Input-Output Database (WIOD) for the period 2000-2014 to compute most of the relevant variables employed in these applications.

### *6.1. The importance of fundamental productivity and trade changes in TFP growth*

Extensive literature exists aimed at decomposing TFP growth into its key drivers using either parametric and non-parametric techniques (see e.g. Sickles and Zelenyuk, 2019). Much of this work focuses on technical change, catching-up effects (efficiency change) and other sources such as misallocation of resources, knowledge spillovers, etc. We will pay special attention to the effect of international trade on productivity because this driver has rarely been examined in the literature. In order to control for other productivity sources, we also examine the effect of changes in fundamental productivity, which can be viewed as a value-added measure of technical change. It is worth mentioning here that that there is also a vast and established discussion regarding how to measure technical change, i.e. in terms of value added or gross output (see Schreyer and Pilat, 2001 for a review of this literature). We cannot contribute to this interesting debate because our empirical model relies on Caliendo et al. (2018)'s fundamental productivity concept, and they state that, if $T_n^j$ instead affected gross output, a sector that just processed materials, without adding any value by way of labour or capital, would see an increase in output at no cost, a result that is not economically sound.[21]

[21] Schreyer and Pilat (2001) concludes that, although both types of measures are valuable complements, value added is also a better measure of technical change when technical progress affects all factors of production proportionally.

Equation (6) provides a theoretical decomposition of measured TFP into a trade-related productivity effect and the effect of changes in fundamental productivity. In this subsection, we first examine whether changes in both fundamental productivity and countries' embeddedness have contributed to improving (or worsening) sectoral productivity. We next study to what extent each of these forces has contributed to within-country changes in sectoral productivity (i.e., across the different sectors of the economy) and/or to between-country changes in productivity for each specific sector.

Using the estimated trade elasticities, as well as the observed own trade shares, and taking first differences in (6), we can express the rate of change of measured TFP in region $n$ and sector $j$ as:

$$\dot{TFP}_n^j = \underbrace{\gamma_n^j \dot{T}_n^j}_{\substack{Fundamental \\ TFP}} \underbrace{- \frac{1}{\theta^j} \dot{\pi}_{nn}^j}_{Trade} + Residual \tag{13}$$

where a dot over a variable indicates a rate of growth. While the first two terms in equation (13) represent respectively the (attenuated) effect of changes in sectoral fundamental productivity and an effect related to changes in the benefits of international trade, the so-called Residual term captures changes in other factors not controlled in our model. Table 5 summarizes the descriptive statistics of the computed TFP rates of growth and their components. For further analyses, Tables 6 and 7 provide the computed TFP rates of growth and their components by country and sector.

[Insert Table 5 here]

[Insert Table 6 here]

[Insert Table 7 here]

Table 5 shows that measured TFP has increased 2.65% annually on average from 2000 to 2014. The country and sector-specific decompositions provided in Tables 6 and 7 show that the average productivity improvement in Europe (2.08%) is smaller than that computed for our set of non-European countries (2.96%). As expected, we find that the improvement in fundamental productivity is the most important TFP driver for the set of countries examined in this paper (2.51%). We also find that the trade-related effect is, on average, much smaller (0.14%). This is an expected result because the trade shares are fairly constant over time, and while many countries exhibit a smaller degree of embeddedness, other countries tend to be more isolated from the world economy. Notice finally that, despite the trade effect being relatively small on average, its volatility (measured by its standard deviation) is as large as the volatility of fundamental productivity changes. This seems to suggest that the trade-related productivity term explains a significant proportion of the variations in measured TFP.

We examine this issue by mimicking the sensitivity analysis carried out by Caliendo et al. (2018). Our sensitivity analysis aims at determining how much of the variability in measured TFP growth is dependent upon each of its components. In general, sensitivity analysis assesses how the input variables of a complex model affect the output. This is the case of the general equilibrium model with trade in intermediate goods, sectoral heterogeneity, and input-output linkages introduced by Caliendo et al. (2018). The information achieved by sensitivity analysis might help to guide the collection of data and/or make more effective research decisions regarding the design of the whole model. Notice that a sensitivity analysis is closely related to a regression model where its coefficients have been estimated by maximizing the goodness-of-fit of the model, that is, by maximizing the variation of a dependent variable that can be explained by the independent variable(s). Kermanshachi and Rouhanizadeh (2019) also point out that sensitivity analysis could be considered as the inverse of uncertainty analysis. While uncertainty analysis is the measurement of uncertainties in the inputs of a model, sensitivity analysis involves identifying the influence that input factors of a model have on variations in the outputs of the model.

As equation (6) decomposes measured TFP into the effect of changes in fundamental productivity and the degree of country's embeddedness, we will focus our sensitivity analysis on these two productivity components. To achieve this objective, we carry out several linear regressions by OLS using the sum of the two productivity components as the dependent variable and the two productivity components as explanatory variables. The estimated coefficients are restricted to sum unity in order to interpret them as the proportion of the variations in measured TFP growth explained by each productivity source.[22]

While Table 8 shows the relative importance of fundamental TFP and trade in (measured) TFP growth differences across countries for each specific sector, Table 9 provides the same information but across the different sectors of each country. As expected, we find that fundamental TFP account for 62% of the variation in measured TFP on average. This percentage is smaller (58%) for European countries than for our set of non-European countries (78%). We find, however, that the trade-related effect is quite large in some European countries (especially in Ireland, Luxembourg, Netherlands, and Belgium) that are highly open to trade as they depend a lot on the importation of intermediated goods from other countries. In contrast, the trade-related effect is almost negligible in the biggest economies, viz-a-viz, in the United States, Russia, China, and Brazil.

[Insert Table 8 here]

[Insert Table 9 here]

If we examine the within-sector variability in measured TFP across countries, we find again that the trade component accounts for 38% of the changes in measured TFP, while the fundamental TFP component accounts for 62% of the variation. As expected, the relative importance of the trade productivity effect is larger for the tradable sectors as this component accounts for 47% of the changes in measured TFP, whereas it only accounts for 32% of the variation in measured TFP for the non-tradable sectors. The trade effect is particularly large in the manufacture of food products, beverages & tobacco products, accommodation & food service activities, and primary sectors. In contrast, the trade effect is relatively small in construction and other service sectors, such as wholesale & retail trade & repair of motor vehicles & motorcycles, IT services, financial service activities, insurance & pension funding, and real estate activities.

As explained already, the fundamental TFP is the most important factor explaining changes in productivity. However, the analysis performed in this sub-section has also shown how heterogeneous this result is by countries. In particular, small and not-so-diversified economies have relied on the improvements coming from the trade benefits to grow, i.e. openness. Examples of this are Malta and, even more clearly, Ireland (see McQuinn and Varthalitis, 2018 for an analysis of the benefits obtained by the Irish economy after adopting an export-led and openness strategy). In this period both countries have experienced greater increases in their productivities due to the trade benefits associated with a lower degree of embeddedness. Eastern European countries have also shown an above average increase in productivity due to the benefits from trade. To the contrary, during this period larger countries have based their growth on their own fundamental productivities. This has clear policy implications. An analysis of this period would appear to indicate the existence of different

[22] Caliendo et al. (2018) used the Sobol's method to decompose measured TFP into a regional, a sectoral, and a regional-sectoral component. We do not use this method due to our decomposition lacking interaction terms. Moreover, this method would prove highly demanding from a computational point of view.

possible strategies for increasing the productivity of a country, depending on the level of development and/or economic size of the country, with one-size-fits-all policies unlikely to prove successful.

*6.2. Changes in the degree of country's embeddedness*

We can define the degree of a country's embeddedness as the share of activities that are linked to one another by buyer–supplier relationships with other activities within the same country (Kitsos et al., 2022). Following the related literature, the degree of embeddedness is essential to understanding the way different shocks propagate along the economy (Diodato and Weterings, 2015), but its effect on the resilience of a country/region is still inconclusive, deriving into what is known as the 'paradox of embeddedness' (see Uzzi, 1997).

Embedded local industrial structures may generate positive externalities that assist a country/region facing a negative shock. When firms have their suppliers and buyers nearby, they benefit from agglomeration effects, local formal and informal knowledge flows (or local knowledge spillovers), and the decrease of transaction costs (Isaksson et al., 2016; Behrens et al., 2020; Delgado and Porter, 2021). Additionally, countries with a more diversified sectoral structure are less sensitive to negative economic shocks since the probability of suffering a shock is spread among the different sectors (Frenken et al., 2007). Additionally, strong ties between sectors in the same area mean extensive propagation channels that can transmit and reinforce downturns across sectors within the country (Jovanovic, 1987; Acemoglu et al., 2012; and McCann and Ortega-Argiles, 2015). In other words, based on this, countries with a more diversified sectoral composition are not necessary less vulnerable if their sectors are locally embedded through supply relationships within the same country (Diodato and Weterings, 2015). Additionally, if you are "too" embedded, you may suffer from negative lock-in effects (limited interaction to outside competition and/or cooperation) such as not being able to benefit from trade (or obtaining the gains from increases in foreign fundamental productivities), seeing your knowledge flows reduced, or even the adaptive capacity of regions in the face of adversity (Boschma and Iammarino, 2009). The proposed model is used here to shed light not only on this debate but also on understanding the nature of the level of embeddedness of each country by decomposing it into the part determined by own fundamental productivity and the part determined by foreign fundamental productivity.

Caliendo et al (2018) show, using the properties of the Fréchet distribution, that country $n$'s degree of embeddedness (i.e., the share of country $n$'s total expenditures on sector $j$'s goods produced by its own firms) is a function of its own fundamental productivity, the fundamental productivity of this sector in other countries, as well as the trade costs or the barriers to import goods from other regions. Taking first differences in equation (2), we can decompose the sectoral own trade share changes ($\dot{\pi}_{nn}^{j}$) as:

$$\dot{\pi}_{nn}^{j} = \underbrace{\theta^{j}\gamma_{n}^{j}\left(1-\pi_{nn}^{j}\right)\dot{T}_{n}^{j}}_{\substack{\text{Own Fundamental}\\ \text{TFP}}} \underbrace{-\theta^{j}\gamma_{-n}^{j}\left(1-\pi_{nn}^{j}\right)\dot{T}_{-n}^{j}}_{\substack{\text{Foreign Fundamental}\\ \text{TFP}}} + Residual \quad (14)$$

where the residual term in this case is equal to

$$Residual = \theta^{j}\left(1-\pi_{nn}^{j}\right)\left[\dot{x}_{n}^{j}-\dot{x}_{-n}^{j}\right] + \theta^{j}\left(1-\pi_{nn}^{j}\right)\dot{\kappa}_{-n}^{j} + other\ factors \quad (15)$$

and $\gamma_{-n}^{j}$ is a weighted average of other regions' sector $j$ value added shares, $\dot{T}_{-n}^{j}$ and $\dot{x}_{-n}^{j}$ are respectively weighted averages of changes in other regions' sector $j$ fundamental productivity and intermediate input costs, and $\dot{\kappa}_{-n}^{j}$ is a weighted average of changes in the cost of delivering a unit from country $i$ to country $n$.[23] The first two terms in equation (14) simply indicate that while the own trade share in country $n$ and sector $j$ increases when this country-sector experiences an increase in its own fundamental productivity, it decreases when the fundamental productivity of this sector in other countries increases. As $\gamma_n^j$ is similar in practice to the average share in other countries, these two terms simply capture the effect on country $n$'s degree of embeddedness of the relative improvements of country $n$'s fundamental productivity with respect to the productivity improvements in other countries. Finally, the residual term (15) in this case captures relative changes in intermediate input costs, larger (smaller) trade costs or geographic barriers, as well as other factors that we do not observe.

