Production Networks and Structural Transformation

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June 13, 2026

Abstract

We examine the aggregate effects of greater integration of traditional and modern services into national supply chains. Using international input–output data, we document substantial cross-country variation in the composition of intermediate goods and identify distinct sectoral patterns. That is, modern services are more prevalent in advanced economies and are becoming increasingly central within production networks. To evaluate the implications, we construct a multisector general equilibrium model incorporating firm-level frictions in labor hiring and intermediate input purchases. These distortions weaken intersectoral linkages and distort production efficiency. Reducing them to US levels generates significant gains—aggregate output increases by 27% on average and by 50% in developing economies—while accelerating structural transformation toward services, particularly modern services, and enhancing 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 propagating technological improvements and amplifying 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 from access to cheaper inputs. The resulting price reductions, in turn, feed back into the industrial sector as it purchases more inputs from those same sectors. This multiplier effect depends on the density and structure of production network linkages, which vary substantially across stages of economic development. While intermediate inputs from the industrial sector are more important in poorer economies, intermediate inputs from the modern services sector are more important in rich economies. Over time, the relevance of agricultural and industrial inputs has declined, whereas the role of services—particularly modern services—as intermediate inputs has exhibited a strong positive trend. This pattern of deindustrialization in intermediate input use mirrors the broader trends in employment and final production documented by Rodrik (2016).

In this paper, we first document large cross-country differences in the composition of intermediate goods and identify distinct sectoral trends, with modern services being more prevalent in advanced economies and increasingly central to production networks worldwide. We then assess both the sectoral and aggregate effects of changes in production network structures, particularly the growing integration of modern and traditional services into supply chains. To conduct this analysis, we introduce firm-level frictions into a multisector 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 input demand from that sector and its relative size but also lowers labor productivity in other sectors, impairing

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

the economy's overall performance.

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. Sector-specific labor and intermediate input distortions are calibrated as wedges that reproduce each country's observed cost shares, taking the US as the zero-distortion benchmark. Additionally, data on gross output per worker (in PPP terms) are used to estimate total factor productivity for each sector and country. The 56 WIOD sectors are grouped into four broad categories: agriculture, industry, modern services, and traditional services, following Ferreira and Silva (2015) for the service sector classification.

Motivated by the documented cross-country gaps in service integration and their central role in production networks, we assess the potential gains from reducing the frictions that restrict these linkages.[2] Using our calibrated model, we conduct a baseline counterfactual in which labor and intermediate input wedges in each country and across all sectors are reduced to the levels observed in the US, treated as the least-distorted economy in our sample. Lowering these frictions strengthens intersectoral connections, allowing sectors to access inputs more efficiently and reshaping the composition of production. Gross domestic product (GDP) per worker increases by 18% on average,[3] while the overall use of intermediate inputs rises by approximately 24%, generating an average productivity gain of 11% and an increase in aggregate gross output of 27%. The effects are even more pronounced 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 US narrows by roughly 30% on average.

At the sectoral level, eliminating all frictions increases employment, on average, by approximately one-third in modern services and one-quarter in traditional services, while it decreases by 9% in industry and by slightly more than half in agriculture. The network

[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.

centrality index rises most sharply for modern services, followed by traditional services, but declines for agriculture and industry. Among lower-income countries, employment in modern services grows by two-thirds, whereas agricultural employment falls by three-quarters.

We also eliminate distortions sector by sector to highlight the importance of production network structures and the amplifying effects of intersectoral linkages. Because sectors occupy different positions within each country's production network, we find that the largest average gains arise from removing the cost wedges faced by firms in 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, sectoral gross output per worker increases across all sectors by between 4.5% and 7% (between 6.3% and 11% for lower-income countries), with the largest improvement occurring in the industrial sector due to productivity spillovers from modern services through the production network. Removing distortions in industry and traditional services raises GDP per worker by 2.8% and 5%, respectively (2.9% and 9% for lower-income countries).

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 emphasized how sectoral linkages shape the transmission of shocks, the diffusion of productivity gains, and the dynamics of aggregate output. For instance, Kazekami (2024) demonstrated that stronger connections between intermediate goods sectors facilitate productivity spillovers throughout the economy. Building on this insight, several studies argued that shocks propagated through production networks 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 are key determinants of economic outcomes. Moro (2012) underscored the importance of the sectoral share of intermediate goods for evaluating the effects of shocks or production changes, while Miranda-Pinto (2021) found that a more diversified network can dampen GDP growth volatility, particularly 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 special emphasis on the expanding 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) showed that in nine transition economies, productivity in manufacturing surpasses that of services, suggesting that labor reallocation toward services may reduce aggregate productivity. Similarly, Duarte and Restuccia (2010) found that shifting labor from agriculture to manufacturing raises productivity, whereas a shift toward services diminishes it. Ferreira and Silva (2015) noted that low productivity in the traditional services sector across nine Latin American countries constrains overall productivity growth. We contribute to this literature by calibrating our model to 35 countries and analyzing how strengthening intersectoral linkages influences 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 documented how regulatory and institutional changes can reduce distortions, enhance efficiency and generate spillover effects across the economy. A notable example is Grassi and Sauvagnat (2019), who simulated, for the French "Transport Equipment" sector, a 21% reduction in the sectoral markup (wedge). This reform lowered prices, stimulated production, and produced positive effects for interconnected sectors, ultimately increasing GDP by 0.08%. Although profits in the target sector declined, the reduction alleviated distortions, improved resource allocation, and enhanced economic welfare.[5]

