Production Networks and Structural Transformation*

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Abstract

We study the aggregate effects of increasing integration of traditional and modern services into countries' supply chains. Using international input–output data, we document large cross-country differences in the composition of intermediate goods and distinct sectoral trends: modern services are more prevalent in advanced economies and are becoming increasingly central to production networks. To assess the implications, we develop a multi-sector general equilibrium model with firm-level frictions in labor and intermediate input purchases. These distortions weaken intersectoral linkages and distort production. Reducing them to U.S. levels yields substantial gains—aggregate output rises by 27% on average and by 50% in developing economies—while accelerating structural transformation toward services, especially modern services, and raising their network centrality.

Keywords: Production Networks; Firm-level Distortions; Structural Transformation; Economic Development.

JEL: C67; C68; O11; O41.

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1 Introduction

Input-output linkages among sectors play a central role in the propagation of technology improvements and the amplification of sector-level distortions (Jones, 2011; Herrendorf et al., 2014; Valentinyi, 2021; Fadinger et al., 2022; Kazekami, 2024). When the industrial sector becomes more efficient and its relative price declines, for instance, other sectors benefit by gaining access to cheaper intermediate goods, which in turn feed back into the industrial sector by buying inputs from those sectors. This multiplier effect depends on the density and structure of production network linkages, which vary significantly across development stages.

In this paper, we first document large differences between countries in the composition of intermediate goods and identify distinct sectoral trends, with modern services more prevalent in advanced economies and becoming increasingly central to production networks worldwide. We then assess the sectoral and aggregate effects of changes in production network structures and, in particular, the increasing integration of modern and traditional services into supply chains. To do the analysis, we introduce firm-level frictions into a multi-sector general equilibrium model based on Carvalho and Tahbaz-Salehi (2019) and Ferreira et al. (2021). These frictions – modeled as cost wedges in hiring labor and purchasing intermediate inputs – weaken intersectoral linkages and distort the sectoral allocation of production. Intuitively, when firms in a given sector face higher cost wedges, their effective productivity declines.[1] This not only reduces the input demand from the sector and the sector size, but also lowers labor productivity in other sectors and impairs the overall performance of the economy.

We use 2011 sector-level data on employment, consumption, and input–output linkages for 35 countries from the World Input–Output Database (WIOD) to calibrate the production function and preference parameters. We calibrate sector-specific labor and intermediate input distortions as the wedges that match each country's observed cost shares, taking the United States as the zero-distortion benchmark. Additionally, data

[1]Such frictions are common in the literature. See, for example, Hsieh and Klenow (2009), Grassi and Sauvagnat (2019), and Delalibera et al. (2024a) for related formulations.

on gross output per worker in PPP are used to estimate the Total Factor Productivity (TFP) for each sector and country. We group the 56 WIOD sectors into four categories: agriculture, industry, modern services, and traditional services, following Ferreira and Silva (2015) for the service sector division.

Motivated by the documented cross-country gaps in service integration and their centrality in production networks, we examine the potential gains from easing the frictions that limit these linkages.[2] Using our calibrated model, we perform a baseline counterfactual in which labor and intermediate input wedges in each country and for all sectors are reduced to the levels observed in the United States, taken as the least-distorted benchmark in our sample. Lowering these frictions strengthens intersectoral connections, allowing sectors to access inputs more efficiently and altering the composition of production. The GDP per worker increased by 18% on average,[3] overall use of intermediate inputs rises by about 24% on average, generating an average productivity gain of 11% and an increase in aggregate gross output of 27%. The effects are even larger for lower-income countries:[4] GDP per worker rises by 29%, intermediate input use by 44%, gross output by 50%, and the gross output-per-worker gap with the United States narrows by about 30% on average.

At the sectoral level, removing all frictions increases employment, on average, by about a third in modern services and a quarter in traditional services, while it decreases by 9% in industry and just over half in agriculture. Network centrality index increases most for modern services, followed by traditional services, and declines for agriculture and industry. For lower-income countries, employment in modern services grows by two-thirds, while agricultural employment falls by three-quarters.

We also eliminate distortions sector by sector to highlight the importance of the production network structure and the amplifying effects of intersectoral linkages. Because sectors play different roles within countries' production networks, we find that the av-

[2] Sectoral centrality within production networks is measured using the Bonacich–Katz Centrality Index, as detailed in Appendix A.

[3] All references to GDP per worker concern the economy as a whole; we do not report sectoral GDP per worker because our framework, which assumes homogeneous wages across sectors, does not allow for its estimation.

[4] We define lower-income countries as those with GDP per worker below the median in our sample.

erage largest gains arise from removing the cost wedges faced by firms in the modern services, followed by traditional services and industry. Specifically, eliminating distortions in modern services alone raises economy-wide GDP per worker by 6% on average (10% for lower-income countries). In this case, the sectoral gross output per worker is increasing in all sectors between 4.5% and 7% (between 6.3% and 11% for countries with lower income), with the highest increase occurring in the industrial sector due to the effect of the production network from productivity gains in modern services. Eliminating distortions in industry and traditional services raises GDP per worker by 2.8% and 5% (2.9% and 9% for lower-income countries), respectively.

Our research contributes to a growing body of literature examining the network effects of intermediate goods (Jones, 2011; Moro, 2012; Baqaee, 2018; Grassi and Sauvagnat, 2019; Frohm and Gunnella, 2021; Valentinyi, 2021; Miranda-Pinto, 2021; Kazekami, 2024). These studies emphasize how sectoral linkages shape the transmission of shocks, the diffusion of productivity gains, and the dynamics of aggregate output. For instance, Kazekami (2024) shows that stronger connections between intermediate goods sectors facilitate productivity spillovers across the economy. Building on this idea, some studies argue that shocks propagated through production networks can help explain the origins of aggregate output volatility (Barrot and Sauvagnat, 2016; Atalay, 2017; Baqaee, 2018; Boehm et al., 2019; Frohm and Gunnella, 2021).

Within this framework, the structure and composition of production networks is a key determinant of economic outcomes. Moro (2012) highlights the importance of the sectoral share of intermediate goods for assessing the effects of shocks or production changes, while Miranda-Pinto (2021) finds that a more diversified network can dampen GDP growth volatility, especially in service-oriented economies. We build on and extend these insights by providing a cross-country quantitative analysis of how reducing sector-specific frictions reshapes production networks and accelerates structural transformation, with a particular focus on the growing role of modern services.

Our findings also relate to the literature on structural transformation and productivity (Bah and Brada, 2009; Duarte and Restuccia, 2010; Ferreira and Silva, 2015). Bah and Brada (2009) show that in nine transition economies, productivity in manufacturing outpaces that of services, suggesting that labor reallocation toward services may reduce aggregate productivity. Similarly, Duarte and Restuccia (2010) find that shifting labor from agriculture to manufacturing boosts productivity, while a shift to services diminishes. Ferreira and Silva (2015) noted that low productivity in the traditional services sector in nine Latin American countries hinders overall productivity growth. We add to this literature by calibrating our model to 35 countries and studying how strengthening intersectoral linkages affects the sectoral composition and productivity.

We also contribute to the empirical literature on sectoral reforms (Arnold et al., 2011; Fernandes and Paunov, 2012; Duggan et al., 2013; Shepotylo and Vakhitov, 2015; Arnold et al., 2016; Dabla-Norris et al., 2016; Grassi and Sauvagnat, 2019), which documents how regulatory and institutional changes can reduce distortions, increase efficiency, and generate spillover effects throughout the economy. An illustrative case is that of Grassi and Sauvagnat (2019), who simulate, for the French "Transport Equipment" sector, a 21 percentage point reduction in the sectoral markup (wedge). This reduces prices, stimulates production, and generates positive effects for interconnected sectors, increasing GDP by 0.08%. Despite reducing profits in the target sector, the reduction mitigates the wedge, improves resource allocation, and increases economic welfare.[5]

The French experience is not an isolated case. Similar sectoral reforms, aimed at reducing barriers and increasing efficiency, have produced positive results in different contexts. In India, for example, the liberalization of the banking, telecommunications, insurance, and transportation sectors after 1991 generated significant industrial productivity gains, driven by improvements in the quality, reliability, and access to services (Arnold et al., 2016). Converging evidence appears for Indonesia (Duggan et al., 2013), Czech Republic (Arnold et al., 2011), Ukraine (Shepotylo and Vakhitov, 2015), Chile (Fernandes and Paunov, 2012) and in cross-national studies (Dabla-Norris et al., 2016), with particularly relevant impacts on developing economies. We extend this literature by quantitatively assessing the aggregate effects of broad-based service sector reforms,

[5] Grassi and Sauvagnat (2019) define wedges as sectoral markup resulting from imperfect competition, which distort production networks and affect the efficient allocation of resources.

particularly in modern services, and their economy-wide spillovers through production networks.

The remainder of the paper is organized as follows: Section 2 presents the dataset and stylized facts on intersectoral linkages. Section 3 outlines the general equilibrium model. Section 4 details the model calibration and presents our counterfactual exercises. Section 5 discusses the policy implications and, finally, Section 6 concludes.

2 Empirical Analysis

In this section, we discuss the datasets used in the empirical analysis and present some important stylized facts. We begin the section by describing the World Input and Output Tables (WIOT) and the Socio-Economic Accounts (SEA) of the WIOD, 2016 Release.[6]

2.1 Datasets

We used the 2016 updated version of the WIOD, which provides an annual time series of WIOT from 2000 to 2014, covering 43 countries and 56 sectors. In addition, we used data from the SEA, which includes information on input quantities, prices, and volumes, as well as data on value added, capital stock, number of workers, and hours worked. We excluded small economies with a workforce of fewer than two million people or with incomplete data from the sample, resulting in a sample of 35 countries. We provide the names and acronyms of each country in Table D1 in appendix D.