Table 10 summarizes the descriptive statistics of changes in countries' own trade share and their own and foreign fundamental TFP components. For further analyses, Tables 11 and 12 provide the computed changes in countries' own trade share and their components by country and sector.

[Insert Table 10 here]

[Insert Table 11 here]

[Insert Table 12 here]

Table 10 shows that the own trade share has dropped -0.26% annually on average from the period 2000 to 2014. As own fundamental TFP affects the degree of embeddedness positively but foreign fundamental TFP affects it negatively, this also means that foreign fundamental TFP has changed more on average during the period (-0.48% versus 0.40%). Therefore, during this period, countries have in general become more open (less embedded). By countries, Table 11 shows how European countries have experienced a larger change in their own trade shares, mainly due to the substitution of the origin of intermediate inputs from domestic to foreign countries, as can be understood by the resulting changes in foreign fundamental TFP (-0.56%). Specially interesting is the large change observed in the eastern European countries such as Estonia (-2.35%), Hungary (2.84%), Malta (-1.84%) or Czech Republic (-1.64%), among others. And this despite the fact that they are also the countries with higher positive changes in their own fundamental TFP. In this respect, it is also important to highlight that in general the change in own fundamental TFP is larger for non-European countries (6.63%) than for European ones (3.70%), with China being the country that increased its fundamental TFP most with a change of 15.29%.

By sectors, again their nature plays a very important role in explaining the differences observed in Table 12. Tradable sectors are obviously more influenced by changes in own and foreign fundamental TFP than non-tradable ones (-0.56% versus -0.09%). In particular, manufacturing of textiles (-1.62%) and manufacturing of computers and electronics (-1.17%) experienced larger changes in their own trade shares. Interestingly, the latter has seen the biggest increases in fundamental TFP, own and foreign, meaning that the sector has undergone a very intensive period of innovations worldwide. Instead, changes in the own trade share of the non-tradable sectors are, as expected, substantially lower given that their production technologies do not incorporate them as much as would be the case in manufacturing sectors. However, it is important to mention that the only sectors where foreign TFP growth is higher than own TFP growth are the wholesale and retail trade, accommodation and food services, professional and technical activities, other services, and IT services (which has also

[23] Each foreign country $i$ is weighted here using the normalized shares of country $n$'s total expenditures on sector $j$'s goods purchased from country $i$, that is, $\pi_{ni}^j / \sum_{i \neq n}^N \pi_{ni}^j$.

experienced an important growth in both own and foreign TFP, 7.12% and 8.75%, respectively).

However, even though foreign fundamental TFP had a greater importance in the evolution of the change in the degree of embeddedness, the standard deviation is larger (almost double) for own fundamental TFP. This suggests that the own fundamental TFP factor explains a higher proportion of the variations in the own trade share. In line with section 6.1, we analyse this issue by country and sector in Tables 13 and 14. In this case, we aim to determine how much of the variability in own trade shares depends on each factor. Few significant differences exist by sector with own fundamental TFP representing more than two thirds of the relative importance in explaining this variation in the degree of embeddedness for almost all the sectors. Nevertheless, by countries, remarkable differences appear. The relative importance of own country TFP is much higher for the more open countries such as Cyprus (88.36%), Greece (80.90%) and Malta (85.60%), and in general more important for European countries (68.15%) in comparison with the other countries (60.35%).

[Insert Table 13 here]

[Insert Table 14 here]

So far, we have examined whether own (foreign) fundamental TFP stimulates (attenuates) countries' embeddedness due to a larger comparative (dis)advantage with respect to other countries. We next try to shed light on the debate as to whether too much or too little embeddedness might exert positive or negative externalities on local industries. If the embeddedness of industrial structures generates positive externalities for local firms, the increases in countries' own trade share (or in their degree of embeddedness) should stimulate countries' own fundamental TFP. If negative externalities arise when the share of intermediate economic activity taking place within our country is greater, we should expect the opposite relationship. Notice that examining this issue implies 'reversing' the previous analysis. As we do not know a priori which approach is more appropriate for examining this issue, when considering our analytical framework, we adopt a holistic approach and propose estimating (several versions of) the following simple auxiliary regression:[24]

$$dlnT_{nt}^{j} = \alpha_0 + \alpha_1 t + \alpha_2 dln\pi_{nnt}^{j} + \varepsilon_{nt}^{j} \tag{16}$$

The target coefficient is $\alpha_2$, i.e. the elasticity of own fundamental productivity with respect to changes in countries' own trade share. We obtain empirical evidence supporting the existence of positive (negative) externalities when this coefficient takes positive (negative) values and it is statistically significant. The parameter estimates are shown in the Appendix. It is only germane to mention here that in our preferred specification we use an adjusted measure of $dln\pi_{nnt}^{j}$ in order to control for the potential endogeneity of this variable,[25] and we allow for sector-specific values for our target coefficient. Table 15 provides the set of estimated embeddedness elasticities ($\alpha_2^j$) for all $j = 1, \ldots, J$ sectors.

[Insert Table 15 here]

In this sub-section we have seen the great heterogeneity present among those factors which explain the degree of embeddedness in both sectoral and country dimensions. The analysis of the complex relationship between fundamental productivities and own trade shares

[24] As we are using a differentiated specification, there is no need to include sector and country-specific dummy variables in (12).

[25] We have used the first term in equation (14) to remove the effect of changes in own fundamental productivity on the observed changes in each country's own trade share.

indicates that, in general, positive agglomeration and proximity effects offset the negative lock-in effects, during the period considered. As summarized by Kitsos et al. (2022), this positive relationship is in line with the findings of Lengnick-Hall and Beck (2005) at the firm level (related to social capital and access to resource networks as a way of building business resilience), but also with the literature highlighting the benefits of industrial cluster policies for the dynamism of local economies, as in Delgado, Porter, and Stern (2010) and Glaeser and Kerr (2009), among others. Finally, at the regional level, Parr et al. (2002) show how the proximity of 'activity-complex economies' (a concept very close to the embeddedness term used in this paper) causes reduced transport, coordination and communication costs, efficiency gains on input utilisation, reductions in the need for inventories, and improvements in knowledge flows (see also McCann, 1995). Our results suggest that on average, countries would benefit from increasing their level of embeddedness, thereby contributing towards an improvement in those aspects that ultimately affect TFP, as demonstrated along the paper.

*6.3. Covid-19 effects*

In this subsection, we simulate the compound economic effects of the Covid-19 pandemic outbreak for our set of European and non-European countries, based on the theoretical framework introduced by Caliendo et al. (2018), and our decomposition of countries' embeddedness.

In their review of the incipient literature on the economics of Covid-19, Brodeur et al. (2021) state that "to understand the potential negative economic impact of Covid-19, it is important to understand the economic transmission channels through which the shocks will adversely affect the economy." As current economies are complex networks of interconnected parties, the Covid-19 pandemic outbreak is producing a cascading effect in most countries. As our model takes into account the high degrees of inter-connectiveness and specialization of productive activities in modern economies, it helps to simulate the expected cascading effect caused by a breakdown in supply chains.

Previous papers (see, e.g., Liu and Sickles, 2021; and Liu and Cheng, 2021) have examined the economic effect of the Covid-19 pandemic on countries' gross output through three channels: the shortage of intermediate inputs, reductions in labour supply, and reduced technology spillovers. We show using Caliendo et al. (2018)'s framework that the Covid-19 pandemic might also impact sectoral and country production by reducing the benefits of international trade, an effect that has been ignored in previous papers.

Following Liu and Sickles (2021) and Liu and Cheng (2021), we will focus our analysis on changes in countries' gross output. From the definition of measured TFP in equation (3), we can express the logarithm of gross output as:

$$lnY_n^j = (1-\beta_n^j)\gamma_n^j lnL_n^j + \beta_n^j\gamma_n^j lnK_n^j + (1-\gamma_n^j)lnM_n^j + \gamma_n^j lnT_n^j - \frac{1}{\theta^j} ln\pi_{nn}^j \quad (16)$$

where $\gamma_n^j = 1 - \sum_{k=1}^{J}\gamma_n^{jk}$ and $lnM_n^j$ is a weighted average of all material inputs (in logs) used by the firms in sector $j$ from all sectors, where the weights are the respective normalized share of sector $j$ goods spent on materials from each sector $k = 1,,.,J$.[26] Notice that, in this case, it is not important to take into account whether these material inputs have been supplied by firms located in one's own country or whether they have been imported from other countries. This feature of intermediate goods is what we examined in our previous application when aiming to explain the degree of country's embeddedness.

[26] That is, $lnM_n^j = \sum_{k=1}^{J}(\gamma_n^{jk} / \sum_{k=1}^{J}\gamma_n^{jk})lnM_n^{jk}$.

Following Liu and Sickles (2021), and assuming that the relative output shares of input factors are fixed, the change in gross output (roughly after the shock of the Covid-19 pandemic) can then be expressed as:

$$\dot{Y}_n^j = \underbrace{\left(1-\beta_n^j\right)\gamma_n^j \dot{L}_n^j}_{LE} + \beta_n^j \gamma_n^j \dot{K}_n^j + \underbrace{\left(1-\gamma_n^j\right)\dot{M}_n^j}_{ME} + \gamma_n^j \dot{T}_n^j \underbrace{- \frac{1}{\theta^j}\dot{\pi}_{nn}^j}_{RE} \tag{17}$$

The first two terms in equation (17) represent respectively the effect of reductions of labour and capital supply on gross output. While the third term represents the effect due to a shortage of intermediate inputs, the fourth term represents the direct effect of changes in fundamental productivity on gross output. The last term measures the effect of changes in the proportion of domestic intermediate goods.