The French case is not unique. Similar reforms aimed at reducing barriers and improving efficiency have yielded positive outcomes in various contexts. In India, for instance,

[5]Grassi and Sauvagnat (2019) defined wedges as sectoral markups arising from imperfect competition, which distort production networks and hinder the efficient allocation of resources.

the post-1991 liberalization of the banking, telecommunications, insurance, and transportation sectors generated substantial industrial productivity gains through improvements in service quality, reliability, and accessibility (Arnold et al., 2016). Comparable evidence emerged for Indonesia (Duggan et al., 2013), the Czech Republic (Arnold et al., 2011), Ukraine (Shepotylo and Vakhitov, 2015), Chile (Fernandes and Paunov, 2012), and in broader cross-country studies (Dabla-Norris et al., 2016), with particularly strong effects in developing economies. We extend this literature by quantitatively assessing the aggregate effects of broad-based service sector reforms—especially 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 describes the model calibration and counterfactual exercises. Section 5 discusses the policy implications, and Section 6 concludes.

2 Empirical Analysis

In this section, we describe the datasets used in the empirical analysis and present key stylized facts. We begin by outlining the World Input–Output Tables (WIOTs) and Socio-Economic Accounts (SEAs) from the 2016 release of the WIOD.[6]

2.1 Datasets

We use 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 use data from the SEAs, which include information on input quantities, prices, and volumes, as well as data on value added, capital stock, number of workers, and hours worked. Small economies with a workforce of fewer than two million people or with incomplete data were excluded, yielding a final sample of 35 countries. The list of countries and their acronyms is provided in Table D1 in Appendix D.

[6] Timmer et al. (2015) and Feenstra et al. (2015) for details.

Following the International Standard Industrial Classification of All Economic Activities (ISIC, Rev. 4), we classify the 56 sectors identified in SEA into four broad categories: agriculture, industry, modern services, and traditional services.[7] The agriculture category includes crop and animal production, hunting, fishing, forestry, and logging. The industry category covers manufacturing, electricity, gas, water, mining and quarrying, waste treatment and disposal, and construction. Regarding services, we follow Ferreira and Silva (2015) in defining modern services as those with the highest average value added per worker (e.g., financial services, real estate activities, insurance, scientific research, management, and consultancy). Traditional services include education, healthcare, postal and courier activities, transportation, public administration and defense, and related activities.[8] On average, value added per worker in modern services is approximately 2.4 times higher than in traditional services.

This classification reflects the heterogeneity of the service sector, where activities differ widely in skill requirements, productivity levels, and economic importance. For instance, workers in education typically have different skills and productivity levels from those in tourism. The full classification of sectors is presented in Table E1 in Appendix E.

To enable cross-country comparisons of monetary values, we also employ gross output PPP data from the Groningen Growth and Development Center (GGDC) Productivity Level Database. The GGDC provides data on relative prices and labor productivity for 84 countries and 12 sectors, for the base years 2005, 2011, and 2017. These data are derived from the International Comparisons Program, which estimates PPPs for a global sample of countries. Since 2011 is the most recent GGDC year compatible with the WIOD, we use data from that year for our analysis.[9]

[7]ISIC Rev. 4 can be viewed on the United Nations website: https://unstats.un.org.

[8]A similar classification is used by Rogerson (2008), Eichengreen and Gupta (2011), and Eichengreen and Gupta (2013).

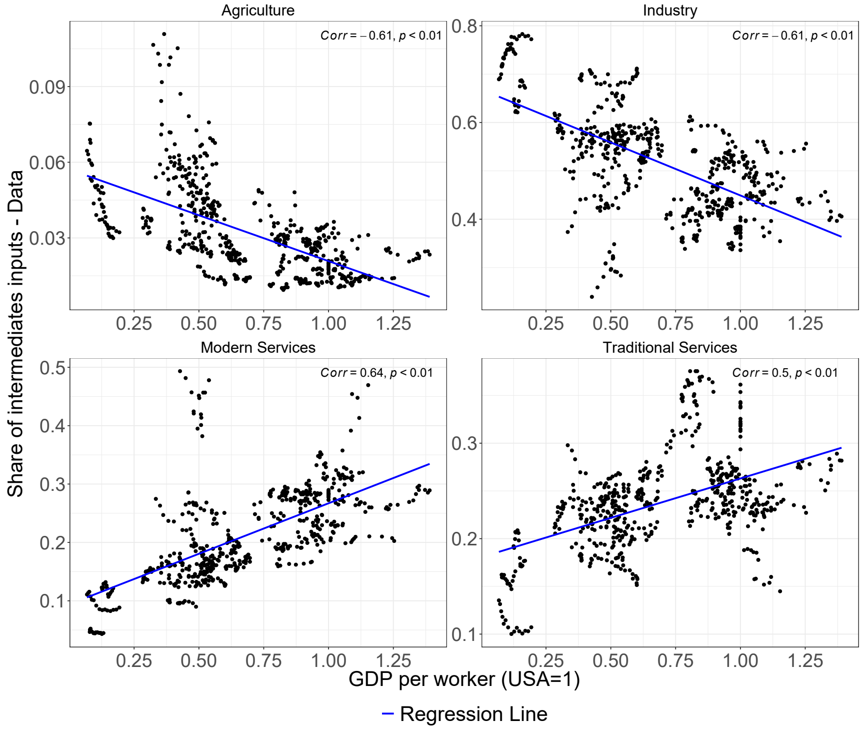
[9]Inklaar et al. (2024) for details. The mapping from our sectors to the GGDC database is as follows: agriculture corresponds to *Agriculture*; industry to *mining, manufacturing, utilities, and construction*; modern services to *transport, business, finance, and real estate*; and traditional services to *trade, government, and other services*.