Based on the International Standard Industrial Classification of All Economic Activities (ISIC 4), we classify the 56 sectors identified in SEA into four broad sectors: agriculture, industry, modern services, and traditional services.[7] The agriculture sector encompasses activities such as crop and animal production, hunting, fishing, forestry, and logging. The industry sector covers manufacturing, electricity, gas, water, mining and quarrying, waste treatment and disposal, and construction. Regarding the services sector, we follow Ferreira and Silva (2015) and consider modern services to be the sectors

[6]See Timmer et al. (2015) and Feenstra et al. (2015) for details.
[7]ISIC4 can be view in United Nations website: https://unstats.un.org.

within services that have the highest average value added per worker. Modern services include financial services, real estate activities, insurance, scientific research, management, consultancy, and others. In contrast, traditional services include educational services, healthcare, postal and courier activities, transportation, public administration and defense, and other related activities.[8] On average, the value added per worker of modern services is 2.4 times higher than in traditional services.

We adopted this approach because the services sector is quite heterogeneous, that is, various activities within this sector involve workers with varying skill levels, distinct levels of productivity, and varying degrees of economic significance. For example, employees in the educational services sector typically have different skills and exhibit different levels of productivity compared to those in the tourism sector. Our sector classification can be seen in Table E1 in Appendix E.

Furthermore, to facilitate cross-country comparisons of monetary values, we also employ the Gross Output Purchasing Power Parity (PPP) data provided by the Groningen Growth and Development Centre (GGDC) Productivity Level Database. The GGDC gathers information on relative prices and labor productivity in 84 countries and 12 sectors, referring to the base years 2005, 2011, and 2017. The data are based on the results of the International Comparisons Program (ICP) for those same years, which estimates PPPs for a global sample of countries. Since the most recent version of the GGDC compatible with the WIOD refers to 2011, we adopted data from that year for our analysis.[9]

2.2 Stylized Facts

The IO matrix represents the flow of intermediate goods between different sectors. The flow of intermediate goods determines the pattern of trade across sectors and creates production networks, acting as a shock propagation mechanism. A positive (negative) shock in the productivity of an important sector has a positive (negative) impact on all

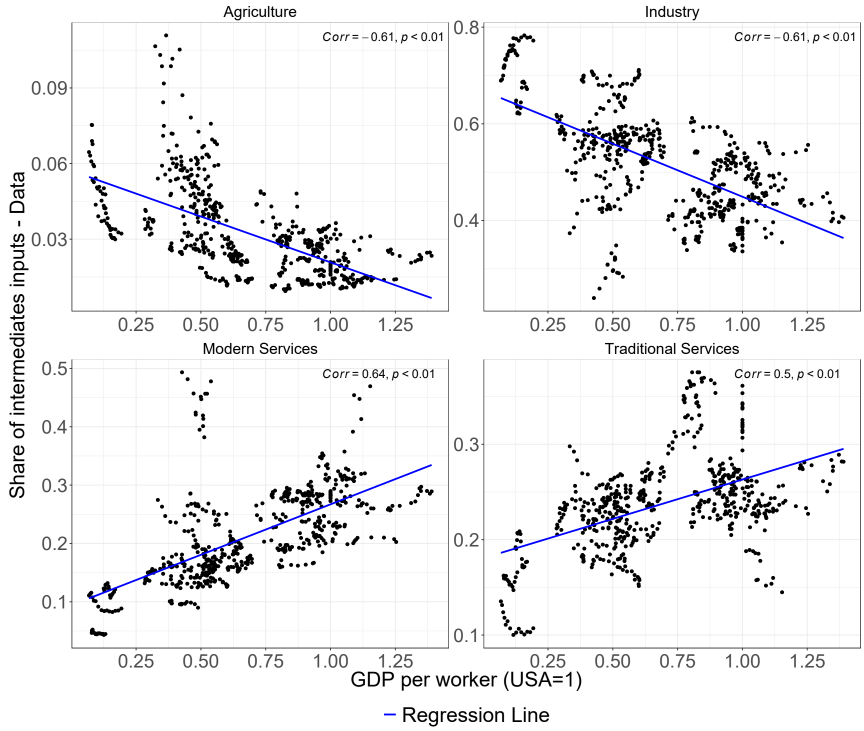
[8] A similar approach was employed by Rogerson (2008), Eichengreen and Gupta (2011) and Eichengreen and Gupta (2013).

[9] See Inklaar et al. (2024) for details. The mapping from our sectors to the GGDC database is as follows: agriculture corresponds to *Agriculture*; industry to *Mining, Manufacturing, Utilities, and Construction*; modern services to *Transport, Business, Finance, and Real Estate*; and traditional services to *Trade, Government, and Other Services*.

the other sectors (Jones, 2011; Carvalho and Tahbaz-Salehi, 2019; Boehm et al., 2019; Fadinger et al., 2022).

There are important cross-country differences in the structure of production networks and the use of intermediates, as we can see in Figure 1. In less developed countries, intermediate inputs from the agricultural and industrial sectors play a relatively more important role, while the opposite is true for intermediate inputs from modern services and, to a lesser extent, traditional services. More specifically, the Pearson correlation between aggregate GDP per worker and the share of intermediate goods from agriculture and industry is -0.61, while for modern services, this correlation is 0.64. These results are in line with the literature on structural change, according to which, although agriculture and industry are highly relevant in the productive structure of less developed economies, their share tends to decline as these economies specialize in the service sector (Eichengreen and Gupta, 2013; Herrendorf et al., 2014; Herrendorf and Schoellman, 2018; Sposi, 2019).

Figure 1: Share of Intermediate Inputs and GDP per Worker - 2000:2014



Notes: **(1)** The share of intermediate inputs is the proportion of intermediate goods and services supplied by a given sector relative to the total intermediate goods and services supplied in the economy. **(2)** GDP per worker data (constant 2021 PPP$) were obtained from the World Bank database. **(3)** Corr: Pearson Correlation; p: Correlation p-value.

Rodrik (2016) documents that there is a trend towards premature deindustrialization in low and middle-income countries in terms of production and employment. More specifically, Rodrik (2016) uses an econometric model with panel data in which the dependent variable is the share of labor in manufacturing, and the controls are the effects of demographic and income trends, as well as fixed effects of countries.[10] We follow Rodrik (2016) and estimate a similar econometric specification to examine whether deindustrialization in intermediates has also been faster in recent periods. Our specification is the following:

$$\begin{aligned} II_{jt}^{share} = \beta_0 + \beta_1 \ln pop_{jt} + \beta_2 (\ln pop_{jt})^2 + \beta_3 \ln y_{jt} + \beta_4 (\ln y_{jt})^2 + \\ \sum_j \gamma_j C_j + \sum_T \omega_T D_T + \epsilon_{jt}, \end{aligned} \tag{1}$$

where II_{jt}^{share} is the share of intermediate inputs of country j in period t, pop is the population, y_{jt} is the GDP per capita, also there are quadratic terms for $\ln pop_{jt}$ and $\ln y_{jt}$, C_j are country fixed effects, D_T are period dummies, and ϵ_{jt} is an error term. Here, we use the full dataset from 2000 to 2014 and capture sectoral trends using period dummies for the 2003 – 2005, 2006 – 2008, 2009 – 2011, and 2012 – 2014.

Table 1 reports the results of the regression estimated using Equation 1 for the four sectors. Key parameters of interest are those for the period dummies: D05, D08, D11, and D14. These parameters show the share of intermediate inputs of each period relative to the excluded period 2000 – 2002. Columns 1 and 2, which display the estimates for agriculture and industry, highlight a downward trend in the share of total intermediate inputs by both sectors over time, especially industry. Columns 3 and 4 report the estimates for modern and traditional services and reveal an opposite trend, especially in modern services. The share of both sectors in the total of intermediate inputs increases, indicating that the production network of these economies is becoming service-oriented.

These findings reveal a clear shift in production networks toward greater reliance on services – especially modern services – in intermediate input use, alongside a declining role

[10] In alternative specifications, Rodrik (2016) also uses as dependent variable the share of value added in real values and the share of value added in current values.

for agriculture and industry. This structural reorientation raises an important question for development: if economies were to adopt a production structure in which modern and traditional services play a more prominent role, could this transformation help narrow income gaps across countries? In the next section, we address this question by quantifying the aggregate effects of service-sector integration using a multi-sector general equilibrium model with intersectoral linkages.

Table 1: Panel Regression - Sectoral Share of Intermediate Inputs, 2000:2014

	Dependent Variable: Share of Intermediate Inputs			
	(1)	(2)	(3)	(4)
	Agriculture	Industry	Modern Services	Traditional Services
Ln GDP per Capita	-0.184^{***}	0.006	0.141^{**}	0.038
Ln GDP per Capita Squared	0.008^{***}	0.003	-0.008^{***}	-0.003
Ln Population	-0.314^{***}	-0.875^{***}	0.848^{***}	0.340^{***}
Ln Population Squared	0.009^{***}	0.025^{***}	-0.025^{***}	-0.009^{**}
D05	-0.001	-0.007^{**}	0.004^{*}	0.004^{**}
D08	-0.001	-0.007	0.008^{**}	0.001
D11	0.001	-0.030^{***}	0.019^{***}	0.011^{***}
D14	0.003	-0.035^{***}	0.023^{***}	0.009^{**}
Country Fixed Effects	✓	✓	✓	✓
Observations	585	585	585	585
R^2	0.628	0.261	0.124	0.115
Adjusted R^2	0.596	0.198	0.050	0.040
F Statistic (df = 8; 538)	113.361^{***}	23.728^{***}	9.561^{***}	8.759^{***}

Notes: **(1)** The share of intermediate goods refers to the proportion of intermediate goods and services produced by a sector in relation to the total intermediate goods and services produced. **(2)** GDP (constant 2021 PPP$) and population data were obtained from the World Bank database. **(3)** Statistical significance is indicated at the $***p < 0.01$, $**p < 0.05$, and $*p < 0.1$ levels. **(4)** Our dataset comprises data from 2000 to 2014. We use four time dummies variables: D05, D08, D11, and D14 that indicate whether the period goes from 2003 to 2005, 2006 to 2008, 2009 to 2011, and 2012 to 2014, respectively. Note that we exclude a dummy that indicates the period goes from 2000 to 2002.