We next follow Liu and Sickles (2021) and assume in our simulations that the economy is first affected by a reduction in the labour supply. We hereafter label this effect on gross output as the *Labour Effect* (LE). We do not take into account reductions in capital because Brodeur et al (2021) point out that, in the short-run, labour is much more affected than capital through reduced working hours, layoffs and government-mandated closure of non-essential businesses, forcing many workers to stay at home.[27] Although aggregate effects are generally dominated by supply-side shocks such as reduced working hours or layoffs, industries such as (air) transportation, tourism, and restaurants have experienced demand-side reductions, due to peoples' response to the pandemic, that is much larger than their corresponding supply-side shocks. As the consumption reduction in these industries has led to additional reductions in the usage of the factors of production, del Rio-Chanona et al (2020) suggest combining both supply and demand-side shocks to obtain a global picture of the immediate shocks attributable to the Covid-19 pandemic. Following these authors, we compute the labour shocks using the worse of the two supply and demand shocks (see Appendix) elaborated by these authors at industry level for the US economy.[28]

We next assume that gross output is affected by shortages in intermediate inputs along the lines of Liu and Sickles (2021). The fall of international intermediate input supply is assumed to be in the same percentage as the fall of trade flows due to most goods traded being intermediate goods (Caliendo and Parro, 2015, p. 6). While Liu and Sickles (2021) use the economy-wide falls of trade flows forecasted by the World Trade Organization (WTO), we simulate the shortages of intermediate inputs using the Hale et al. (2020)'s lockdown stringency index and the results found by Cerdeiro et al. (2020) in order to obtain the sector-specific shortages of intermediate inputs. Using a novel dataset of daily bilateral seaborne trade and the lockdown stringency indices of each country, these authors find a decrease of 22.6 percentage points in imports if *all* partners go from no lockdown to a *full* lockdown. Most countries did not implement all control coronavirus measures but did achieve the so-called full lockdown. To graduate this effect, we construct a weighted measure for each sector and country using taking into account the different degrees of other countries' stringency indices.[29] We hereafter label the effect of shortages in intermediate inputs on gross output as the *Materials Effect* (ME).

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[27] That is, we assume that $\dot{K}_n^j = 0$ in our simulations. Maliszewska et al (2020) point out, however, that lower labour also means lower demand for capital, as firms need a combination of labour and capital to produce goods and services.

[28] Liu and Cheng (2020) also calculated the output changes in three industries (i.e., accommodation and food services, education, and arts and entertainment) based on the worse value between the output after the shock from the supply-side and the output after the shock from the demand-side.

[29] That is, the shortage of intermediate inputs ($\dot{M}_n^j$) is measured as $-0.226\sum_{i\neq n}^{N}(\pi_{ni}^j/\sum_{i\neq n}^{N}\pi_{ni}^j)l_i$, where $l_i$ is country $i$'s lockdown stringency index (for all $i \neq n$).

Liu and Cheng (2021) and Liu and Sickles (2021) assume that the Covid-19 pandemic has also impacted the economies because of the disruption of technology spillovers through input-output linkages. It is possible to accommodate this effect in our model if we assume in equation (7) that the fundamental productivity in industry $j$ in region $n$ is also influenced by other sectors' fundamental productivity. Leaving for future research the analysis of those Covid-19 effects related with knowledge spillovers, we do not consider reductions in fundamental productivity caused by the Covid-19 pandemic in our simulation. That is, we assume that $\dot{T}_n^j = 0$ in our simulations. Obviously, if we incorporate the blockage of technology diffusion, we will obtain larger effects than those outlined below. In this sense, we are using a *conservative* approach to computing the total impacts of the Covid-19 pandemic on countries' production and our estimated effects can be interpreted as a lower bound of the real impact of the pandemic on the total output of each country.[30]

The last term in equation (17) is a Ricardian or a trade-related spillover effect that has to do with larger (smaller) prices of both intermediate and final goods if trade barriers and transport costs increase (decrease) over time. It is worth mentioning in this sense that many countries chose to lockdown the ports of entry, suspend flights or shipments, and restrict the volumes of import and export trade to combat the global spread of Covid-19. As these control policies are equivalent to raising trade barriers and transport costs, we expect a deterioration of the benefits of international trade of intermediate goods during the Covid-19 pandemic. Notice that the larger trade barriers and transport costs are captured by $\dot{\kappa}_{-n}^j$ in equation (15). Once we plug equation (15) into (14) we can measure the effect of larger transport costs on the proportion of domestic intermediate goods. If we plug the resulting equation into equation (17) we can simulate the effect on gross output of the larger trade barriers and transport costs caused by the Covid -19 pandemic as follows:

$$RE_n^j = -\left(1 - \pi_{nn}^j\right)\dot{\kappa}_{-n}^j \tag{18}$$

We finally assume that the increase in trade barriers and transport costs is of the same magnitude as the fall in trade flows for the purpose of computing the *Ricardian Effect* using equation (18). That is, we assume that $\dot{\kappa}_{-n}^j = -\dot{M}_n^j$. Based on the growth model in equation (17) and the simulated Covid-19 shocks, we estimate the impact of the pandemic on countries' production and decompose the total impact into three components: labour supply reduction (LE), shortage of intermediate inputs (ME) and the reduced benefits of international trade (RE).

The estimated impacts of the pandemic on the total output of each country are shown in Table 16.

[Insert Table 16 here]

We find that the Covid-19 pandemic has reduced countries' gross output by 14.42% on average. Most of this effect can be attributed to shortages in intermediate inputs through the global value chains (6.57%) and demand and supply-side reductions in labour supply (6.51%). Liu and Cheng (2021) also find that, under their optimistic scenario, the intermediate shortage is the most important factor in causing output losses because this channel accounts for 56% of the average output change, whereas labour supply reductions only represent 17% of output losses.[31] In general, we find larger labour effects for those countries that use a large proportion

[30] In this sense, it is worth mentioning that Liu and Cheng (2020) find that the blockage of technology diffusion induced by the Covid-19 contributed 27% of the output losses. Therefore, the total impact estimated in our paper might represent about 73% of the total effect.

[31] It is worth mentioning that output is particularly sensitive to shortages in intermediate inputs in Liu and Cheng (2021) simulations with the estimated output elasticity of the intermediate input proving six times greater than

of labour in the production of goods as the so-called *Labour Effect* (LE) in equation (17) negatively depends on the share of capital in value added. Similar comments can be made regarding the effect of the shortage of intermediate inputs on countries' production with respect to the proportion of materials in the production of goods because the so-called *Materials Effect* (ME) in equation (17) negatively depends on the share of value added in gross output. Table 16 shows how accounting for deteriorations in the benefits of international trade amplifies the Covid-19 effects as they reduce aggregate gross output by 1.34%. In other words, whereas the shortages in intermediate inputs and labour supply reductions each represent 45% of output losses, the larger trade barriers and transport costs caused by the Covid-19 pandemic account for 10% of the average output change, a small but non-negligible percentage.

Abstracting for other transmission channels through which the Covid-19 pandemic might impact countries' economies,[32] we find a larger effect for the EU countries (15.44%) than for non-European countries (13.77%) due to their larger reductions in labour supply and their greater dependency on the purchase of (cheap) intermediate inputs by foreign countries. Indeed, while the deterioration (in the benefits) of international trade only reduced non-European countries' gross output by 0.88% on average, the larger trade barriers and higher transport costs reduced European countries' production by 2.09% on average.

The countries that experienced severely negative effects are Luxembourg, Ireland, Belgium, Slovenia, United Kingdom, Hungary, and Germany with an output decline larger than 16%. The reductions in gross output for Luxembourg and Ireland are especially large. The so-called Material and Ricardian effects in these two countries are much larger than the average effects of these two channels due to their high degree of dependence on foreign intermediate products. The larger trade barriers and transport costs caused by the Covid-19 pandemic reduced Luxembourg and Ireland's production by an overwhelming 6.17% and 4.71%, respectively. In contrast, the estimated output reduction for Mexico, Bulgaria, Brazil, Estonia, and Turkey proves far smaller when compared to average global output losses, with an output decline of less than 13%.

Using equations (17) and (18), we next focus our analysis on the reduction in average output experienced by industrial sectors as a result of the Covid-19 pandemic. The results for both tradable and non-tradable sector groups and individual sectors are shown in Table 17.

[Insert Table 17 here]

We have already mentioned that the Covid-19 pandemic reduced gross output by 14.42% on average. We find a larger average effect on tradable sectors (16.58%) as compared to non-tradable sectors (13.15%). The impact of the pandemic on sectors' production differs notably sector by sector. Indeed, while our simulation suggests that the output losses in manufacturing industries range from 10.47% to 22.92%, the production decline in the construction sector and the set of services sectors ranges from 4.84% to 33.18%. Interestingly, we find a larger average effect on tradable sectors despite the effect attributable to reductions in labour supply being much larger in the non-tradable sectors group (7.28%) than in the tradable sectors group (5.26%). The accommodation and food services (18.63%), transport and postal services (26.20%), and other service activities (15.46%) such as arts and entertainment

that for labour, a proportion that seems to be too ample given the observed shares of intermediate and labour inputs in gross output.

[32] For instance, Liu and Cheng (2020) find that the countries that are the most important regional hubs in global value chain networks (e.g., United States, China, and Germany), were highly affected by the blockage of technological spillovers caused by Covid-19 pandemic.

industries experience an incredibly large decline in output caused by strong demand-side reductions in labour supply.

As expected we find larger reductions in sectors' production caused by both shortages in intermediate inputs and larger trade barriers and higher transport costs for tradable sectors, as compared to non-tradable sectors due to their greater dependency on the purchase of (cheap) intermediate inputs by foreign countries. Indeed, while the average Material and Ricardian effects for tradable sectors are estimated at 8.59% and 2.73% respectively, for non-tradable sectors these output losses are estimated at 5.36% and 0.52% respectively. It is germane to mention here that the estimated effect of shortages in intermediate inputs for the construction sector is also quite large (7.84%) due to the latter being closely linked to those upstream and downstream industries that supply raw materials, mechanical equipment, and logistics services from other industries (Liu and Cheng, 2021).

We also find noteworthy impacts of the Covid-19 pandemic in the case of some manufacturing industries, where losses exceed 22% of gross production. The production losses in the manufacture of textiles, wearing apparel and leather products are mainly explained by labour supply reductions (10.30%) and shortages in intermediate inputs (9.82%). The deteriorations in the benefits of international trade amplify the Covid-19 effects in this sector by 2.79 percentage points. Similar comments can be made for the manufacture of basic metals and metal products where the above-mentioned channels through which the Covid-19 pandemic might impact the sector's production are estimated at 10.36%, 9.47% and 2.49%, respectively.

The figures for the manufacture of machinery and equipment, vehicles and transport equipment are similar, but the production losses in the sector's gross output caused by larger trade barriers and transport costs, are noteworthy. The deteriorations in the benefits of international trade obtained for this sector (4.04%) amplify markedly the effects caused by labour supply reductions (9.40%) and shortages in intermediate inputs (9.18%). Liu and Cheng (2021) also find substantial drops in output in the motor vehicles, trailers, and semi-trailers industry due to the automobile industry being characterized by long supply chains with a high proportion of intermediates from worldwide upstream industries. The estimated Ricardian effect for the manufacture of vehicles and transport equipment seems to indicate that the international spread of the pandemic not only disrupted the supply chain, but also significantly increased the price of many components used in numerous automobile production lines.