2.2 Stylized Facts

The input–output matrix represents the flow of intermediate goods between sectors. These flows determine the pattern of trade across industries and form the basis of production networks, which act as mechanisms for propagating shocks. A positive (negative) productivity shock in an important sector generates a positive (negative) impact across all other sectors (Jones, 2011; Carvalho and Tahbaz-Salehi, 2019; Boehm et al., 2019; Fadinger et al., 2022).

There are notable cross-country differences in the structure of production networks and the use of intermediate goods, as illustrated in Figure 1. In less developed economies, intermediate inputs from agriculture and industry play a comparatively larger role, while modern services—and to a lesser extent, traditional services—are more prominent in advanced economies. Specifically, the Pearson correlation between aggregate GDP per worker and the share of intermediate goods from agriculture and industry is -0.59 and -0.50, respectively, whereas the correlation for modern services is 0.56. These findings align with the literature on structural change, which suggests that although agriculture and industry are central to the productive structure of less developed economies, their relative shares decline as economies become more service-oriented (Eichengreen and Gupta, 2013; Herrendorf et al., 2014; Herrendorf and Schoellman, 2018; Sposi, 2019).

Figure 1: Share of intermediate inputs and gross domestic product per worker, 2000:2014



Notes: **(1)** The share of intermediate inputs refers to 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) documented a trend of premature deindustrialization in low- and middle-income countries, both in terms of production and employment. Specifically, Rodrik (2016) employed a panel-data econometric model in which the dependent variable is the share of labor in manufacturing, while the controls capture demographic and income effects, along with country fixed effects.[10] Following Rodrik (2016), we estimate a similar specification to investigate whether deindustrialization in intermediate inputs has accelerated in more recent periods. Our specification is as follows:

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

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

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

Table 1 reports the results of the regression estimated using Eq. 1 for the four sectors. The key parameters of interest are the period dummies (i.e., D05, D08, D11, and D14), which indicate the share of intermediate inputs in each period relative to the baseline period 2000–2002. Columns (1) and (2), corresponding to agriculture and industry, show a declining trend in the total share of intermediate inputs over time, particularly in industry. Columns (3) and (4), representing modern and traditional services, reveal the opposite trend, especially for modern services. The share of both service sectors in total intermediate inputs rises, suggesting that production networks in these economies are becoming increasingly service-oriented.

These findings indicate a clear structural shift in production networks toward greater dependence on services—particularly modern services—in the use of intermediate inputs, alongside a diminishing role for agriculture and industry. This reorientation raises an important question for development: if economies were to adopt a production structure where modern and traditional services play more prominent roles, could this transformation help narrow income disparities across countries? In the next section, we explore this question by quantifying the aggregate effects of service sector integration using a multisector 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 relative to the total intermediate goods and services produced in the economy. **(2)** GDP (constant 2021 PPP$) and population data were obtained from the World Bank database. **(3)** Statistical significance levels are denoted as follows: $***p < 0.01$, $**p < 0.05$, and $*p < 0.1$. **(4)** The dataset spans 2000–2014. We use four time dummy variables—D05, D08, D11, and D14—representing the periods 2003–2005, 2006–2008, 2009–2011, and 2012–2014, respectively. The dummy for the baseline period 2000–2002 is omitted.

3 Model

In this section, we present an overview of the model. First, we describe the production technology and the optimization problem faced by firms. Second, we outline consumer preferences and the representative consumer's optimization problem. We then derive the equilibrium conditions and, finally, discuss intersectoral dependencies and the propagation of shocks through the production network.

3.1 Firms

In this economy, a continuum of homogeneous and competitive firms operates in each of the N productive sectors. Firms maximize profits by optimally choosing the amount of labor to hire and the quantity of intermediate goods to purchase. The production technology is defined as

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

where $\sum_{j \in N} \beta_{ij} = 1$, Q_i denotes the gross output of sector i, A_i represents TFP, L_i is the amount of labor employed, and X_{ij} is the matrix of intermediate goods (with rows indicating the sector of destination and columns indicating the sector of origin). Furthermore, σ_i measures 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 higher β_{ij} indicates that inputs from sector j are more important for production in sector i, whereas a lower value indicates limited relevance.

Firms face frictions in the form of cost wedges when hiring labor and purchasing intermediate inputs. The optimization problem of a representative firm is given by

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

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 is the wage rate, τ_i^w denotes 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

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

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

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 input demand from that sector and its overall size but also lowers labor productivity in other sectors, thereby impairing the economy's overall performance.