3 Model

In this section, we provide an overview of the model. First, we describe the production technology and the optimization problem of the firm. Second, we describe the consumer preferences and the optimization problem of the representative consumer. Next, we present the equilibrium conditions, and finally, we discuss the intersectoral dependence and the propagation of shocks in the production network.

3.1 Firms

In this economy, there is a continuum of homogeneous and competitive firms in each of the N productive sectors. They maximize profits by optimally choosing the amount of labor hired as well as the amount of intermediate goods purchased. The production technology is given by:

$$Q_i = A_i L_i^{\sigma_i} \left(\prod_{j \in N} X_{ij}^{\beta_{ij}} \right)^{1-\sigma_i}, \tag{2}$$

where $\sum_{j \in N} \beta_{ij} = 1$, Q_i is the gross output of sector i, A_i is the total factor productivity (TFP), L_i is the amount of labor employed, and X_{ij} is the matrix of intermediate goods (the rows indicating the sector of destination and the columns indicating the sector of origin). Furthermore, σ_i denotes the elasticity of gross output in sector i with respect to labor, while $(1 - \sigma_i)\beta_{ij}$ represents the elasticity with respect to the intermediate input from sector j. A high β_{ij} implies that inputs from sector j are crucial for production in sector i, whereas a low value indicates limited importance.

Firms face frictions in the form of cost wedges when hiring labor and purchasing intermediate inputs. The optimization problem of the representative firm can be written as:

$$\max_{X_{ij}, L_i} \quad p_i Q_i - (1 + \tau_i^w) w L_i - \sum_{j \in N} (1 + \tau_{ij}^X) p_j X_{ij}, \tag{3}$$

subject to

$$Q_i = A_i L_i^{\sigma_i} \left(\prod_{j \in N} X_{ij}^{\beta_{ij}} \right)^{1-\sigma_i},$$

where w denotes the wage rate, τ_i^w is the labor cost wedge in sector i, and $\{\tau_{ij}^X\}_{j=1}^N$ are the cost wedges applied to intermediate inputs purchased by firms in sector i. The first-order conditions of this problem are given by:

$$X_{ij} = (1 - \sigma_i) \frac{p_i}{(1 + \tau_{ij}^X) p_j} Q_i \beta_{ij}, \tag{4}$$

$$L_i = \frac{\sigma_i p_i Q_i}{(1 + \tau_i^w) w}. \tag{5}$$

These cost wedges weaken intersectoral linkages and distort the sectoral allocation of production. Intuitively, when firms in a given sector face higher cost wedges, their effective productivity declines. This not only reduces the input demand from the sector and the sector size, but also lowers labor productivity in other sectors and impairs the overall performance of the economy.

3.2 Consumers

The economy is populated by a continuum of homogeneous consumers who inelastically supply labor L. The representative consumer has Stone-Geary preferences and chooses the consumption c_i of each of the N goods available in the economy to solve the following optimization problem:[11]

$$\begin{aligned} \max_{c} \quad & \log \left[\prod_{i \in N} (c_i - \bar{c}_i)^{\alpha_i} \right] \\ \text{subject to} \quad & \sum_{i \in N} p_i c_i = wL, \end{aligned} \tag{6}$$

where $\sum_{i \in N} \alpha_i = 1$, $\bar{c}_i$ is the minimum consumption level of good i, α_i is the nonnegative weight of good i in the utility function, p_i is the price of good i, and w is the wage rate.

The first-order conditions of the optimization problem yield the optimal demand functions for each sector $i \in N$:

$$c_i = \bar{c}_i + \frac{\alpha_i}{p_i} \left(wL - \sum_{j=1}^{N} p_j \bar{c}_j \right). \tag{7}$$

[11] This preference specification is common in the literature; see, for example, Herrendorf et al. (2013) and Herrendorf et al. (2014).

3.3 Equilibrium conditions

A competitive equilibrium in this economy is a set of prices p_i, a wage rate w, and allocations $c_i, L_i, Q_i, \{X_{ij}\}_{j=1}^{N}$ such that:[12]

1. c_i solves the consumer optimization problem, taking p_i and w as given, $\forall i \in N$.
2. L_i, and X_{ij} solve the firm optimization problem, taking p_i and w as given, $\forall i \in N$.
3. Markets clear:
   (a) The demand for labor by firms must be equal to the available supply:

$$\sum_{i \in N} L_i = L. \tag{8}$$

   (b) The supply of each good must be equal to the consumption demand by individuals plus the demand by firms:

$$Q_j = c_j + \sum_{i \in N} X_{ij}, \qquad \forall j \in N. \tag{9}$$

3.4 Discussion: sectoral interdependence and propagation

The production technology in Equation (2) incorporates intersectoral interdependence through the use of intermediate inputs. This network structure means that changes in one sector can spill over to others. For instance, if a sector becomes more efficient – through innovation, factor reallocation, or technological progress – its productivity rises, benefiting all sectors that use its goods and services.

Consider a simple economy with two sectors, A and B. A reform that reduces distortions in sector A, increases production, and then lowers the price of its intermediate good, prompting sector B to demand more from A and expand its own output. The resulting price drop in B's good then induces A to purchase more from B, creating a feedback loop. The strength of these spillovers depends on the parameters β_{ij} and σ_i.

[12] See Appendix A for the complete solution of the model.

4 Quantitative Analysis

In this section, we describe the model's parametrization (Calibration), assess its quantitative fit (Results), and conduct the counterfactual experiments (Counterfactual).

4.1 Calibration

We describe the calibration procedure by first establishing the benchmark parameters using U.S. data and then outlining the estimation of country-specific parameters for the rest of the sample.

United States. We begin by calibrating the production and utility function parameters using data from the United States in 2011. The U.S. economy serves as our benchmark frictionless economy, from which we take all common parameters. Only the Total Factor Productivity (A_i) parameters and cost wedges are estimated separately for each country.

Production function parameters. For each of the four sectors, we compute the labor share parameter σ_i as the ratio of labor compensation to gross output, using data from the Socio-Economic Accounts (SEA) of the WIOD, 2016 Release. The resulting values: 0.15 for agriculture, 0.20 for industry, 0.27 for modern services, and 0.46 for traditional services—are reported in Appendix C. The intermediate input share parameters β_{ij} are calculated directly using the input-output matrix for each country.[13] Furthermore, the sectoral productivity (A_i) is calibrated endogenously so that the model matches gross output per worker in each sector.

Utility function parameters. The consumption share parameters α_i are computed from the WIOT as the share of final household consumption expenditure attributed to each sector.[14] The non-homothetic consumption term $\bar{c}_i$ is set to zero in all sectors except agriculture. The agricultural subsistence level $\bar{c}_{agr}$ is endogenously calibrated to match the share of persons employed in agriculture in the United States in 2011, based on SEA

[13]See Table C1 in the Appendix for detailed values.
[14]See Table C2 in the Appendix.

data.[15]

Exogenous normalization. We normalize the total labor supply L to one in all countries. The wage rate w is then calibrated separately for each country to match its observed GDP per worker. Since total income is given by $w \cdot L$ and we set $L = 1$, the wage rate w corresponds directly to GDP per worker and therefore varies across countries.

Other Countries. We assume that preferences and technology parameters are the same as those calibrated for the United States. For each country in the sample, we then estimate a set of country-specific parameters: sectoral productivity levels $\{A_i\}_{i \in N}$, labor cost wedges $\{\tau_i^w\}_{i \in N}$, and intermediate input wedges $\{\tau_{ij}^X\}_{i,j \in N}$.

Sectoral productivity. TFP levels $\{A_i\}_{i \in N}$ are calibrated endogenously so that the model matches gross output per worker in each sector, expressed in common prices. In the model, we adopt U.S. prices. In the data, we use Gross Output PPPs from the GGDC Productivity Level Database (2023) to convert SEA data on gross output per worker into common prices for the year 2011.

Cost wedges. We assume that cost wedges are zero for the United States. For all other countries, we compute them using firms' first-order conditions. The labor cost wedge τ_i^w is set so that $\frac{\sigma_i^{USA}}{1+\tau_i^w}$ matches the observed ratio of labor compensation to gross output in sector i. Similarly, the intermediate input wedge τ_{ij}^X is calibrated such that $\frac{(1-\sigma_i^{USA})\beta_{ij}^{USA}}{1+\tau_{ij}^X}$ equals the share of intermediate inputs from sector j used in sector i, relative to gross output in sector i.