It is worth mentioning that similar price effects have also been revealed for the manufacture of computer, electronic and electrical equipment because the effect of deteriorations in the benefits of international trade is larger than 4% in this sector. Nevertheless, the total impact of the Covid-19 pandemic is relatively small (19.96%) as a result of the effect attributable to reductions in labour supply being three or four percentage points less than in the two aforementioned manufacturing industries.

Finally, it is worth noting the tiny, even null, effect of reductions in labour supply in the manufacture of both food and pharmaceutical products, and educational and health services. The positive demand-side shocks (e.g., food, groceries, and healthcare e-commerce offering increased demand opportunities for serving consumers at home) have attenuated the negative supply-side shocks in these industries.

Many different sources fuelled the effects of Covid-19 on the economy, causing a propagation of the negative impacts not only within countries but also from country to country. The total reduction in terms of gross output came not only from the restrictions imposed by each country in their attempts to avoid the transmission of the virus, but also from the restrictions imposed by trading partners. In an interconnected world trying to be well prepared for something like this or to reduce the economic exposure is to say the least, complex. And again, the possible recommendations cannot be one-size-fits-all type of policies. Depending on the sectoral specialization of each country, restrictions will affect production to a lesser or greater extent. Spain, as an example, depending heavily on the accommodation and food services (a tourism characteristic activity), was expected to suffer more from the Labour Effect, as shown in the results. This country and those in a similar situation would benefit from a more diversified economy with a lesser reliance on activities traditionally operated through personal contact or the need for displacements. Secondly, countries that are an important part of international global value chains, such as China and India, are the ones that are more exposed to drops in intermediate inputs imports (Materials Effect) and the negative effect the latter have on own production. The greater the level of manufacturing activity and the more open the economy, the larger the dependence on intermediate inputs, therefore implying a bigger exposure to this second impact. Finally, the Ricardian Effect exerts a greater effect on those country with more dependence on foreign economies. For these economies, increasing their degree of embeddedness would, in principle, reduce the negative effect of the Covid-19 via the benefits of trade.

## 7. Conclusions and future research

This paper provides novel evidence on three issues that traditionally or recently have attracted the interest of many academics and policy makers: i) the sources of sectoral TFP growth; ii) the determinants of countries' degree of embeddedness; and iii) the economic impact of the Covid-19 pandemic. We provide insight into these issues using a common but flexible analytical framework based on the model introduced by Caliendo et al. (2018) that is fed with sectoral data from the World Input-Output Database for a set of 41 countries over a 15-year period (2000-2014).

Our analyses allow us to establish the following results. While measured TFP increased in Europe by 2.08% a year on average over the years 2000 to 2014, we find a better performance from our set of non-European countries with an increase of 2.96% during the same period. As expected, we find that the improvement in fundamental productivity is the most important TFP driver. However, changes in international trade explain a significant proportion of the variations in measured TFP growth across countries and sectors.

The proposed model is next used to shed light on the traditional debate on whether too much or too little embeddedness might have positive or negative externalities on local industries. We find that the effect on a country's degree of embeddedness of improvements in its own fundamental productivity is similar, but with opposite signs as expected, to the effect of improvements in other countries' fundamental productivity. Our results also indicate that two thirds of the variations in the degree of embeddedness across countries and sectors are explained by differences in own fundamental productivity changes. As own fundamental productivity is probably capturing the existence of local economies of agglomeration and/or local knowledge spillovers, our results thus seem to support the strand of the literature that opts for increasing the within-country economic activity.

In terms of policy, our results suggest that, first, the economic measures designed cannot be one-size-fits-all type of policies due to the great heterogeneity we found both at the sectoral and country level. This being said, in general, policies aimed at increasing own trade shares (reducing the amount of foreign dependency) can help to increase TFP. Policies such as the recent "Levelling Up" in the UK go in that direction at the regional level (McCann, 2022). The design of this policy has two main objectives, tackling the growing spatial inequality (Carrascal-Incera et al., 2020) and addressing the low productivity figures of more recent decades (Westwood et al., 2022). To try to rebalance the situation in the UK regions, there is a need to reduce their excessive dependency on the south-east part of the country (Carrascal and Hewings, 2022). However, previous literature has also shown that the way in which these measures are applied is important too. For example, Rodriguez-Clare (2007) finds that, even though the creation of clusters and agglomeration of industries generate positive externalities for the local economies, embeddedness cannot be reached at the expenses of creating other negative distortions (such as increasing of prices and production costs). In line also with Boschma and Iammarino (2009), Rodriguez-Clare (2007) suggests that countries should focus on promoting clustering and, therefore embeddedness measures, in established and related sectors where they possess the strongest comparative advantage.

In our last simulation analysis we find that the Covid-19 pandemic has reduced countries' gross output by 14.42% on average. The European countries have experienced larger production losses (15.44%) than the set of non-European countries (13.77%) due to their larger reductions in labour supply and their larger dependency on the purchase of intermediate inputs by foreign countries. Although most of this effect is attributable to shortages in intermediate inputs (6.57%) and reductions in labour supply (6.51%), our results also indicate the existence of non-negligible effects of the Covid-19 pandemic on countries' output through a deterioration in the benefits of international trade that increases the price of intermediate and final goods (1.34%).

The main methodological contributions of our paper are threefold. First, unlike previous papers which use gravity models of trade, we propose a new method for estimating trade elasticities based on a production model where trade elasticities and technological parameters are estimated simultaneously. Despite the methodological differences, the different sets of countries, and sector disaggregation, the magnitudes of the sectoral trade elasticities found here are in the range of the trade elasticities estimated in the literature. Moreover, the estimated trade elasticities reveal that trade openness (i.e., a low degree of embeddedness) is crucial for TFP. Second, we encourage researchers using general equilibrium models to search for ways of testing empirically their theoretical framework by simply developing an empirical counterpart of one of their key equations. For instance, our estimates confirm the validity of the central equation developed by Caliendo et al. (2018) aimed at understanding the sources of change in sectoral productivity following a change in fundamental productivity. Third, the proposed model allows measuring econometrically the productivity effects caused by changes in the benefits of international trade (in terms of cheaper intermediate inputs), a productivity driver that has been examined in the literature on productivity growth decomposition on an exceptional basis, and, when appropriate, using non-parametric techniques.

We next use a time polynomial of degree two to capture exogenous technological progress or technical change. It is worth mentioning here that Eaton and Kortum (2002, p. 1747) stated that (fundamental) productivity reflects a country's stock of original or *imported* ideas. In this sense, fundamental productivity might increase over time not only due to improvements in the state of technology (technological progress) but also due to larger knowledge spillovers across countries. We did not disentangle these two productivity sources in our paper because the main objective of our empirical model was to estimate trade elasticities using the simplest empirical specification of Caliendo et al. (2018)'s central equation which decomposes changes in sectoral TFP into a traditional technological component and a selective effect that depends on the international trade of intermediate goods.

In the near future, our objective is to account for knowledge spillovers through the global supply chain. We also aim to examine this issue using more disaggregated data: data at the regional level. As pointed out by Liu and Cheng (2021) and Liu and Sickles (2021), the productivity growth occurring in supplier industries may bring know-how to downstream industries. Similarly, customer industries may stimulate learning and capability building in upstream industries. If this is the case, the fundamental productivity in sector $j$ in region $n$ should also depend on other sectors' fundamental productivity.

In our simulations we have decomposed changes in own trade share increases into the effect of changes in own and other countries' fundamental productivity, and changes in trade costs. It should be recognized, however, that our decomposition relies on the *direct* elasticities of trade shares that are *conditional* on the cost of an input bundle, and for this reason, they do not depend on other sectors' fundamental productivities. Unfortunately, it is not possible to compute changes in the cost of an input bundle because we do not use a general equilibrium model. In the near future, we will try to mimic this result by rewriting the definition of own trade shares in Caliendo et al. (2018) as a function of both sector $j$'s and sector $k$'s fundamental productivities that depends on a new industry-specific parameter that measures how the region's share of its own intermediate goods reacts to changes in an aggregate measure of other sectors' relative fundamental productivity.

Deriving overall impact estimates resulting from the Covid-19 pandemic should not only involve modelling first-order shocks, but also second-order effects that consider the feedback loops in the economy. In this context, del Rio-Chanona et al (2020) point out that the initial drops in wages and income will cause marked second-order negative impacts on demand reinforcing the downward spiral in output, employment, income, and demand. We will try to simulate these feedback loops in further research.

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**Table 1.** Own trade share and share of intermediates in gross output by country (%).

| Country | $\pi_{nn}^j$ | $1\text{-}\gamma_n^j$ | Country | $\pi_{nn}^j$ | $1\text{-}\gamma_n^j$ |
|---|---|---|---|---|---|
| Austria | 75.9 | 50.7 | Portugal | 86.1 | 53.2 |
| Belgium | 69.2 | 57.0 | Romania | 83.2 | 53.3 |
| Bulgaria | 79.0 | 59.3 | Slovakia | 71.1 | 60.5 |
| Croatia | 78.4 | 51.7 | Slovenia | 74.7 | 54.9 |
| Cyprus | 80.8 | 47.3 | Spain | 88.9 | 53.7 |
| Czech Republic | 76.5 | 60.9 | Sweden | 79.4 | 51.4 |
| Denmark | 77.0 | 51.0 | Switzerland | 83.9 | 51.2 |
| Estonia | 76.5 | 57.0 | Turkey | 89.9 | 52.5 |
| Finland | 82.7 | 54.3 | United Kingdom | 86.2 | 49.9 |
| France | 86.0 | 49.6 | Australia | 94.9 | 52.1 |
| Germany | 82.5 | 50.6 | Brazil | 94.6 | 51.5 |
| Greece | 86.5 | 46.0 | Canada | 86.5 | 48.5 |
| Hungary | 66.0 | 57.9 | China | 95.6 | 64.0 |
| Ireland | 61.9 | 57.7 | India | 91.1 | 49.6 |
| Italy | 89.4 | 53.9 | Indonesia | 90.1 | 49.4 |
| Latvia | 83.2 | 56.8 | Korea | 89.2 | 59.7 |
| Lithuania | 73.4 | 47.8 | Mexico | 78.8 | 42.4 |
| Luxembourg | 49.2 | 66.4 | Russia | 93.2 | 51.0 |
| Malta | 60.2 | 61.4 | United States | 95.0 | 44.1 |
| Netherlands | 75.1 | 52.4 | EU countries | 83.5 | 52.0 |
| Norway | 83.3 | 45.5 | Other countries | 93.6 | 50.2 |
| Poland | 83.6 | 55.5 | All countries | 89.8 | 51.1 |

Notes: $\pi_{nn}^j$ is the country average share of its own intermediate goods. ($1\text{-}\gamma_n^j$) is the country average share of intermediate inputs in gross output.