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 level 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 $i \in N$:

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

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's optimization problem, taking p_i and w as given, $\forall i \in N$.

2. L_i and X_{ij} solve the firm's optimization problem, taking p_i and w as given, $\forall i \in N$.

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

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

3. Markets clear:

   (a) The demand for labor by firms equals the total available supply:

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

   (b) The supply of each good equals total consumption demand by individuals plus the intermediate 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 Eq. (2) incorporates intersectoral interdependence through the use of intermediate inputs. This network structure implies that shocks in one sector can spill over to others. For example, if a sector becomes more efficient—through innovation, resource 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 its production and lowers the price of its intermediate good, prompting sector B to purchase more inputs from A and expand its own output. The resulting price decline in B's good then leads A to buy more from B, creating a feedback loop. The strength of these spillovers depends on the parameters β_{ij} and σ_i.

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 US data and then outlining the estimation of country-specific parameters for the rest of the sample.

The US We begin by calibrating the production and utility function parameters using data from the US in 2011. The US economy serves as our benchmark frictionless economy, from which we take all common parameters. Only TFP (A_i) 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 SEAs 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 computed directly from the input–output matrix for each country.[13] Furthermore, sectoral productivity (A_i) is calibrated endogenously to match gross output per worker in each sector.

Utility function parameters. The consumption share parameters α_i are calculated from the WIOT as the share of final household consumption expenditure attributed to each sector.[14] The nonhomothetic consumption term $\bar{c}_i$ is set to zero for 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 U.S. in 2011, based on SEA data.[15]

Exogenous normalization. We normalize 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.

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

[14]Table C2 in the Appendix.

[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 gross output per worker in sector i, Lsh_{agr} is the labor share of agriculture, and superscripts M and D denote the model and data (target statistics), respectively.

Other Countries. We assume that the preference and technology parameters are identical to those calibrated for the U.S. For each country in the sample, we 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 US prices as the benchmark. 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 US 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.

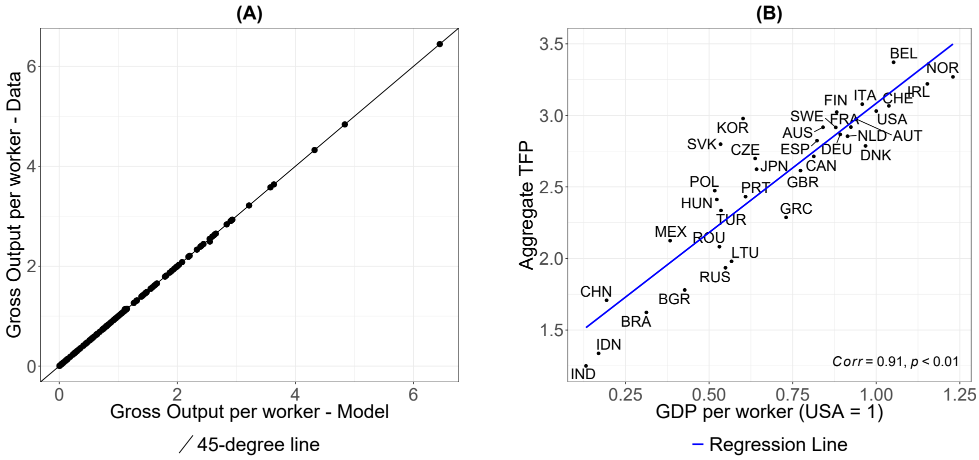
4.2 Results

In this section, we present the numerical results of the analysis. Panel (A) of Fig. 2 shows that across all sectors and countries, the model accurately replicates gross output per worker when expressed in a common set of prices. Panel (B) compares the aggregate TFP from the model—computed as the labor-share-weighted average of sectoral TFPs—with value added per worker in the data. As shown, these two measures exhibit a strong cross-country correlation, supporting the model's empirical validity.

The values obtained for TFP, A_i, are plotted in Fig. 3 for all countries and sectors. Appendix D provides the corresponding numerical values. As expected, productivity in all four sectors is positively associated with each country's level of development, indicating that more developed economies exhibit higher productivity across sectors.