4.2 Results

In this section, we present the numerical results of the paper. Panel (A) of Figure 2 shows that, across all sectors and countries, the model successfully matches gross output per worker expressed in a common set of prices. Panel (B) compares the aggregate

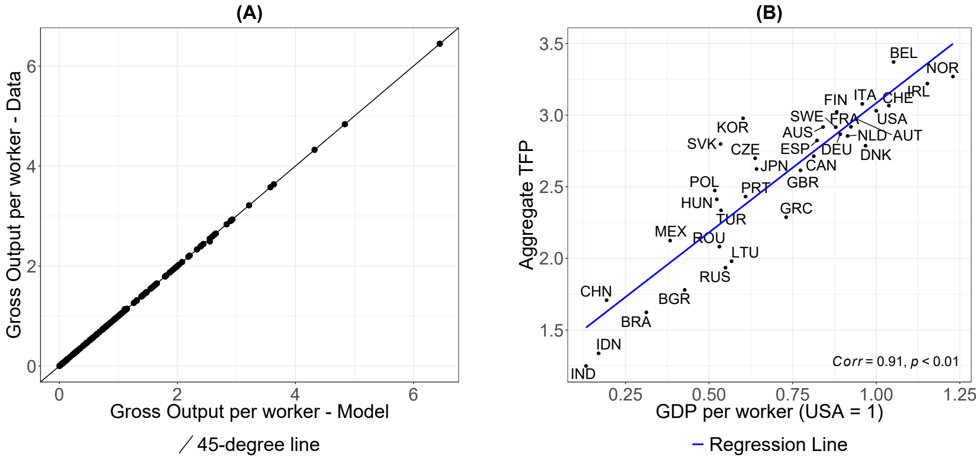
[15] We define the following objective function, which we minimize in the calibration procedure to estimate $\{A_i\}_{i \in N}$ and $\bar{c}_{agr}$:

$$D = \sum_{i=1}^{N} \left(\frac{GO.L_i^M - GO.L_i^D}{GO.L_i^D} \right)^2 + \left(\frac{L_{agr}^M - L_{agr}^D}{L_{agr}^D} \right)^2 ,$$

where $GO.L_i$ is the gross output per worker in sector i, Lsh_{agr} is the labor share of agriculture, and the superscripts M and D indicate the model and data (target statistics).

TFP from the model, calculated as the labor-share-weighted average of sectoral TFPs, with value added per worker in the data. As shown, the two measures exhibit a strong correlation across countries.

Figure 2: Endogenous Calibration: Model versus Data



Notes: **(1)** Panel (A) shows the model's fit for gross output per worker, plotting model predictions against observed data. The 45-degree line represents points where the model exactly matches the data. Panel (B) shows the correlation between value added per worker relative to the U.S. and aggregate TFP, where aggregate TFP is computed as the labor-share-weighted average of sectoral TFPs. **(2)** Corr: Pearson Correlation; p: Correlation p-value.

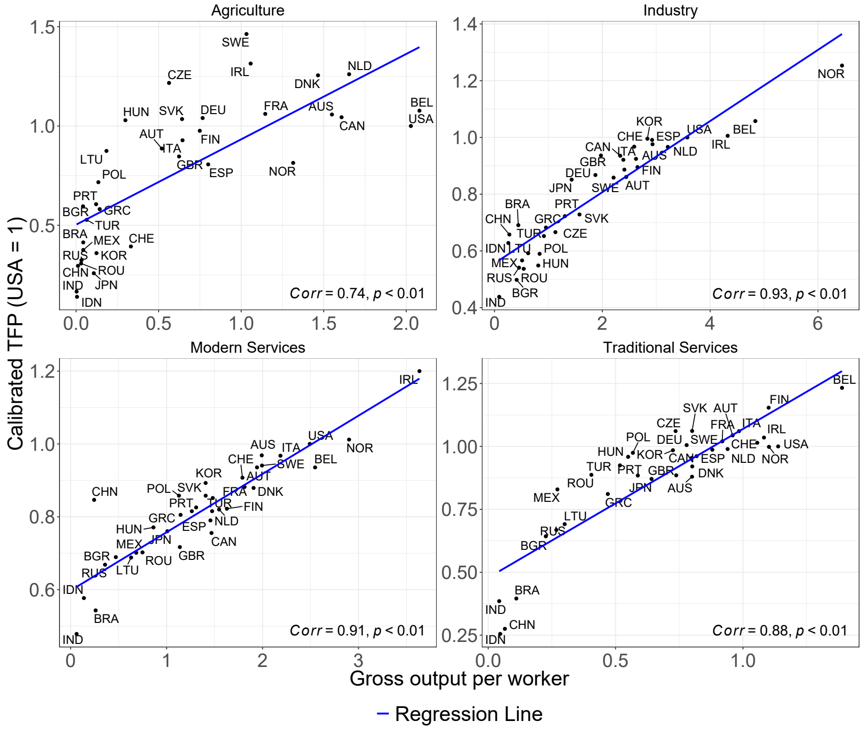
The values obtained for the total factor productivity, A_i, are plotted in Figure 3 for all countries and sectors. Appendix D contains the actual values. As expected, the productivity of the four sectors is positively associated with the level of development in the countries, implying that more developed countries tend to be more productive in all sectors.

Figure 4 presents the model's performance in replicating the allocation of labor (Panel A) and intermediate inputs (Panel B) across sectors. In both cases, the correlation exceeds 0.9, indicating that the model is able to capture the sectoral composition of the economies.

4.3 Counterfactual

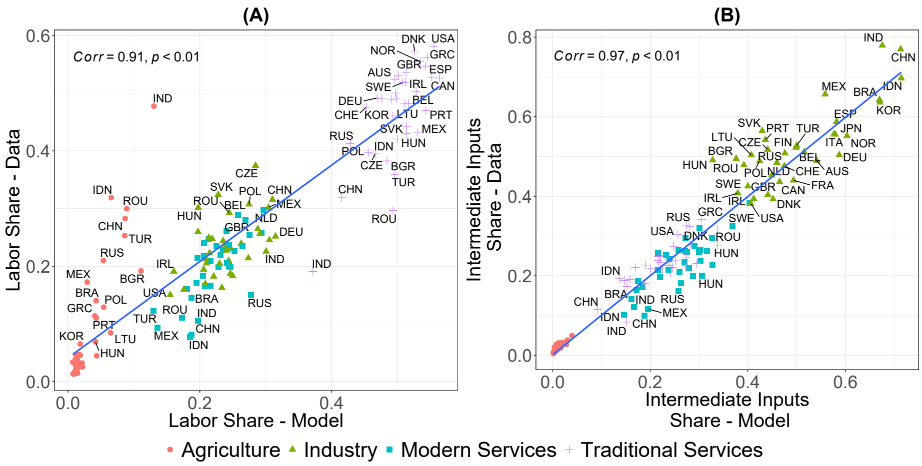
The goal of this section is to examine the quantitative effects of increased sectoral integration within supply chains. First, we quantify the effects of reducing all sectoral distortions in each country to the levels observed in the United States—specifically, the

Figure 3: Calibration Results: TFP and Gross Output per Worker



Notes: **(1)** This figure illustrates the relationship between calibrated sectoral TFP and gross output per worker across the four sectors: agriculture, industry, modern services, and traditional services. **(2)** Corr: Pearson Correlation; p: Correlation p-value.

Figure 4: Model Fit – Labor and intermediate inputs



Notes: **(1)** Panel (A) shows the model's fit for labor share, plotting model predictions against observed data. Panel (B) presents the fit of the intermediate goods share. **(2)** The share of intermediate goods refers to the proportion of intermediate goods and services produced by a sector in relation to the total intermediate goods and services produced, and the labor share refers to the amount of sectoral labor in relation to the total labor. **(3)** Corr: Pearson Correlation; p: Correlation p-value.

labor cost wedges τ_i^w and the intermediate input cost wedges $\{\tau_{ij}^X\}_{j=1}^N$, $\forall i$. Second, we quantify the effects of eliminating the distortions of each sector, one at a time. Finally, we analyze the role of network effects, exploring how the removal of sectoral distortions influences sectoral interconnectedness and labor reallocation through input–output linkages.[16]

4.3.1 Effects of eliminating all sectoral distortions

We now analyze a counterfactual scenario in which all cost wedges are eliminated across the entire economy. In this setting, both the sector-specific labor cost wedges, τ_i^w, and all intermediate input wedges, τ_{ij}^X, are set to zero for all $i, j \in N$. Removing these wedges increases the integration of sectors through their supply chains, enhancing productivity and raising total output. As a result, in almost all countries, gross output per worker rises across all sectors, narrowing the productivity gaps with respect to the United States, as shown in Figure 5.[17] The largest relative improvement occurs in agriculture, which experiences the most pronounced reduction in the productivity gap, on average 53%, although substantial gains are also observed in services.

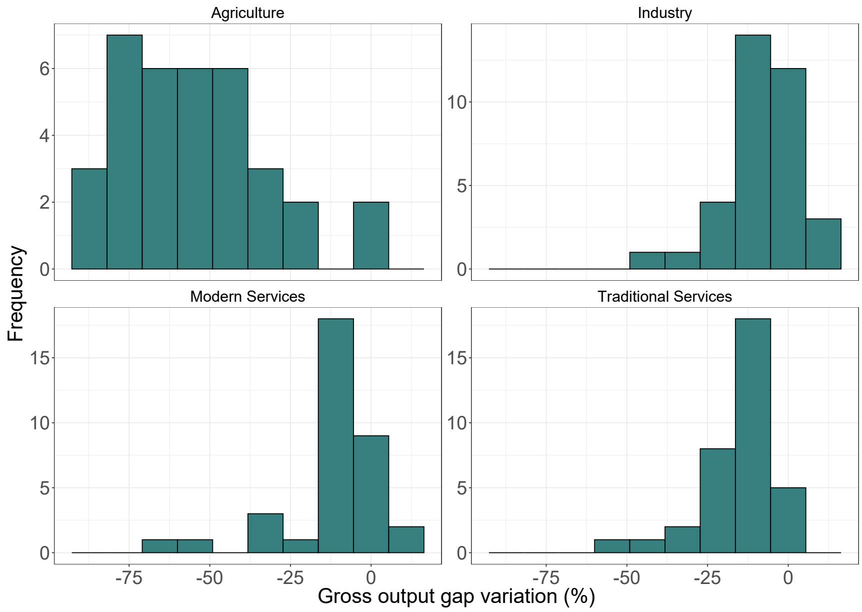
Table 2 shows the average effects on each sector of eliminating all the distortions. Focusing first on the intermediate inputs supplied by each sector (column 1), we find a substantial increase for services—approximately 85% for both modern and traditional services—while agriculture and industry experience declines of about 10% and 6%, respectively. Productivity (column 3), measured as gross output per worker also rises in all sectors, on average: by 173% in agriculture, 10% in industry, 19% in modern services, and 20% in traditional services.[18] At the same time, countries experience a significant structural transformation towards services (column 4), with employment falling by 58% in agriculture and by 8.5% in industry, and rising by 37% in modern services and by 25% in traditional services. This all leads to an important rise in average gross output (column

[16]In this section, we follow Delalibera et al. (2024b) and use the Laspeyres quantity index to compute the percentage changes between the benchmark and counterfactual scenarios, keeping the benchmark economy's price vector fixed while allowing quantities to vary.