**Table 2.** Own trade share and share of intermediates in gross output by sector (%).

| Sector | Description | $\pi_{nn}^{j}$ | $1\text{-}\gamma_{n}^{j}$ |
|---|---|---|---|
| 1 | Primary sectors | 94.0 | 45.5 |
| 2 | Mining, coke, petroleum & energy sectors | 84.9 | 60.2 |
| 3 | Manufacture of food products, beverages & tobacco products | 93.0 | 73.7 |
| 4 | Manufacture of textiles, wearing apparel & leather products | 78.3 | 71.5 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | 84.8 | 67.7 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | 74.5 | 67.6 |
| 7 | Manufacture of basic metals & metal products | 79.7 | 71.6 |
| 8 | Manufacture of computer, electronic & electrical equipment | 63.3 | 66.9 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | 67.2 | 71.0 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | 86.7 | 58.3 |
| 11 | Construction | 98.6 | 60.0 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | 94.4 | 38.6 |
| 13 | Transport and postal services | 91.2 | 54.5 |
| 14 | Accommodation & food service activities | 94.2 | 48.9 |
| 15 | IT services | 95.6 | 45.9 |
| 16 | Financial service activities, insurance & pension funding | 95.7 | 46.0 |
| 17 | Real estate activities | 99.3 | 25.0 |
| 18 | Other professional, scientific & technical activities | 93.4 | 41.6 |
| 19 | Public administration & defence; education & human health services | 96.2 | 34.5 |
| 20 | Other service activities | 97.7 | 40.6 |
| | Tradable sectors | 79.7 | 65.8 |
| | Non-Tradable sectors | 95.7 | 42.2 |
| | All sectors | 89.8 | 51.1 |

Notes: $\pi_{nn}^{j}$ is the country average share of its own intermediate goods. ($1\text{-}\gamma_{n}^{j}$) is the country average share of intermediate inputs in gross output.

**Table 3**. Parameter estimates

| | Non-Parametric trade elasticities | | | | | | | | | Parametric trade elasticities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MODEL 1 | | | MODEL 2 | | | MODEL 3 | | | MODEL 4 | | | MODEL 5 | | |
| | Coef. | s.e. | t-stat | Coef. | s.e. | t-stat | Coef. | s.e. | t-stat | Coef. | s.e. | t-stat | Coef. | s.e. | t-stat |
| $t$ | 0.133 | 0.014 | 9.45 | 0.139 | 0.014 | 10.00 | 0.132 | 0.013 | 10.34 | 0.126 | 0.014 | 9.32 | 0.138 | 0.014 | 9.66 |
| $t^2$ | -0.011 | 0.002 | -6.23 | -0.011 | 0.002 | -6.34 | -0.010 | 0.002 | -6.63 | -0.010 | 0.002 | -6.17 | -0.011 | 0.002 | -6.32 |
| $\ln\pi_{nn}^j$ | -0.317 | 0.011 | -29.61 | | | | | | | -1.275 | 0.033 | -38.20 | | | |
| $SD^j\cdot\ln\pi_{nn}^j$ | | | | | | | | | | 0.593 | 0.039 | 15.17 | | | |
| $TR^j\cdot\ln\pi_{nn}^j$ | | | | | | | | | | 0.537 | 0.038 | 14.17 | -0.548 | 0.035 | -15.48 |
| $TR^j\cdot SD^j\cdot\ln\pi_{nn}^j$ | | | | | | | | | | | | | 0.410 | 0.041 | 9.95 |
| *Sector-specific elasticities* | | | | | | | | | | | | | | | |
| Tradable sectors | | No | | | Yes | | | Yes | | | No | | | No | |
| Non-tradable sectors | | No | | | No | | | Yes | | | No | | | No | |
| R-squared | | 0.697 | | | 0.706 | | | 0.750 | | | 0.718 | | | 0.687 | |
| *p-values of the tests* | | | | | | | | | | | | | | | |
| $H_0$: Common TC | | 0.084 | | | 0.340 | | | 0.192 | | | 0.235 | | | 0.256 | |

**Table 4**. Trade elasticities.[(a)]

| | | Trade elasticities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Parametric | | | | | | Parametric | | | |
| Sector | Description | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | |
| 1 | Primary sectors | 3.16 | *** | 1.20 | *** | 1.08 | *** | 1.68 | *** | 2.22 | *** |
| 2 | Mining, coke, petroleum & energy sectors | 3.16 | *** | 0.78 | *** | 0.74 | *** | 1.78 | *** | 2.34 | *** |
| 3 | Food products, beverages & tobacco products | 3.16 | *** | -2.75 | *** | -3.17 | *** | 1.65 | *** | 2.19 | *** |
| 4 | Textiles, wearing apparel & leather products | 3.16 | *** | 84.85 | | 47.00 | | 7.02 | *** | 7.29 | *** |
| 5 | Wood, paper & printing | 3.16 | *** | 7.36 | * | 4.05 | *** | 1.82 | *** | 2.39 | *** |
| 6 | Chemicals, pharmaceuticals, rubber, other non-metallic | 3.16 | *** | -14.87 | | -44.61 | | 2.08 | *** | 2.70 | *** |
| 7 | Basic metals & metal products | 3.16 | *** | 4.04 | *** | 3.26 | *** | 2.12 | *** | 2.74 | *** |
| 8 | Computer, electronic & electrical equipment | 3.16 | *** | 3.73 | *** | 3.49 | *** | 5.83 | *** | 6.35 | *** |
| 9 | Machinery & equipment, vehicles & transport equipment | 3.16 | *** | 11.11 | *** | 9.15 | *** | 3.06 | *** | 3.78 | *** |
| 10 | Other manufacturing | 3.16 | *** | -7.22 | | 1687.3 | | 1.70 | *** | 2.25 | *** |
| 11 | Construction | 3.16 | *** | | | -1.06 | * | 0.81 | *** | | |
| 12 | Wholesale & retail trade, repair of vehicles & motorcycles | 3.16 | *** | | | 1.43 | *** | 0.84 | *** | | |
| 13 | Transport and postal services | 3.16 | *** | | | 0.99 | *** | 0.85 | *** | | |
| 14 | Accommodation & food service activities | 3.16 | *** | | | -4.48 | | 0.85 | *** | | |
| 15 | IT services | 3.16 | *** | | | 0.79 | *** | 0.84 | *** | | |
| 16 | Financial service activities, insurance & pension funding | 3.16 | *** | | | 0.66 | *** | 0.87 | *** | | |
| 17 | Real estate activities | 3.16 | *** | | | 0.19 | *** | 1.17 | *** | | |
| 18 | Other professional, scientific & technical activities | 3.16 | *** | | | -3.13 | *** | 0.94 | *** | | |
| 19 | Public administration & defence; education & health services | 3.16 | *** | | | -3.31 | | 0.85 | *** | | |
| 20 | Other service activities | 3.16 | *** | | | -10.48 | | 0.94 | *** | | |
| | Tradable sectors [(b)] | 3.16 | | 3.02 | | 2.66 | | 2.87 | | 3.43 | |
| | Non-tradable sectors [(b)] | 3.16 | | | | 0.16 | | 0.90 | | | |
| | All sectors [(b)] | 3.16 | | | | 1.50 | | 1.88 | | | |

Notes: (a) *(**)(***) stands for statistically significance at 10%(5%)(1%). (b) Arithmetic means computed using only values that are statistically significant.

**Table 5**. Decomposition of measured TFP growth (%)

| | Obs. | Mean [(a)] | Std. Dev. |
|---|---|---|---|
| Changes in measured TFP | 11,480 | 2.65 | 22.05 |
| *Decomposition* | | | |
| - Fundamental TFP | 11,480 | 2.51 | 7.43 |
| - Trade | 11,480 | 0.14 | 6.15 |
| - Residual | 11,480 | 0.00 | 21.82 |

Notes: (a) weighted average using gross output shares.

**Table 6.** Decomposition of measured TFP by country (%)

| | | Decomposition | | | | | Decomposition | | |
|---|---|---|---|---|---|---|---|---|---|
| Country | Measured TFP | Fundamental TFP | Trade | Residual | Country | Measured TFP | Fundamental TFP | Trade | Residual |
| Austria | 0.95 | 1.85 | 0.38 | -1.29 | Portugal | 1.40 | 0.90 | 0.30 | 0.21 |
| Belgium | 2.30 | 1.91 | 1.04 | -0.65 | Romania | 4.28 | 3.98 | 0.24 | 0.06 |
| Bulgaria | 2.83 | 2.85 | 0.77 | -0.79 | Slovakia | 3.59 | 3.71 | 0.76 | -0.87 |
| Croatia | 2.44 | 2.82 | 0.51 | -0.89 | Slovenia | 2.76 | 2.57 | 0.76 | -0.58 |
| Cyprus | 2.33 | 1.67 | 0.37 | 0.29 | Spain | 1.71 | 1.77 | -0.02 | -0.04 |
| Czech Republic | 2.54 | 2.40 | 0.80 | -0.65 | Sweden | 1.97 | 1.91 | 0.31 | -0.25 |
| Denmark | 1.95 | 1.92 | 0.65 | -0.61 | Switzerland | 2.35 | 2.46 | 0.17 | -0.28 |
| Estonia | 2.93 | 3.24 | 1.31 | -1.62 | Turkey | 4.52 | 2.30 | 0.29 | 1.93 |
| Finland | 1.38 | 1.71 | 0.44 | -0.77 | United Kingdom | 3.32 | 2.22 | 0.03 | 1.07 |
| France | 0.58 | 1.75 | 0.34 | -1.51 | Australia | 4.19 | 3.44 | 0.07 | 0.69 |
| Germany | 3.12 | 1.83 | 0.38 | 0.91 | Brazil | 3.44 | 3.16 | 0.10 | 0.18 |
| Greece | 1.05 | 0.91 | 0.02 | 0.12 | Canada | 1.94 | 2.23 | -0.02 | -0.27 |
| Hungary | -0.20 | 2.33 | 1.23 | -3.76 | China | 5.27 | 5.25 | -0.01 | 0.04 |
| Ireland | 3.14 | 1.20 | 1.24 | 0.71 | India | 3.38 | 4.47 | -0.14 | -0.95 |
| Italy | 0.72 | 0.74 | 0.14 | -0.16 | Indonesia | 4.22 | 3.95 | -0.06 | 0.32 |
| Latvia | 3.68 | 3.87 | 0.63 | -0.81 | Korea | 1.86 | 2.23 | -0.01 | -0.37 |
| Lithuania | 4.42 | 5.10 | 0.97 | -1.64 | Mexico | 1.54 | 1.30 | -0.12 | 0.36 |
| Luxembourg | 1.14 | 1.94 | 0.71 | -1.51 | Russia | 8.30 | 5.65 | -0.02 | 2.67 |
| Malta | 2.20 | 1.64 | 1.66 | -1.20 | United States | 1.79 | 1.80 | 0.09 | -0.11 |
| Netherlands | 1.24 | 2.13 | 0.67 | -1.56 | EU countries | 2.08 | 1.84 | 0.31 | -0.07 |
| Norway | 2.38 | 2.12 | 0.26 | -0.01 | Other countries | 2.96 | 2.89 | 0.04 | 0.04 |
| Poland | 2.52 | 3.13 | 0.32 | -0.92 | All countries | 2.65 | 2.51 | 0.14 | 0.00 |

Note: weighted averages of sector-specific measures TFP and its components in each country, where the weights are their shares in country total gross output.