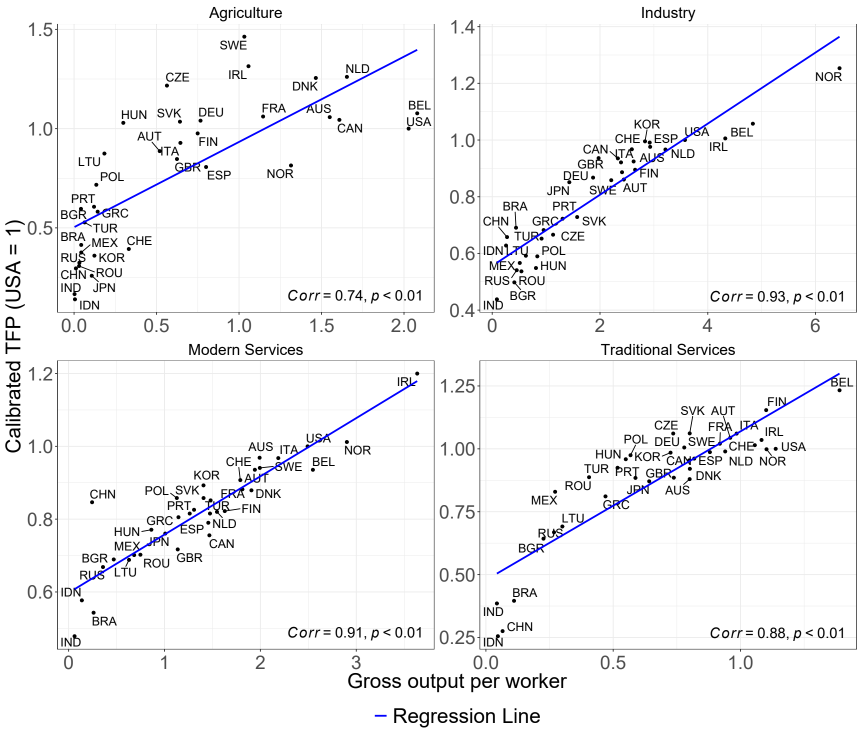
Figure 4 presents the model's performance in replicating the allocation of labor (Panel A) and intermediate inputs (Panel B) across sectors. In both cases, the correlation exceeds

Figure 2: Endogenous calibration—Model vs. data



Notes: **(1)** Panel (A) displays the model's fit for gross output per worker, plotting model predictions against observed data. The 45° line represents perfect match between the model and data. Panel (B) illustrates the correlation between value added per worker relative to the US and aggregate TFP, where aggregate TFP is calculated as the labor-share-weighted average of sectoral TFPs. **(2)** Corr: Pearson correlation; p: correlation p-value.

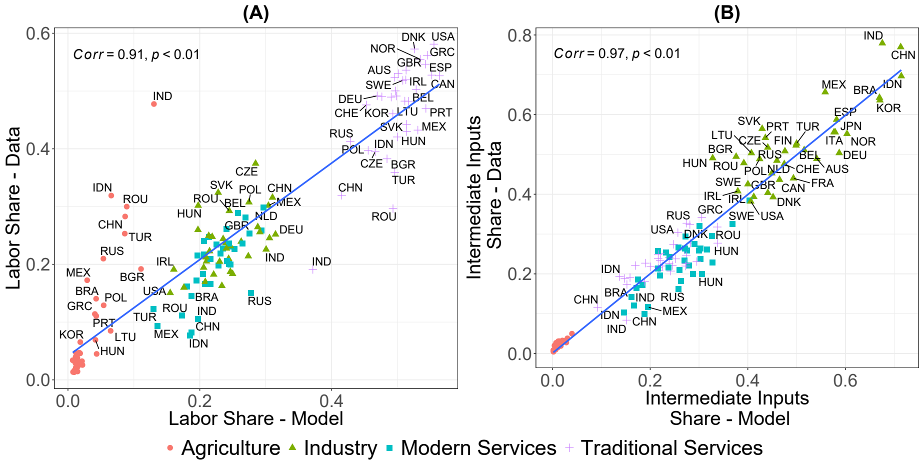
Figure 3: Calibration results—Total factor productivity and gross output per worker



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.

0.9, indicating that the model is able to capture the sectoral composition of the economies.

Figure 4: Model fit—Labor and intermediate inputs



Notes: **(1)** Panel (A) displays the model's fit for the labor share, plotting model predictions against observed data. Panel (B) presents the fit for the intermediate goods share. **(2)** The share of intermediate goods refers to the proportion of intermediate goods and services produced by a sector relative to the total intermediate goods and services produced, while the labor share represents the sector's share of total employment. **(3)** Corr: Pearson correlation; p: correlation p-value.

4.3 Counterfactual

The purpose of this section is to quantify the economic effects of increasing sectoral integration within supply chains. First, we evaluate the impact of reducing all sectoral distortions in each country to the levels observed in the US—specifically, the labor cost wedges τ_i^w and the intermediate input cost wedges $\{\tau_{ij}^X\}_{j=1}^N$, $\forall i$. Second, we assess the effects of eliminating distortions in each sector individually. Finally, we analyze the role of network effects, examining how removing sectoral distortions influences intersectoral linkages and labor reallocation through input–output connections.[16]