[17]In a few cases, the productivity gap with the United States widens. This is because the United States serves as the zero-distortion benchmark. Some countries have negative distortions in certain sectors—i.e., wedges below U.S. levels—so reducing these to zero can lower productivity in those sectors, increasing the overall gap.

[18]Eliminating all distortions increases agricultural productivity by 172%. Although gross output decreases, the proportionally larger reduction in employment results in a significant increase in productivity.

Figure 5: Histogram of changes in the sectoral productivity gap to the United States when all distortions are eliminated



Note: This figure shows the histogram of the variation in sectoral gross output per worker gaps when all distortions are removed. We define the *gap* as the distance to U.S. values, measured by the ratio $\frac{X_{\text{US}}}{X_{\text{country}}}$.

2): 64% in modern services and 54% in traditional services, but a fall in industry (-0.7%), and in agriculture (-9%). Interestingly, modern services is the sector that experiences the largest increase in the network centrality index, while agriculture and industry experience a fall in their centrality.[19] Specifically, the centrality index (column 5) increases by 10% in modern services and by 8% in traditional services, and decreases by 4.6% in agriculture and by 2.7% in industry, indicating the growing importance of both service sectors in the aggregate production network.

We now turn to analyzing the aggregate effects on the entire economy. According to the results, the use of intermediate inputs increases by 24% on average, aggregate gross output rises by 27%, and GDP per worker by 18%. Figure 6 shows the results by country for GDP per worker and intermediate inputs. Unsurprisingly, the effects are larger among poorer countries—defined as those with income per capita below the sample median—where distortions are more prevalent.[20] In this group, the use of intermediate

[19]See Appendix A for a description of the centrality index used.

[20]In our sample, 18 countries are considered high-income and 17 low-income.

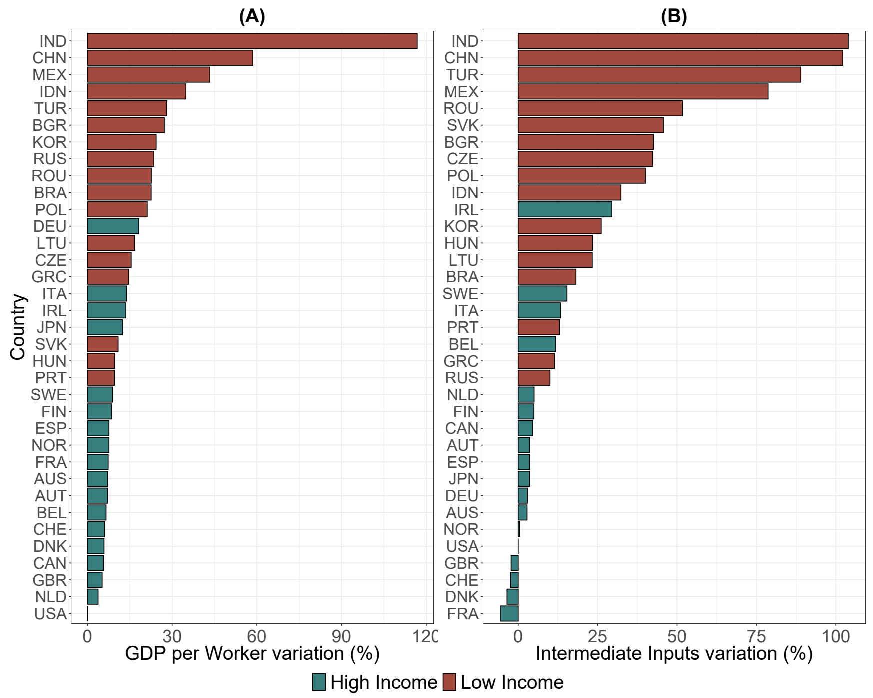
Table 2: Percentage Changes in the main variables when eliminating all distortions

Sectors (Δ%)	**II**	**GO**	**Productivity**	**Employment**	**Centrality**
Agriculture	-10.11	-8.87	172.97	-57.68	-4.60
Industry	-6.29	-0.66	9.77	-8.54	-2.69
Modern Services	84.77	63.93	19.31	36.64	9.94
Traditional Services	84.38	53.67	19.98	25.51	7.91

Note: This table presents the variation in the model's main sectoral variables after removing all distortions. Each row corresponds to a sector, while the columns report the results for each variable. II refers to intermediate goods; GO to gross output; productivity to gross output per worker; employment to labor; and centrality to the Bonacich–Katz centrality index.

inputs increases by 44% on average, compared to just 5% in richer countries. Similarly, the GDP per worker rises by 29% in poorer countries and by 8% in richer ones. As illustrated in Figure 6, countries such as India, China, Mexico, and Turkey show significant increases in both GDP per worker and the use of intermediate inputs—exceeding 75% in intermediate inputs—while richer countries show small or negative gains.

Figure 6: Percentage Changes in GDP per worker and Intermediate Input Use by Country



Notes: **(1)** Panel (A) shows the change in aggregate GDP per worker, and panel (B) shows the change in total intermediate goods after removing all distortions. **(2)** We consider high-income countries those whose GDP per worker is greater than or equal to the median; otherwise, it is a low-income country.

4.3.2 Effects of eliminating distortions sector by sector

We now analyze a counterfactual scenario in which distortions are set to zero only for firms in a given sector:

$$\tau_i^w = 0 \quad \text{and} \quad \tau_{ij}^X = 0 \quad \text{for all } j = 1, \ldots, N,$$

while distortions in all other sectors $k \neq i$ remain unchanged:

$$\tau_k^w \neq 0 \quad \text{and} \quad \tau_{kj} \neq 0 \quad \text{for all } j = 1, \ldots, N.$$

This experiment allows us to assess the strength of intersectoral linkages and the role of production networks within our framework. Table 3 presents the results for sectoral gross output.[21] Each row corresponds to the sector in which distortions are set to zero in the counterfactual scenario, while each column reports the resulting effect of this policy on the gross output of the corresponding sector. Results are shown for both the full sample of countries and the subsample of lower-income countries. As expected, removing distortions in agriculture generates only modest effects, as this sector plays a relatively minor role in most countries' production networks. In contrast, eliminating distortions in other sectors leads to substantially larger effects due to their central position as suppliers of intermediate inputs. More specifically, when firms in the industrial sectors stop facing distortions, gross output in that sector rises by 10% on average. Given that other sectors can now increase their use of industrial intermediates, gross output rises by 5% in agriculture, 11% in modern services, and 17% in traditional services.

Even though gross output declines in some sectors, removing distortions in modern services raises labor productivity—measured as gross output per worker—across all sectors.[22] In this case, employment shifts from agriculture and industry toward the service sectors, resulting in an average gross output increase of 27% in modern services and 12% in traditional services, while output falls by 2% in agriculture and 3% in industry due to the reduction in their workforce. Similarly, eliminating distortions in traditional services

[21] In Appendix B, we present detailed results for other key variables.
[22] See Table B1 in Appendix B for the results of all sectoral counterfactuals.

Table 3: Percentage Changes in Gross Output from Removing Sectoral Distortions

Sectors (Δ%)	Whole sample				Lower-income countries			
	Q_A	Q_I	Q_{MS}	Q_{TS}	Q_A	Q_I	Q_{MS}	Q_{TS}
Agriculture	-1.20	0.25	-0.24	-0.45	-6.98	0.27	-0.27	-0.66
Industry	5.14	10.32	10.99	17.13	9.15	20.36	18.07	25.10
Modern Services	-2.18	-2.94	26.63	11.83	-2.97	-1.92	47.81	15.91
Traditional Services	-6.68	-3.50	12.38	16.90	-11.43	-2.91	20.95	32.71