**Table 7.** Decomposition of measured TFP by sector (%)

| Sector | Description | Measured TFP | Decomposition | | |
|---|---|---|---|---|---|
| | | | Fundamental TFP | Trade | Residual |
| 1 | Primary sectors | 4.99 | 4.72 | 0.12 | 0.16 |
| 2 | Mining, coke, petroleum & energy sectors | 1.44 | 1.35 | 0.17 | -0.09 |
| 3 | Manufacture of food products, beverages & tobacco products | 1.14 | 1.50 | 0.11 | -0.47 |
| 4 | Manufacture of textiles, wearing apparel & leather products | 2.47 | 1.40 | 0.23 | 0.84 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | 2.34 | 1.22 | 0.10 | 1.02 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | 1.53 | 1.73 | 0.40 | -0.59 |
| 7 | Manufacture of basic metals & metal products | 1.53 | 1.39 | 0.15 | 0.00 |
| 8 | Manufacture of computer, electronic & electrical equipment | 3.31 | 2.81 | 0.20 | 0.30 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | 2.49 | 2.08 | 0.24 | 0.17 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | 1.38 | 1.31 | 0.24 | -0.17 |
| 11 | Construction | 1.87 | 1.74 | 0.06 | 0.07 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | 3.10 | 2.95 | 0.43 | -0.28 |
| 13 | Transport and postal services | 2.53 | 2.48 | 0.10 | -0.06 |
| 14 | Accommodation & food service activities | 2.03 | 1.90 | -0.45 | 0.58 |
| 15 | IT services | 3.96 | 3.89 | 0.17 | -0.09 |
| 16 | Financial service activities, insurance & pension funding | 3.38 | 3.52 | -0.04 | -0.10 |
| 17 | Real estate activities | 2.47 | 2.23 | 0.01 | 0.23 |
| 18 | Other professional, scientific & technical activities | 2.64 | 2.68 | 0.21 | -0.25 |
| 19 | Public administration & defence; education & human health services | 3.85 | 3.65 | 0.03 | 0.17 |
| 20 | Other service activities | 2.73 | 2.78 | -0.06 | 0.01 |
| | Tradable | 2.12 | 1.91 | 0.21 | -0.01 |
| | Non-Tradable | 2.97 | 2.87 | 0.10 | 0.00 |
| | All sectors | 2.65 | 2.51 | 0.14 | 0.00 |

Note: weighted averages of country-specific measures of TFP and its components in each sector, where the weights are country shares in total sector gross output.

**Table 8**. Sensitivity analysis by country. Relative importance of fundamental TFP and trade in measured TFP (%)

| | Drivers of sectors' measured TFP | | | Drivers of sectors' measured TFP | |
|---|---|---|---|---|---|
| Country | Fundamental TFP | Trade | Country | Fundamental TFP | Trade |
| Austria | 78.58 | 21.42 | Portugal | 95.60 | 4.40 |
| Belgium | 39.99 | 60.01 | Romania | 95.01 | 4.99 |
| Bulgaria | 56.49 | 43.51 | Slovakia | 90.49 | 9.51 |
| Croatia | 77.24 | 22.76 | Slovenia | 89.80 | 10.20 |
| Cyprus | 60.40 | 39.60 | Spain | 92.69 | 7.31 |
| Czech Republic | 85.33 | 14.67 | Sweden | 93.64 | 6.36 |
| Denmark | 79.40 | 20.60 | Switzerland | 90.56 | 9.44 |
| Estonia | 76.00 | 24.00 | Turkey | 85.98 | 14.02 |
| Finland | 90.85 | 9.15 | United Kingdom | 67.32 | 32.68 |
| France | 74.78 | 25.22 | Australia | 95.30 | 4.70 |
| Germany | 85.44 | 14.56 | Brazil | 99.07 | 0.93 |
| Greece | 90.42 | 9.58 | Canada | 78.39 | 21.61 |
| Hungary | 67.82 | 32.18 | China | 98.23 | 1.77 |
| Ireland | 11.76 | 88.24 | India | 41.44 | 58.56 |
| Italy | 93.83 | 6.17 | Indonesia | 82.32 | 17.68 |
| Latvia | 84.49 | 15.51 | Korea | 95.03 | 4.97 |
| Lithuania | 82.43 | 17.57 | Mexico | 62.45 | 37.55 |
| Luxembourg | 18.81 | 81.19 | Russia | 97.28 | 2.72 |
| Malta | 61.52 | 38.48 | United States | 100.0 | 0.00 |
| Netherlands | 37.00 | 63.00 | EU countries | 58.21 | 41.79 |
| Norway | 80.10 | 19.90 | Other countries | 78.75 | 21.25 |
| Poland | 92.62 | 7.38 | All countries | 61.76 | 38.24 |

**Table 9**. Sensitivity analysis by sectors. Relative importance of fundamental TFP and trade in measured TFP (%)

| | | Drivers of sectors' measured TFP | |
|---|---|---|---|
| Sector | Description | Fundamental TFP | International trade |
| 1 | Primary sectors | 39.2 | 60.8 |
| 2 | Mining, coke, petroleum & energy sectors | 56.7 | 43.3 |
| 3 | Manufacture of food products, beverages & tobacco products | 16.7 | 83.3 |
| 4 | Manufacture of textiles, wearing apparel & leather products | 75.3 | 24.7 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | 67.2 | 32.8 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | 54.4 | 45.6 |
| 7 | Manufacture of basic metals & metal products | 63.4 | 36.6 |
| 8 | Manufacture of computer, electronic & electrical equipment | 72.6 | 27.4 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | 60.5 | 39.5 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | 74.8 | 25.2 |
| 11 | Construction | 90.7 | 9.3 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | 83.3 | 16.7 |
| 13 | Transport and postal services | 75.6 | 24.4 |
| 14 | Accommodation & food service activities | 25.0 | 75.0 |
| 15 | IT services | 83.8 | 16.2 |
| 16 | Financial service activities, insurance & pension funding | 93.2 | 6.8 |
| 17 | Real estate activities | 99.8 | 0.2 |
| 18 | Other professional, scientific & technical activities | 50.3 | 49.7 |
| 19 | Public administration & defence; education & human health services | 75.9 | 24.1 |
| 20 | Other service activities | 48.9 | 51.1 |
| | Tradable sectors | 53.28 | 46.72 |
| | Non-Tradable sectors | 67.88 | 32.12 |
| | All sectors | 61.76 | 38.24 |

**Table 10**. Decomposition of changes in countries' own trade share (%)

| | Obs. | Mean[a] | Std. Dev. |
|---|---|---|---|
| Change in own trade share | 11,480 | -0.26 | 13.04 |
| *Decomposition* | | | |
| - Own Fundamental TFP | 11,480 | 0.40 | 11.41 |
| - Foreign Fundamental TFP | 11,480 | -0.48 | 6.53 |
| - Residual | 11,480 | -0.18 | 16.00 |

Notes: (a) weighted average using gross output shares

**Table 11.** Decomposition of changes in own trade of intermediates by countries

| Country | Changes in $\pi_{nn}^{j}$ | Decomposition | | | Changes in Fundamental TFP | |
|---|---|---|---|---|---|---|
| | | Own | Foreign | Residual | Own | Foreign |
| Austria | -0.49 | 0.84 | -1.13 | -0.21 | 3.63 | 4.75 |
| Belgium | -1.44 | 0.43 | -0.86 | -1.00 | 4.40 | 4.22 |
| Bulgaria | -1.33 | 1.28 | -0.76 | -1.85 | 6.87 | 4.94 |
| Croatia | -0.95 | 0.71 | -0.69 | -0.97 | 5.56 | 4.63 |
| Cyprus | -0.47 | 0.11 | -0.50 | -0.08 | 1.85 | 4.48 |
| Czech Rep. | -1.64 | 1.64 | -1.38 | -1.91 | 6.31 | 5.37 |
| Denmark | -0.94 | 0.50 | -0.82 | -0.62 | 3.74 | 4.84 |
| Estonia | -2.35 | 1.98 | -1.11 | -3.22 | 7.56 | 5.29 |
| Finland | -0.74 | 0.06 | -1.07 | 0.28 | 3.42 | 5.29 |
| France | -0.67 | 0.29 | -0.56 | -0.40 | 3.30 | 4.48 |
| Germany | -0.71 | 0.81 | -0.81 | -0.70 | 3.84 | 5.06 |
| Greece | -0.13 | -0.12 | -0.37 | 0.36 | 0.86 | 4.39 |
| Hungary | -2.84 | 1.27 | -2.23 | -1.89 | 5.48 | 5.78 |
| Ireland | -0.59 | -0.11 | -2.45 | 1.97 | 2.63 | 4.64 |
| Italy | -0.28 | 0.07 | -0.45 | 0.10 | 1.35 | 4.75 |
| Latvia | -0.90 | 0.97 | -0.77 | -1.10 | 8.89 | 5.85 |
| Lithuania | -1.59 | 2.17 | -1.12 | -2.64 | 9.82 | 6.04 |
| Luxembourg | -0.79 | 0.67 | -1.28 | -0.19 | 5.64 | 4.74 |
| Malta | -1.84 | -0.86 | -0.99 | -0.01 | 3.29 | 3.81 |
| Netherlands | -1.04 | 0.57 | -0.80 | -0.82 | 4.18 | 4.83 |
| Norway | -0.26 | 0.54 | -0.49 | -0.31 | 4.69 | 3.87 |
| Poland | -0.40 | 1.27 | -0.66 | -1.01 | 7.51 | 4.91 |
| Portugal | -0.50 | 0.27 | -0.46 | -0.31 | 1.66 | 3.98 |
| Romania | -0.36 | 1.83 | -0.68 | -1.51 | 8.89 | 4.73 |
| Slovakia | -1.39 | 2.29 | -1.47 | -2.21 | 9.91 | 5.29 |
| Slovenia | -1.53 | 1.43 | -0.95 | -2.02 | 5.92 | 4.55 |
| Spain | -0.12 | 0.26 | -0.40 | 0.02 | 3.15 | 4.00 |
| Sweden | -0.37 | 0.76 | -0.85 | -0.28 | 3.59 | 4.66 |
| Switzerland | -0.21 | 0.74 | -0.54 | -0.41 | 5.10 | 4.57 |
| Turkey | -0.90 | 0.35 | -0.45 | -0.81 | 4.80 | 4.98 |
| UK | -0.04 | 0.36 | -0.53 | 0.13 | 4.19 | 4.38 |
| Australia | -0.14 | 0.16 | -0.25 | -0.06 | 7.13 | 5.32 |
| Brazil | -0.22 | 0.17 | -0.34 | -0.04 | 5.94 | 4.78 |
| Canada | 0.18 | 0.18 | -0.55 | 0.54 | 4.33 | 4.22 |
| China | 0.07 | 0.61 | -0.28 | -0.25 | 15.29 | 4.90 |
| India | 0.07 | 0.61 | -0.43 | -0.11 | 8.91 | 5.70 |
| Indonesia | -0.01 | 0.60 | -0.70 | 0.09 | 7.83 | 6.71 |
| Korea | 0.02 | 0.51 | -0.96 | 0.47 | 5.60 | 7.39 |
| Mexico | -0.45 | 0.02 | -1.44 | 0.97 | 2.15 | 4.13 |
| Russia | -0.13 | 0.59 | -0.37 | -0.35 | 10.94 | 5.33 |
| United States | -0.18 | 0.21 | -0.21 | -0.19 | 3.13 | 4.97 |
| EU countries | -0.54 | 0.49 | -0.69 | -0.34 | 3.70 | 4.65 |
| Other countries | -0.10 | 0.34 | -0.34 | -0.09 | 6.63 | 5.05 |
| All countries | -0.26 | 0.40 | -0.48 | -0.18 | 4.83 | 4.90 |