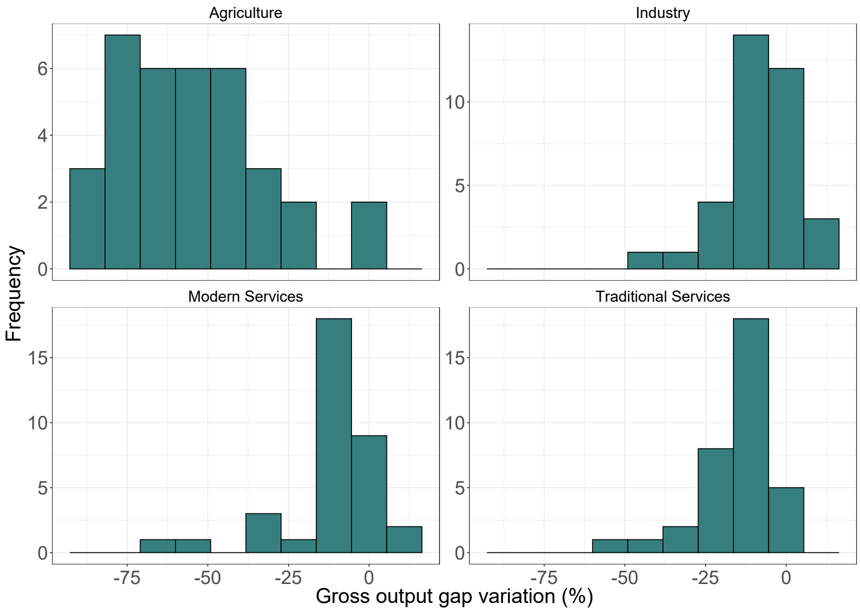
4.3.1 Effects of Eliminating All Sectoral Distortions

We now analyze a counterfactual scenario in which all cost wedges are eliminated across the entire economy. In this case, 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

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

wedges increases sectoral integration through supply chains, enhances productivity, and raises total output. Consequently, in nearly all countries, gross output per worker increases across all sectors, narrowing productivity gaps relative to the U.S., as illustrated in Figure 5.[17] The largest relative improvement occurs in agriculture, where the average reduction in the productivity gap reaches approximately 53%, although substantial gains are also observed in service sectors.

Figure 5: Histogram of changes in the sectoral productivity gap toof the US after all distortions are eliminated



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

Table 2 reports the average effects on each sector after eliminating all 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 approximately 10% and 6%, respectively. Productivity (Column 3), measured as gross output per worker, also rises across all sectors on average: by 173% in agriculture, 10% in industry, 19% in

[17] In a few cases, the productivity gap with the U.S. widens because the U.S. serves as the zero-distortion benchmark. Some countries exhibit negative distortions in certain sectors (i.e., wedges below US levels). Hence, reducing these to zero can lower productivity in those sectors, widening the overall gap.

modern services, and 20% in traditional services.[18]

Similarly, countries undergo significant structural transformation toward services (Column 4). Employment declines by 58% in agriculture and by 8.5% in industry, while it rises by 37% in modern services and 25% in traditional services. This transformation results in a marked increase in average gross output (Column 2): 64% in modern services and 54% in traditional services, but slight decreases in industry (-0.7%) and agriculture (-9%).

Interestingly, modern services exhibit the largest increase in the network centrality index, whereas agriculture and industry experience declines.[19] Specifically, the centrality index (Column 5) increases by 10% in modern services and by 8% in traditional services, while it decreases by 4.6% in agriculture and by 2.7% in industry. These results underscore the growing importance of both service sectors within the aggregate production network.

Table 2: Percentage changes in the main variables after 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.

We now turn to the aggregate effects on the overall 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 grows by 18%. Figure 6 presents the results by country for GDP per worker and intermediate inputs. As expected, the effects are stronger among poorer countries—defined as those with income per capita below the sample median—where distortions are more pronounced.[20]

Within this group, the use of intermediate inputs increases by 44% on average, com-

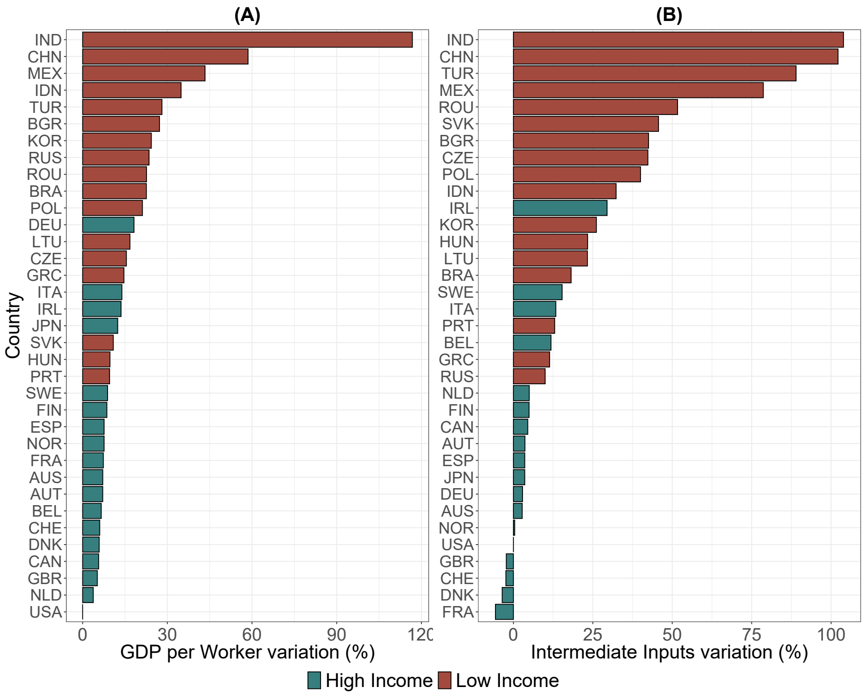
[18] Eliminating all distortions increases agricultural productivity by 172%. Although gross output decreases, the proportionally larger reduction in employment results in a substantial productivity gain.