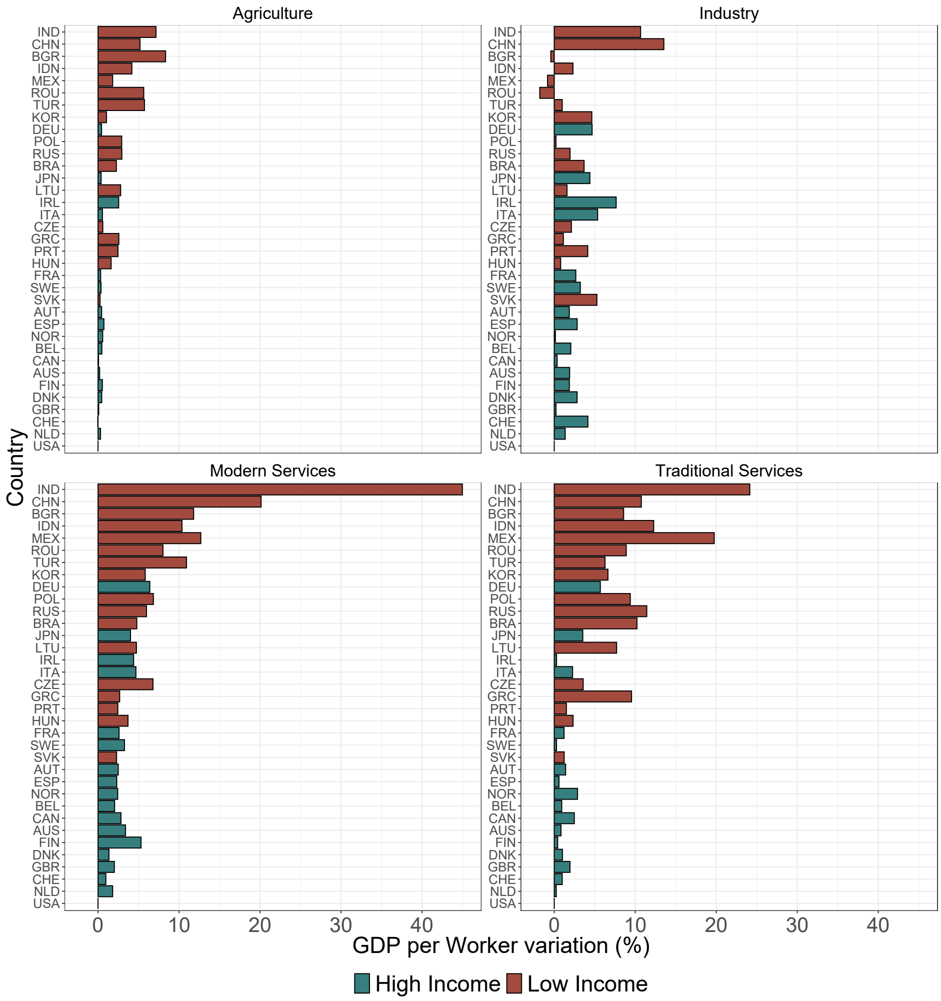
Notes: **(1)**: This table shows the sectoral variation in gross output after removing distortions one sector at a time. The row indicates the sector in which distortions are eliminated, and the column shows the variable being analyzed. **(2)**: Q_A, Q_I, Q_{MS}, and Q_{TS} denote the percentage change in gross output between the benchmark and counterfactual scenarios for agriculture, industry, modern services, and traditional services, respectively. **(3)**: We consider lower-income countries to be those whose GDP per worker is below the median.

raises labor productivity in all sectors and also triggers a reallocation of employment from agriculture and industry toward services. In this case, average gross output rises by 17% in traditional services and 12% in modern services, while it declines by 6.7% in agriculture and 3.5% in industry (See Table B1 from Appendix B). The largest gain in GDP per worker occurs when distortions in modern services are removed, with an increase of 6% in the full sample and 10% in lower-income countries.

Table 3 also reports the average sectoral output effects of each counterfactual for the sample of lower-income countries. As shown, the qualitative patterns remain similar to those in the full sample, but the magnitudes are substantially larger. In particular, when distortions are removed in industry, gross output increases on average by 20% in industry, 9% in agriculture, 18% in modern services, and 25% in traditional services. When distortions are removed in modern services, gross output in that sector rises by 48%, while gross output in traditional services increases by 16%, and declines slightly in agriculture and industry due to the large reallocation of labor toward modern services. Similarly, when distortions are removed in traditional services, gross output in that sector increases by 33% and by 21% in modern services, while it falls in agriculture and industry as labor shifts toward traditional services.

Figure 7 shows the variation in aggregate GDP per worker, country by country, due to the removal of distortions in agriculture (upper left panel), industry (upper right panel), modern services (lower left panel), and traditional services (lower right panel). We can see a significant rise in GDP per worker due to the rise in the use of intermediates in each sector. The average effects are 0.5%, 2.6%, 2.9%, and 1.5% for each of the experiments in developed countries, while they are 3.4%, 3%, 10%, and 9% in the developing countries sample.

Figure 7: Percentage change in GDP per worker from removing sectoral distortions



Notes: **(1)** This figure shows the sectoral variation in GDP per worker after removing sector-by-sector distortions. **(2)** We consider high-income countries to be those whose value added per worker is greater than or equal to the median, otherwise it is low income.

4.3.3 Network effects

In the absence of production networks, each sector would produce solely for final consumption, and the concept of sectoral centrality would be irrelevant. However, in modern economies, sectors are interlinked through complex input-output relationships: the output of one sector serves as an intermediate input for others. This interconnectedness means that distortions or productivity changes in one sector can propagate through the economy via input linkages, amplifying or dampening aggregate effects.

Table 4 reports the percentage change in the centrality index, where each row shows the results of removing distortions in a specific sector. The reported values correspond to the percentage difference between the baseline economy and a counterfactual economy without distortions in the sector indicated by the row. Results are presented for both the full sample of countries and for the subsample of lower-income countries. The centrality index captures the role of each sector as a supplier of intermediate goods to others. A higher value indicates that a sector is more central in the production network—that is, its output is used more intensively as an intermediate input across sectors.

Table 4: Percentage Change of Centrality Index (CI) by Sector

	Whole sample				Lower-income countries			
Sectors (Δ%)	CI_A	CI_I	CI_{MS}	CI_{TS}	CI_A	CI_I	CI_{MS}	CI_{TS}
Agriculture	-0.68	-0.10	-0.03	-0.08	-1.29	-0.22	0.03	-0.07
Industry	3.25	2.32	2.37	4.85	6.90	5.56	4.65	7.20
Modern Services	-1.15	-1.72	6.00	1.04	-1.15	-1.72	12.08	0.88
Traditional Services	-1.70	-1.15	2.70	4.22	-3.72	-1.68	3.52	7.85

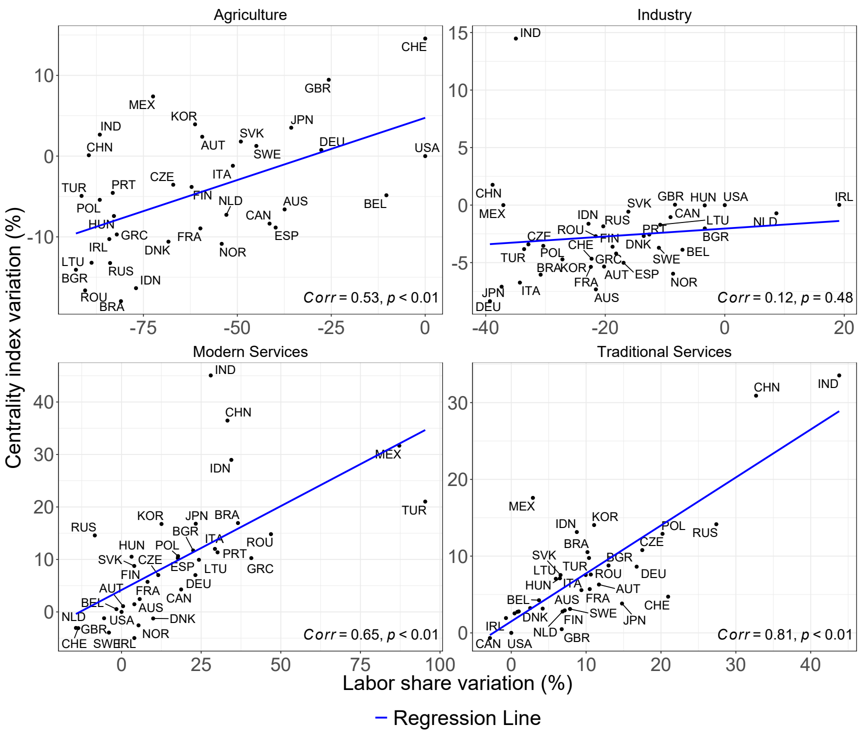
Notes: **(1)**: This table shows the sectoral variation in Bonacich–Katz Centrality Index after removing sector-by-sector distortions. The row indicates the sector in which distortions are eliminated, and the column shows the variable being analyzed. **(2)**: CI_A, CI_I, CI_{MS} and CI_{TS} refer to the percentage change in Bonacich-Katz centrality index from agriculture, industry, modern services, and traditional services, respectively. **(3)**: We consider lower-income countries to be those whose GDP per worker is below the median.

Table 4 shows that the counterfactual scenario without distortions in the industrial sector generates positive spillovers across all sectors in both samples, indicating that the entire economy would become more interconnected. Reducing distortions in the industrial sector can, through network effects, lead to relatively larger increases in the centrality of the services sector than in the industrial sector itself. For example, in the full sample, the centrality index for the industrial sector would rise by 2%, while it would increase by 2% for modern services and 5% for traditional services.

Service sectors also display notable increases in the centrality index, particularly in lower-income countries. Modern services, in particular, show the largest self-centrality increase (12%), indicating strong intra-sectoral linkages. Moreover, modern services are the only sector in lower-income countries that experience an increase in centrality under all sectoral counterfactuals: 0.03% in the agriculture counterfactual, 5% in the industry counterfactual, and 4% in the traditional services counterfactual (column CI_{MS}).

These network effects, captured by the centrality index, are closely linked to structural transformation. Figure 8 presents results for all four sectors, illustrating the relationship between the change in labor share and the change in the centrality index when all distortions are removed. A positive correlation emerges for all sectors except industry, with a particularly strong association for services. Sectors that experience a greater increase in centrality also tend to absorb more workers. This pattern is intuitive: as sectors become more central, they expand their role as suppliers to other sectors, which in turn increases their production needs and drives higher labor demand. These findings underscore the importance of accounting for production network linkages when analyzing structural transformation.