**Table 12**. Decomposition of changes in countries' own trade of intermediates by sectors

| Sector | Description | Changes in $\pi_{nn}^{j}$ | Decomposition | | | Fundamental TFP growth | |
|---|---|---|---|---|---|---|---|
| | | | Own | Foreign | Residual | Own | Other countries |
| 1 | Primary sectors | -0.19 | 0.28 | -0.26 | -0.21 | 8.28 | 5.86 |
| 2 | Mining, coke, petroleum & energy sectors | -0.31 | 0.18 | -0.16 | -0.33 | 3.70 | 2.18 |
| 3 | Food products, beverages & tobacco products | -0.19 | 0.13 | -0.12 | -0.19 | 5.79 | 4.53 |
| 4 | Textiles, wearing apparel & leather products | -1.62 | 0.84 | -1.63 | -0.84 | 6.12 | 4.22 |
| 5 | Wood & of products of wood & cork, paper & printing | -0.19 | 0.22 | -0.23 | -0.18 | 4.34 | 2.68 |
| 6 | Chemicals, pharmaceuticals, rubber & other non-metallic | -0.83 | 0.71 | -0.81 | -0.73 | 6.40 | 4.82 |
| 7 | Basic metals & metal products | -0.32 | 0.53 | -0.60 | -0.25 | 5.76 | 4.21 |
| 8 | Computer, electronic & electrical equipment | -1.17 | 4.06 | -5.69 | 0.45 | 10.38 | 7.76 |
| 9 | Machinery & equipment, vehicles & transport equipment | -0.74 | 1.57 | -1.80 | -0.51 | 7.91 | 6.12 |
| 10 | Repair of machinery, water collection, sewerage & other | -0.42 | 0.28 | -0.31 | -0.38 | 3.33 | 3.24 |
| 11 | Construction | -0.05 | 0.03 | -0.02 | -0.06 | 5.45 | 4.41 |
| 12 | Wholesale & retail trade & repair of vehicles | -0.36 | 0.11 | -0.12 | -0.35 | 4.88 | 4.97 |
| 13 | Transport and postal services | -0.09 | 0.15 | -0.17 | -0.07 | 5.45 | 5.27 |
| 14 | Accommodation & food service activities | 0.38 | 0.09 | -0.12 | 0.41 | 4.13 | 4.36 |
| 15 | IT services | -0.14 | 0.13 | -0.15 | -0.12 | 7.12 | 8.57 |
| 16 | Financial services, insurance & pension funding | 0.04 | 0.10 | -0.09 | 0.03 | 6.12 | 5.53 |
| 17 | Real estate activities | -0.02 | 0.03 | -0.01 | -0.03 | 2.94 | 1.50 |
| 18 | Other professional, scientific & technical activities | -0.20 | 0.17 | -0.17 | -0.20 | 4.85 | 5.25 |
| 19 | Public adm. & defence; education & health services | -0.02 | 0.16 | -0.12 | -0.06 | 5.70 | 5.59 |
| 20 | Other service activities | 0.06 | 0.07 | -0.10 | 0.09 | 4.98 | 7.45 |
| | Tradable sectors | -0.56 | 0.88 | -1.10 | -0.34 | 6.23 | 4.57 |
| | Non-Tradable sectors | -0.09 | 0.11 | -0.11 | -0.09 | 5.19 | 5.10 |
| | All sectors | -0.26 | 0.40 | -0.48 | -0.18 | 4.83 | 4.90 |

**Table 13**. Sensitivity analysis by country. Relative importance of own and foreign fundamental TFP in the degree of embeddedness

| | TFP drivers of sectors' embeddedness | | | TFP drivers of sectors' embeddedness | |
|---|---|---|---|---|---|
| Country | Own country | Other countries | Country | Own country | Other countries |
| Austria | 49.20 | 50.80 | Portugal | 46.11 | 53.89 |
| Belgium | 56.95 | 43.05 | Romania | 77.27 | 22.73 |
| Bulgaria | 72.09 | 27.91 | Slovakia | 75.42 | 24.58 |
| Croatia | 59.71 | 40.29 | Slovenia | 56.00 | 44.00 |
| Cyprus | 88.36 | 11.64 | Spain | 44.49 | 55.51 |
| Czech Republic | 60.06 | 39.94 | Sweden | 61.80 | 38.20 |
| Denmark | 54.38 | 45.62 | Switzerland | 55.18 | 44.82 |
| Estonia | 61.57 | 38.43 | Turkey | 48.65 | 51.35 |
| Finland | 69.96 | 30.04 | United Kingdom | 60.21 | 39.79 |
| France | 46.87 | 53.13 | Australia | 60.16 | 39.84 |
| Germany | 62.88 | 37.12 | Brazil | 50.93 | 49.07 |
| Greece | 80.90 | 19.10 | Canada | 64.66 | 35.34 |
| Hungary | 56.13 | 43.87 | China | 59.99 | 40.01 |
| Ireland | 73.33 | 26.67 | India | 57.14 | 42.86 |
| Italy | 41.77 | 58.23 | Indonesia | 55.88 | 44.12 |
| Latvia | 76.25 | 23.75 | Korea | 39.01 | 60.99 |
| Lithuania | 72.98 | 27.02 | Mexico | 37.63 | 62.37 |
| Luxembourg | 62.69 | 37.31 | Russia | 70.77 | 29.23 |
| Malta | 85.60 | 14.40 | United States | 65.75 | 34.25 |
| Netherlands | 53.66 | 46.34 | EU countries | 68.15 | 31.85 |
| Norway | 56.52 | 43.48 | Other countries | 60.35 | 39.65 |
| Poland | 55.53 | 44.47 | All countries | 67.54 | 32.46 |

**Table 14**. Sensitivity analysis by sector. Relative importance of own and foreign fundamental TFP in the degree of embeddedness

| | | TFP drivers of sectors' embeddedness | |
|---|---|---|---|
| Sector | Description | Own country | Other countries |
| 1 | Primary sectors | 71.87 | 28.13 |
| 2 | Mining, coke, petroleum & energy sectors | 68.63 | 31.37 |
| 3 | Manufacture of food products, beverages & tobacco products | 79.91 | 20.09 |
| 4 | Manufacture of textiles, wearing apparel & leather products | 71.76 | 28.24 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | 68.61 | 31.39 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | 66.01 | 33.99 |
| 7 | Manufacture of basic metals & metal products | 61.15 | 38.85 |
| 8 | Manufacture of computer, electronic & electrical equipment | 65.97 | 34.03 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | 60.39 | 39.61 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | 72.81 | 27.19 |
| 11 | Construction | 61.44 | 38.56 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | 60.53 | 39.47 |
| 13 | Transport and postal services | 80.22 | 19.78 |
| 14 | Accommodation & food service activities | 62.78 | 37.22 |
| 15 | IT services | 61.77 | 38.23 |
| 16 | Financial service activities, insurance & pension funding | 57.10 | 42.90 |
| 17 | Real estate activities | 47.42 | 52.58 |
| 18 | Other professional, scientific & technical activities | 67.57 | 32.43 |
| 19 | Public administration & defence; education & human health services | 66.78 | 33.22 |
| 20 | Other service activities | 60.18 | 39.82 |
| | Tradable sectors | 67.55 | 32.45 |
| | Non-Tradable sectors | 67.15 | 32.85 |
| | All sectors | 67.54 | 32.46 |

**Table 15.** Sector-specific embeddedness elasticities of our preferred auxiliary regression.

| Sector | Description | Coef. | | s.e. | t |
|---|---|---|---|---|---|
| 1 | Primary sectors | -0.088 | *** | 0.032 | -2.72 |
| 2 | Mining, coke, petroleum & energy sectors | -0.502 | *** | 0.064 | -7.78 |
| 3 | Manufacture of food products, beverages & tobacco products | -0.019 | | 0.049 | -0.37 |
| 4 | Manufacture of textiles, wearing apparel & leather products | -0.270 | *** | 0.014 | -18.96 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | -0.672 | *** | 0.083 | -8.07 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | -0.556 | *** | 0.053 | -10.52 |
| 7 | Manufacture of basic metals & metal products | -0.829 | *** | 0.048 | -17.42 |
| 8 | Manufacture of computer, electronic & electrical equipment | -0.364 | *** | 0.014 | -25.61 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | -0.506 | *** | 0.025 | -20.44 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | -0.513 | *** | 0.094 | -5.43 |
| 11 | Construction | -0.493 | | 0.330 | -1.49 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | -0.632 | *** | 0.198 | -3.19 |
| 13 | Transport and postal services | -1.030 | *** | 0.158 | -6.51 |
| 14 | Accommodation & food service activities | -0.077 | | 0.066 | -1.17 |
| 15 | IT services | -0.858 | *** | 0.192 | -4.46 |
| 16 | Financial service activities, insurance & pension funding | -1.102 | *** | 0.248 | -4.45 |
| 17 | Real estate activities | -3.086 | *** | 0.830 | -3.72 |
| 18 | Other professional, scientific & technical activities | -0.162 | * | 0.091 | -1.78 |
| 19 | Public administration & defence; education & human health services | -0.198 | | 0.174 | -1.14 |
| 20 | Other service activities | -0.114 | | 0.082 | -1.38 |