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

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

pared with only 5% in richer countries. Similarly, GDP per worker rises by 29% in poorer economies and by 8% in richer ones. As illustrated in Fig. 6, countries such as India, China, Mexico, and Turkey experience substantial increases in both GDP per worker and intermediate input use—exceeding 75% in intermediate inputs—while wealthier nations exhibit smaller or even negative gains.

Figure 6: Percentage changes in gross domestic product 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)** High-income countries are defined as those whose GDP per worker is greater than or equal to the sample median; otherwise, the country is classified as low-income.

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 specific 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 removed in the counterfactual scenario, while each column reports the resulting effect on the gross output of the corresponding sector. Results are shown for both the full sample of countries and the subsample of lower-income economies.

As expected, removing distortions in agriculture yields only modest effects, as this sector plays a relatively limited role in most countries' production networks. In contrast, eliminating distortions in other sectors leads to substantially larger effects due to their centrality as suppliers of intermediate inputs. Specifically, when firms in the industrial sector face no distortions, gross output in that sector increases by 10% on average. Because other sectors can now expand their use of industrial intermediates, gross output rises by 5% in agriculture, 11% in modern services, and 17% in traditional services.

Table 3: Percentage changes in gross output after removing sectoral distortions

	Whole sample				Lower-income countries			
Sectors (Δ%)	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 reports the sectoral variation in gross output after removing distortions one sector at a time. Each row indicates the sector in which distortions are eliminated, and each 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)** Lower-income countries are defined as those whose GDP per worker is below the sample median.

Although gross output declines in some sectors, removing distortions in modern services increases labor productivity—measured as gross output per worker—across all sectors.[22] In this case, employment shifts from agriculture and industry toward service sectors, resulting in an average gross output increase of 27% in modern services and 12%

[21] Detailed results for other key variables are provided in Appendix B.

[22] Table B1 in Appendix B for the results of all sectoral counterfactuals.

in traditional services, while output falls by 2% in agriculture and 3% in industry due to reduced labor shares. Similarly, eliminating distortions in traditional services raises labor productivity across all sectors and triggers a further reallocation of employment from agriculture and industry toward services. In this scenario, 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 (Table B1 in Appendix B). The largest gain in GDP per worker occurs when distortions in modern services are removed, yielding an increase of 6% for the full sample and 10% for lower-income countries.

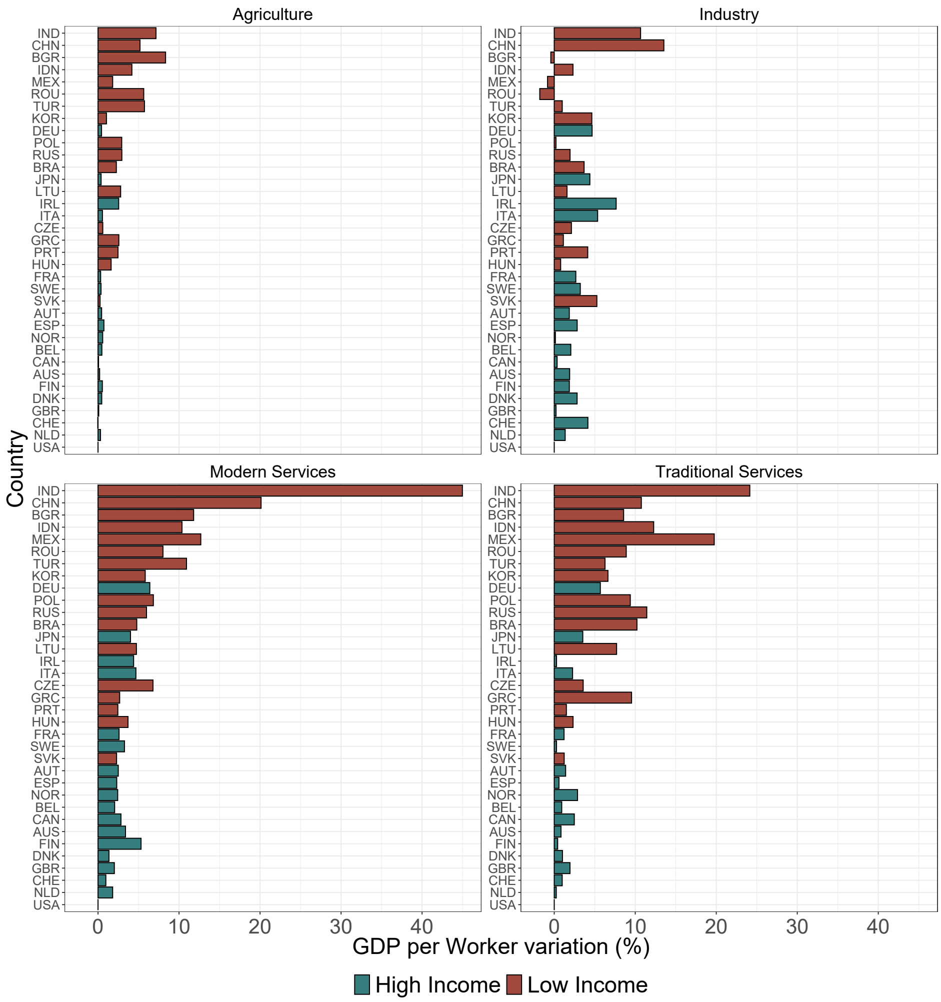
Table 3 also reports the average sectoral output effects of each counterfactual for lower-income countries. As shown, the qualitative patterns mirror those of the full sample, though the magnitudes are considerably larger. Specifically, when distortions are eliminated in industry, gross output rises 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 increases by 48%, while traditional services rise by 16%, and agriculture and industry experience small declines due to the large reallocation of labor toward modern services. Likewise, when distortions are removed in traditional services, gross output increases by 33% in that sector and by 21% in modern services, but decreases in agriculture and industry as labor shifts toward traditional services.