Figure 8: Percentage Change in Labor Share and Centrality Index After Removing All Sectoral Distortions



Notes: **(1)** This figure presents, for each sector, the variation in labor shares and the Bonacich-Katz centrality index following the removal of all distortions. **(2)** Corr: Pearson Correlation; p: Correlation p-value.

5 Policy Implications

We have shown that reducing distortions in the services sector can generate substantial economic gains by boosting activity through intermediate input channels. While our approach emphasizes a general framework based on sectoral wedges, empirical studies have provided complementary evidence by evaluating the effects of specific reforms. These studies consistently find that developing economies, in particular, stand to benefit significantly from service sector liberalization. For instance, Arnold et al. (2016) investigate India's post-1991 reforms in banking, telecommunications, insurance, and transport, using panel data for about 4,000 manufacturing firms from 1993–2005. Their findings show that a one-standard-deviation increase in the liberalization index led to productivity increases of 11.7% for domestic firms and 13.2% for foreign firms. Among the various services, transport reforms had the largest impact, followed by telecommunications and banking, while insurance reforms benefited only foreign firms. The authors argue that the reforms enhanced manufacturing performance by improving service quality, increasing access (even in rural areas), enhancing reliability, and reducing upstream market power—thereby promoting innovation and downstream efficiency. Importantly, these productivity gains occurred even after goods trade had already been liberalized, highlighting the unique role of services reforms as a driver of industrial growth.

Further macroeconomic evidence is offered by Lee and McKibbin (2018), who use a general equilibrium model to simulate the consequences of sustained services productivity growth in Asia. Their results show that such shocks raise long-run GDP and have strong transitional effects via investment surges, labor reallocation, and inter-sector linkages. Related insights emerge from Duggan et al. (2013), who examine the Indonesian experience of relaxing FDI restrictions in services like transport and utilities after the Asian financial crisis. They find that these reforms accounted for approximately 8% of the total observed growth in manufacturing TFP. Simulations suggest that reducing services' barriers to levels seen in more open economies would yield additional TFP gains of 5–6%. These findings are reinforced by broader cross-country studies, such as Dabla-Norris et al. (2016), which document that liberalizing services FDI and reducing entry barriers systematically raise productivity in both services and manufacturing, with the largest returns observed in middle-income countries. Given the increasingly central role of services in input-output structures, especially in emerging economies, reforming these sectors is viewed as a high-yield strategy for sustaining growth. The evidence suggests that modern services—when improved through better infrastructure, digital access, and regulatory capacity—function as new engines of development. Similar results have been found in countries such as the Czech Republic (Arnold et al., 2011), Ukraine (Shepotylo and Vakhitov, 2015), Chile (Fernandes and Paunov, 2012), and others (Arnold et al., 2008; Tarr, 2012).

The policy implications are clear: governments should focus on removing distortions in service industries, such as restrictive licensing, foreign equity limits, and bureaucratic red tape. Doing so strengthens inter-sectoral linkages and catalyzes broad-based productivity growth, thereby positioning services as a key channel for structural transformation. These benefits are amplified when reforms target upstream bottlenecks in industrial and infrastructure sectors, such as electricity, logistics, and raw materials. Many developing economies face severe inefficiencies in these sectors, which act as "weak links" that limit the performance of downstream users. Given the strong forward linkages of manufacturing and modern services, improvements in upstream sectors can propagate widely. This logic aligns with the insights from network-based development theories (Jones, 2011), which suggest that removing constraints in low-productivity sectors can yield economy-wide multipliers. Empirical support comes from OECD studies showing that deregulation in energy, transport, and communication has raised economy-wide labor productivity by about 5%, and manufacturing productivity by more than 10% (Andrews et al., 2025). In other words, manufacturers reap disproportionately large benefits from reforms targeting upstream bottlenecks.

For developing countries, the benefits from tackling upstream distortions are especially large. Dabla-Norris et al. (2016) estimate that if countries in Africa, Asia, or Latin America lowered services and input costs to OECD levels, they would experience significant acceleration in industrialization and aggregate output growth. Structural models confirm that production networks play a critical role in amplifying these effects. Reducing sector-specific wedges to U.S. levels can increase output by approximately 30% on average—and by 50% in developing countries—while also speeding up the shift of resources toward modern, high-productivity services. These gains are not merely sectoral: they are driven largely by network spillovers. Enhancing productivity in one sector lowers the cost and improves the availability of intermediate inputs for others, thereby lifting the entire production system. For example, reducing frictions in the services sector benefits manufacturing and agriculture indirectly through cheaper logistics, finance, and communication. This underscores the need to view reform through a network lens. Policies aimed at strengthening inter-sectoral connectivity—such as supply chain infrastructure, digital platforms, or logistics upgrades—can significantly magnify the returns to targeted reforms.

Countries that are more integrated into dense production networks derive larger gains from domestic reforms, as improvements propagate along the chain, including to foreign partners. Jakubik and Zhou (2025) find that deep liberalization of services trade would raise welfare by about 3% on average, and by over 8% in developing economies with highly connected production networks. Moreover, these reforms generate cross-border spillovers: advanced economies supplying intermediate goods benefit when developing countries lower service barriers, making such reforms mutually beneficial. In sum, the recent literature—spanning firm-level data, structural models, and policy simulations—strongly supports prioritizing reforms in services and upstream sectors. For emerging and developing economies, these reforms offer a powerful lever to unlock productivity, accelerate structural transformation, and benefit from the compounded effects of better-connected production systems.

6 Conclusion

This paper develops a multi-sector general equilibrium model with intermediate goods to quantitatively assess the rising importance of service sectors within the production network, as observed in the data. We document substantial cross-country differences in production structures: the industrial sector tends to dominate in lower-income economies, while service sectors—both modern and traditional—are more prominent in developed countries. Our quantitative framework is able to replicate the production networks of countries when introducing country-specific sectoral distortions.

We find large effects of removing the sectoral distortions to the US levels and making the production networks converge, mainly in lower-income countries. As sectors become more integrated, the use of intermediate inputs rises, and aggregate gross output increases by 27% on average and by 50% in lower-income countries, implying a fall in their productivity gap to the United States of almost a third on average. The service sectors become more central in the production network and countries accelerate their structural transformation towards the service sectors, especially the modern services sector. Eliminating the distortions sector by sector shows the importance of network effects. When the distortions faced by modern sector firms are eliminated, for instance, output per worker rises at least by 5% in all sectors, with the use of intermediates increasing very significantly.

Our analysis identifies policy priorities for reducing income disparities and increasing economic resilience. Given the role of services—particularly modern services—as providers of intermediate inputs, policymakers should focus on measures that raise sectoral productivity, such as investments in digital infrastructure, human capital formation, and regulatory reforms to lower market frictions. In parallel, strengthening intersectoral linkages through supply chain coordination, logistics improvements, and lower transaction costs in the exchange of intermediate goods can improve allocative efficiency and support economic development.

Our framework abstracts from real-world complexities by assuming homogeneous workers and uniform wages across sectors. Extending the model to include sectoral mobility frictions or worker heterogeneity would add realism but also increase analytical complexity, and is left for future research. Since modern services often generate higher value added and greater demand for skilled labor, introducing heterogeneity would likely magnify the gains from structural transformation toward that sector.

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Appendix A Model Solution and centrality index

A.1 Model solution

To solve the equilibrium first we calculate the labor amount L_i and then the prices p_i. First, to calculate the labour we can rewrite Equation (5) as: $Q_i = (1+\tau_i^w)wL_i/(\sigma_i p_i)$, and replace in Equation (4) to get the demand of X_{ij} in terms of L_i:

$$X_{ij} = \left(\frac{1+\tau_i^w}{1+\tau_{ij}^X}\right)\left(\frac{1-\sigma_i}{\sigma_i}\right)\frac{\beta_{ij}wL_i}{p_j}. \tag{10}$$

Replacing Equation (10) in Equation (2) we have:

$$Q_i = A_i L_i \left(\frac{1-\sigma_i}{\sigma_i}(1+\tau_i^w)w\right)^{(1-\sigma_i)} \prod_{j\in N}\left(\frac{\beta_{ij}}{(1+\tau_{ij}^X)p_j}\right)^{(1-\sigma_i)\beta_{ij}}. \tag{11}$$

To get the solution of equilibrium we can use Equations (10) and (11) to rewrite Equation (9) as:

$$G_j L_j = c_j + \sum_{i\in N} B_{ij} L_j. \tag{12}$$

Note that G_i and B_{ij} are simply Q_i and X_{ij} divided by L_i, respectively. The next steps are to divide both sides of the Equation (12) by G_i, transform the system of equations into matrix form and solve to find the amount of labor L_i in each sector:

$$\mathbf{L} = \left(\mathbf{I} - \hat{\mathbf{B}}'\right)^{-1} \hat{\mathbf{c}}, \tag{13}$$

where $\mathbf{I}$ is the identity matrix, and $\hat{\mathbf{B}}$ and $\hat{\mathbf{c}}$ are B_{ij} and c_i divided by G_i, respectively.