**Table 16**. Covid-19 effects on countries' production (%)

| Country | TOTAL | EL | EM | ER | Country | TOTAL | EL | EM | ER |
|---|---|---|---|---|---|---|---|---|---|
| Austria | -15.73 | -7.46 | -5.53 | -2.74 | Portugal | -14.85 | -6.73 | -6.53 | -1.59 |
| Belgium | -16.69 | -6.09 | -6.67 | -3.93 | Romania | -13.51 | -5.62 | -6.05 | -1.84 |
| Bulgaria | -12.93 | -5.21 | -5.54 | -2.18 | Slovakia | -14.68 | -5.27 | -6.42 | -2.98 |
| Croatia | -15.97 | -8.51 | -5.18 | -2.28 | Slovenia | -16.61 | -7.61 | -6.13 | -2.87 |
| Cyprus | -13.42 | -6.58 | -4.67 | -2.16 | Spain | -15.83 | -7.69 | -6.81 | -1.33 |
| Czech Republic | -14.39 | -5.45 | -6.37 | -2.57 | Sweden | -14.39 | -6.37 | -5.70 | -2.32 |
| Denmark | -15.17 | -7.10 | -5.43 | -2.64 | Switzerland | -14.29 | -7.24 | -5.18 | -1.87 |
| Estonia | -12.50 | -6.16 | -3.92 | -2.43 | Turkey | -11.92 | -4.39 | -6.35 | -1.18 |
| Finland | -13.69 | -6.73 | -5.02 | -1.94 | United Kingdom | -16.28 | -8.07 | -6.32 | -1.89 |
| France | -14.87 | -7.09 | -6.07 | -1.70 | Australia | -13.61 | -6.32 | -6.58 | -0.71 |
| Germany | -16.06 | -7.69 | -5.94 | -2.44 | Brazil | -12.54 | -5.19 | -6.67 | -0.67 |
| Greece | -13.94 | -6.77 | -5.67 | -1.50 | Canada | -14.28 | -6.44 | -6.11 | -1.73 |
| Hungary | -16.18 | -5.81 | -6.51 | -3.86 | China | -14.74 | -4.45 | -9.78 | -0.51 |
| Ireland | -17.73 | -5.73 | -7.29 | -4.71 | India | -14.15 | -5.70 | -7.34 | -1.10 |
| Italy | -15.87 | -6.86 | -7.71 | -1.29 | Indonesia | -14.16 | -6.72 | -6.13 | -1.31 |
| Latvia | -14.80 | -8.15 | -5.04 | -1.61 | Korea | -15.42 | -7.19 | -6.83 | -1.40 |
| Lithuania | -13.65 | -6.66 | -4.32 | -2.67 | Mexico | -12.98 | -4.86 | -5.47 | -2.64 |
| Luxembourg | -18.26 | -4.39 | -7.70 | -6.17 | Russia | -14.07 | -7.43 | -5.71 | -0.93 |
| Malta | -14.93 | -6.77 | -3.65 | -4.51 | United States | -13.24 | -6.86 | -5.59 | -0.78 |
| Netherlands | -15.41 | -6.37 | -5.91 | -3.12 | EU countries | -15.44 | -7.06 | -6.29 | -2.09 |
| Norway | -13.87 | -6.33 | -4.40 | -3.14 | Other countries | -13.77 | -6.20 | -6.69 | -0.88 |
| Poland | -13.08 | -5.17 | -6.06 | -1.85 | All countries | -14.42 | -6.51 | -6.57 | -1.34 |

**Table 17**. Covid-19 effects on sectors' production.

| Sector | Description | TOTAL | LE | ME | RE |
|---|---|---|---|---|---|
| 1 | Primary sectors | -10.47 | -3.73 | -5.99 | -0.74 |
| 2 | Mining, coke, petroleum & energy sectors | -13.45 | -2.54 | -7.71 | -3.19 |
| 3 | Manufacture of food products, beverages & tobacco products | -11.59 | -1.22 | -9.51 | -0.85 |
| 4 | Manufacture of textiles, wearing apparel & leather products | -22.92 | -10.30 | -9.82 | -2.79 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | -15.11 | -4.58 | -8.73 | -1.79 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | -13.47 | -1.47 | -8.88 | -3.12 |
| 7 | Manufacture of basic metals & metal products | -22.32 | -10.36 | -9.47 | -2.49 |
| 8 | Manufacture of computer, electronic & electrical equipment | -19.97 | -6.55 | -8.83 | -4.59 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | -22.63 | -9.40 | -9.18 | -4.04 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | -16.14 | -6.99 | -7.51 | -1.64 |
| 11 | Construction | -15.81 | -7.81 | -7.84 | -0.17 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | -18.11 | -12.60 | -4.86 | -0.66 |
| 13 | Transport and postal services | -26.57 | -18.63 | -6.89 | -1.05 |
| 14 | Accommodation & food service activities | -33.18 | -26.20 | -6.29 | -0.69 |
| 15 | IT services | -11.07 | -4.76 | -5.76 | -0.55 |
| 16 | Financial service activities, insurance & pension funding | -6.26 | 0.00 | -5.77 | -0.49 |
| 17 | Real estate activities | -6.23 | -3.05 | -3.10 | -0.08 |
| 18 | Other professional, scientific & technical activities | -12.43 | -6.36 | -5.25 | -0.81 |
| 19 | Public administration & defence; education & human health services | -4.84 | 0.00 | -4.37 | -0.47 |
| 20 | Other service activities | -20.95 | -15.46 | -5.18 | -0.31 |
| | Tradable sectors | -16.58 | -5.26 | -8.59 | -2.73 |
| | Non-Tradable sectors | -13.15 | -7.28 | -5.36 | -0.52 |
| | All sectors | -14.42 | -6.51 | -6.57 | -1.34 |

# APPENDIX

**Table A.** List of countries

| **EU countries** | | | **Other countries** |
|---|---|---|---|
| Austria | Greece | Portugal | Australia |
| Belgium | Hungary | Romania | Brazil |
| Bulgaria | Ireland | Slovakia | Canada |
| Croatia | Italy | Slovenia | China |
| Cyprus | Latvia | Spain | India |
| Czech Republic | Lithuania | Sweden | Indonesia |
| Denmark | Luxembourg | Switzerland | Korea |
| Estonia | Malta | Turkey | Mexico |
| Finland | Netherlands | United Kingdom | Russia |
| France | Norway | | United States |
| Germany | Poland | | |

**Table B**. List of sectors. Standard Industrial Classification (SIC)

| Sector | Description | SIC section |
|---|---|---|
| 1 | Primary sectors | A |
| 2 | Mining, coke, petroleum & energy sectors | B, C19, D |
| 3 | Manufacture of food products, beverages & tobacco products | C10-C12 |
| 4 | Manufacture of textiles, wearing apparel & leather products | C13-C15 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | C16, C17, C18 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | C20, C21, C22, C23 |
| 7 | Manufacture of basic metals & metal products | C24, C25 |
| 8 | Manufacture of computer, electronic & electrical equipment | C26, C27 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | C28, C29, C30 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | C31_C32, C33, E |
| 11 | Construction | F |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | G |
| 13 | Transport and postal services | H |
| 14 | Accommodation & food service activities | I |
| 15 | IT services | J |
| 16 | Financial service activities, insurance & pension funding | K |
| 17 | Real estate activities | L |
| 18 | Other professional, scientific & technical activities | M, N |
| 19 | Public administration & defence; education & human health services | O, P, Q |
| 20 | Other service activities | R, S, T, U |

**Table C**. Auxiliary regression. Own fundamental productivity vs. embeddedness

| | MODEL A | | | MODEL B | | | MODEL C | | | MODEL D (Preferred Model) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dep. Var: $dlnT^j$ | Coef. | s.e. | t | Coef. | s.e. | t | Coef. | s.e. | t | Coef. | s.e. | t |
| Intercept | 0.116 | 0.004 | 30.65 | 0.115 | 0.004 | 30.45 | 0.101 | 0.004 | 28.44 | 0.096 | 0.004 | 27.10 |
| t | -0.008 | 0.000 | -18.73 | -0.007 | 0.000 | -18.65 | -0.007 | 0.000 | -17.43 | -0.006 | 0.000 | -16.69 |
| Observed $dln\pi_{nn}^j$ | | | | -0.026 | 0.012 | -2.11 | | | | | | |
| Adjusted $dln\pi_{nn}^j$ | | | | | | | -0.340 | 0.008 | -40.39 | | | |
| Sector-specific $dln\pi_{nn}^j$ | | No | | | No | | | No | | | Yes | |
| R-squared | | 0.030 | | | 0.030 | | | 0.151 | | | 0.179 | |
| F-test common elasticity | | | | | | | | | | | 20.91 | |
| p-value | | | | | | | | | | | 0.000 | |

**Table C**. Demand and Supply Covid-19 shocks by sector

| Sector | Description | Supply S | Demand D | Min(S,D) |
|---|---|---|---|---|
| 1 | Primary sectors | 0 | -10 | -10 |
| 2 | Mining, coke, petroleum & energy sectors | -24.5 | -9.3 | -24.5 |
| 3 | Manufacture of food products, beverages & tobacco products | -0.4 | -10 | -10 |
| 4 | Manufacture of textiles, wearing apparel & leather products | -57.5 | -10 | -57.5 |
| 5 | Manufacture of wood & of products of wood & cork, paper & printing | -23.2 | -10 | -23.2 |
| 6 | Manufacture of chemicals, pharmaceuticals, rubber & other non-metallic | -4.8 | -10 | -10 |
| 7 | Manufacture of basic metals & metal products | -61.9 | -10 | -61.9 |
| 8 | Manufacture of computer, electronic & electrical equipment | -36.1 | -10 | -36.1 |
| 9 | Manufacture of machinery & equipment, vehicles & transport equipment | -54.4 | -10 | -54.4 |
| 10 | Other manufacturing, repair of machinery, water collection & sewerage | -28.3 | -10 | -28.3 |
| 11 | Construction | -27 | -10 | -27 |
| 12 | Wholesale & retail trade & repair of motor vehicles & motorcycles | -35.4 | -10 | -35.4 |
| 13 | Transport and postal services | -1.2 | -67 | -67 |
| 14 | Accommodation & food service activities | -59.5 | -80 | -80.0 |
| 15 | IT services | -17.4 | 0 | -17 |
| 16 | Financial service activities, insurance & pension funding | 0 | 0 | 0 |
| 17 | Real estate activities | -53 | 0 | -53 |
| 18 | Other professional, scientific & technical activities | -16.6 | 0 | -16.6 |
| 19 | Public administration & defence; education & human health services | 0 | 7.1 | 0 |
| 20 | Other service activities | -34.7 | -32.5 | -34.7 |

Source: del Rio-Chanona, et al. (2020) and own elaboration