To obtain prices, we substitute Equation (11) into (5) and take the logarithm, which implies:

$$\ln p_i - (1-\sigma_i) \sum_j \beta_{ij} \ln p_j = \Phi_i, \tag{14}$$

where

$$\Phi_i = -\ln A_i - (1-\sigma_i)\ln(1-\sigma_i) - \sigma_i \ln(\sigma_i) - (1-\sigma_i)\sum_j \beta_{ij} \ln \beta_{ij}$$
$$+ \sigma_i \ln(w) + \sigma_i \ln(1+\tau_i^w) + (1-\sigma_i)\sum_j \beta_{ij} \ln(1+\tau_{ij}^X).$$

This system of equations can be written in matrix form

$$\hat{\mathbf{p}} - \mathbf{D}\boldsymbol{\beta}'\hat{\mathbf{p}} = \boldsymbol{\Phi},$$

and solved to find vector prices $\hat{\mathbf{p}}$:

$$\hat{\mathbf{p}} = \left(\mathbf{I} - \mathbf{D}\boldsymbol{\beta}'\right)^{-1} \boldsymbol{\Phi}, \tag{15}$$

where $\hat{\mathbf{p}}$ is the logarithm of vector prices and $\mathbf{D}$ is a diagonal matrix defined as $\mathbf{D} = \mathrm{diag}(1-\sigma_i, \cdots, 1-\sigma_N)$. If we take the exponential of $\hat{\mathbf{p}}$ we then have a vector of sectoral prices that depend on TFP, and constants.

A.2 Bonacich-Katz centrality index

The Bonacich-Katz centrality index measure the importance of a sector as supplier to economy. According to Grassi and Sauvagnat (2019) Bonacich-Katz centrality index can be defined by:

$$b_i = \gamma_i + \sum_j b_j \Sigma_{ji}, \tag{16}$$

where $\gamma_i = \frac{c_i}{C}$ is the importance of sector i as supplier to final demand and $\Sigma_{ji} = \frac{X_{ij}}{Q_i}$.[23] This shows that the centrality of a sector is equal to the importance of that sector as a supplier to the final demand plus the weighted sum of the centrality of its customer sectors. This equation is a system with four equations with four unknowns, that is, the Bonacity-Katz centrality index for each sector. The solution of this system can be written as follows.

$$b' = \gamma'(I - \Sigma)^{-1} \tag{17}$$

where b' is the centrality vector.

Appendix B Numerical exercises

Table B1 presents the effects of removing distortions in each sector on the main variables of the four sectors of the economy. Column II represents sectoral intermediate inputs; GO corresponds to gross output; Productivity is measured as gross output per worker; Employment refers to the number of workers; and Centrality corresponds to the Bonacich-Katz Centrality Index.

[23]We highlight that c_i is sectoral consumption and $C = \sum_{i=1}^{N} p_i c_i$.

Table B1: Percentage Change in Main Variables by Sector When Eliminating Distortions in Each Sector

Distortion Removed From	Sector	II	GO	Productivity	Employment	Centrality
Agriculture	Agriculture	-0.53	-1.20	92.71	-41.50	-0.68
	Industry	0.33	0.25	-0.24	0.49	-0.10
	Modern Services	-0.25	-0.24	-0.13	-0.11	-0.03
	Traditional Services	-0.68	-0.45	-0.14	-0.31	-0.08
Industry	Agriculture	6.04	5.14	21.47	-12.44	3.25
	Industry	8.17	10.32	-2.36	14.90	2.32
	Modern Services	14.51	10.99	7.26	3.21	2.37
	Traditional Services	28.89	17.13	7.21	8.89	4.85
Modern Services	Agriculture	-2.85	-2.18	5.49	-7.09	-1.15
	Industry	-4.18	-2.94	6.86	-8.98	-1.72
	Modern Services	31.98	26.63	4.54	24.42	6.00
	Traditional Services	18.58	11.83	5.36	5.99	1.04
Traditional Services	Agriculture	-7.46	-6.68	4.69	-10.53	-1.70
	Industry	-4.58	-3.50	5.56	-8.36	-1.15
	Modern Services	17.31	12.38	5.68	6.20	2.70
	Traditional Services	22.94	16.90	5.68	10.73	4.22

Notes: (1) This table shows the sectoral variation in the main variables after removing sector-by-sector distortions. (2) II refers to intermediate inputs; GO to gross output; productivity to gross output per worker; employment to the quantity of labor; and centrality to the Bonacich–Katz centrality index.

Appendix C US parameters

Table C1: β_{ij} from US

Sector	Agriculture	Industry	Modern Services	Traditional Services
Agriculture	0.23	0.73	0.00	0.04
Industry	0.02	0.58	0.16	0.24
Modern Services	0.01	0.15	0.46	0.38
Traditional Services	0.02	0.33	0.28	0.38

Table C2: α_i and σ_i from US

Sector	α	σ
Agriculture	0.01	0.15
Industry	0.16	0.20
Modern Services	0.32	0.27
Traditional Services	0.52	0.46

Appendix D TFP calibration relative to US

Table D1: Sectoral TFP of 35 countries relative to US

Country	Code	Agriculture	Industry	Modern Services	Traditional Services
Australia	AUS	1.06	0.98	0.97	0.88
Austria	AUT	0.89	0.86	0.94	1.04
Belgium	BEL	1.08	1.06	0.94	1.23
Brazil	BRA	0.41	0.69	0.54	0.40
Bulgaria	BGR	0.60	0.50	0.69	0.64
Canada	CAN	1.04	0.94	0.76	0.95
China	CHN	0.30	0.66	0.85	0.28
Czechia	CZE	1.22	0.67	0.83	1.06
Denmark	DNK	1.26	0.92	0.88	0.92
Finland	FIN	0.98	0.90	0.82	1.15
France	FRA	1.06	0.89	0.88	1.02
Germany	DEU	1.04	0.87	0.82	1.01
Greece	GRC	0.58	0.68	0.81	0.81
Hungary	HUN	1.03	0.55	0.77	0.96
India	IND	0.17	0.44	0.48	0.39
Indonesia	IDN	0.14	0.63	0.58	0.26
Ireland	IRL	1.31	1.01	1.20	1.04
Italy	ITA	0.93	0.92	0.97	1.06
Japan	JPN	0.26	0.85	0.76	0.87
Lithuania	LTU	0.87	0.59	0.69	0.69
Mexico	MEX	0.38	0.57	0.70	0.83
Netherlands	NLD	1.26	0.97	0.82	0.99
Norway	NOR	0.81	1.25	1.01	1.00
Poland	POL	0.72	0.59	0.86	0.97
Portugal	PRT	0.61	0.72	0.82	0.88
Romania	ROU	0.31	0.54	0.70	0.89
Russia	RUS	0.32	0.54	0.67	0.67
Slovakia	SVK	1.03	0.73	0.86	1.06
South Korea	KOR	0.36	1.00	0.89	0.98
Spain	ESP	0.81	0.99	0.79	0.96
Sweden	SWE	1.46	0.86	0.94	0.99
Switzerland	CHE	0.39	0.97	0.91	1.01
Turkey	TUR	0.53	0.65	0.85	0.92
United Kingdom	GBR	0.85	0.94	0.72	0.89
United States	USA	1	1	1	1

Appendix E Sectoral Classification

Table E1: Sectoral classification

Sector names	Sector group
Crop and animal production, hunting and related service activities	Agriculture
Forestry and logging	Agriculture
Fishing and aquaculture	Agriculture
Mining and quarrying	Industry
Manufacture of food products, beverages and tobacco products	Industry
Manufacture of textiles, wearing apparel and leather products	Industry
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Industry
Manufacture of paper and paper products	Industry
Printing and reproduction of recorded media	Industry
Manufacture of coke and refined petroleum products	Industry
Manufacture of chemicals and chemical products	Industry
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Industry
Manufacture of rubber and plastic products	Industry
Manufacture of other non-metallic mineral products	Industry
Manufacture of basic metals	Industry
Manufacture of fabricated metal products, except machinery and equipment	Industry
Manufacture of computer, electronic and optical products	Industry
Manufacture of electrical equipment	Industry
Manufacture of machinery and equipment n.e.c.	Industry
Manufacture of motor vehicles, trailers and semi-trailers	Industry
Manufacture of other transport equipment	Industry
Manufacture of furniture; other manufacturing	Industry
Repair and installation of machinery and equipment	Industry
Electricity, gas, steam and air conditioning supply	Industry
Water collection, treatment and supply	Industry
Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	Industry
Construction	Industry
Wholesale and retail trade and repair of motor vehicles and motorcycles	Traditional Services
Wholesale trade, except of motor vehicles and motorcycles	Traditional Services
Retail trade, except of motor vehicles and motorcycles	Traditional Services
Land transport and transport via pipelines	Traditional Services
Water transport	Modern Services
Air transport	Modern Services
Warehousing and support activities for transportation	Modern Services
Postal and courier activities	Traditional Services
Accommodation and food service activities	Traditional Services
Publishing activities	Modern Services
Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	Modern Services
Telecommunications	Modern Services
Computer programming, consultancy and related activities; information service activities	Modern Services
Financial service activities, except insurance and pension funding	Modern Services
Insurance, reinsurance and pension funding, except compulsory social security	Modern Services

Continued on next page

Table E1: Sectoral classification (Continued)

Sector names	Sector group
Activities auxiliary to financial services and insurance activities	Modern Services
Real estate activities	Modern Services
Legal and accounting activities; activities of head offices; management consultancy activities	Modern Services
Architectural and engineering activities; technical testing and analysis	Modern Services
Scientific research and development	Modern Services
Advertising and market research	Traditional Services
Other professional, scientific and technical activities; veterinary activities	Traditional Services
Administrative and support service activities	Traditional Services
Public administration and defence; compulsory social security	Traditional Services
Education	Traditional Services
Human health and social work activities	Traditional Services
Other service activities	Traditional Services
Activities of households as employers; undifferentiated goods-and services-producing activities of households for own use	Traditional Services
Activities of extraterritorial organizations and bodies	Modern Services

Note: Adapted from World Input-Output Database.