Figure 7 displays the variation in aggregate GDP per worker, country by country, resulting from 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 observe a significant rise in GDP per worker driven by increased use of intermediate inputs in each sector. The average effects are 0.5%, 2.6%, 2.9%, and 1.5% for developed countries, and 3.4%, 3%, 10%, and 9% for developing countries, respectively.

4.3.3 Network Effects

In the absence of production networks, each sector would produce exclusively for final consumption, rendering the concept of sectoral centrality irrelevant. In modern

Figure 7: Percentage change in gross domestic product per worker after removing sectoral distortions



Notes: **(1)** This figure shows the sectoral variation in GDP per worker after removing sector-by-sector distortions. **(2)** High-income countries are defined as those whose value added per worker is greater than or equal to the sample median; otherwise, the country is classified as low-income.

economies, however, sectors are interconnected through complex input–output relationships, where the output of one sector serves as an intermediate input for others. This interconnectedness implies that distortions or productivity changes in one sector can propagate throughout the economy via input linkages, amplifying or mitigating 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 represent 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 the subsample of lower-income economies.

The centrality index measures the extent to which a sector acts as a supplier of intermediate goods to others. A higher value indicates that a sector is more central within 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

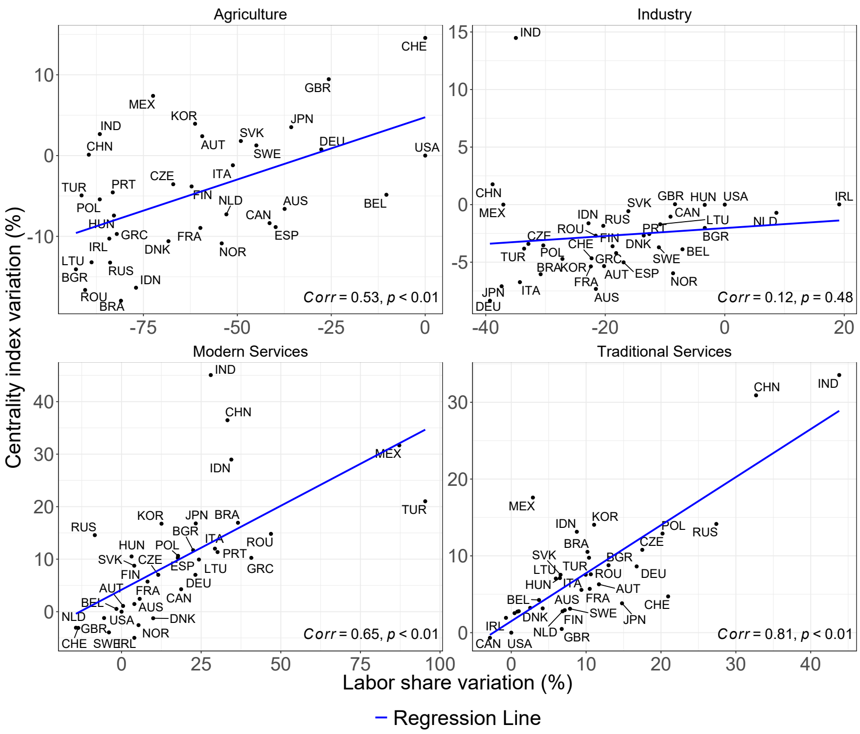
Notes: **(1)** This table reports the sectoral variation in the Bonacich–Katz centrality index after removing sector-by-sector distortions. Each row indicates the sector in which distortions are eliminated, and each column presents the variable being analyzed. **(2)** CI_A, CI_I, CI_{MS}, and CI_{TS} denote the percentage change in the Bonacich–Katz centrality index for agriculture, industry, modern services, and traditional services, respectively. **(3)** Lower-income countries are defined as those whose GDP per worker is below the sample 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 overall economy would become more interconnected. Reducing distortions in the industrial sector can, through network effects, produce relatively larger increases in the centrality of service sectors 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 exhibit notable increases in the centrality index, particularly in lower-income countries. Modern services, in particular, experience the largest self-centrality gain (12%), reflecting strong intrasectoral linkages. Moreover, modern services are the only sector in lower-income economies that show 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 tied 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 in services. Sectors that experience greater increases 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, thereby increasing production needs and driving higher labor demand. These findings highlight the critical role of production network linkages in shaping structural transformation.

Figure 8: Percentage change in labor share and centrality index after removing all sectoral distortions



Notes: **(1)** For each sector, this figure presents 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 stimulating activity through intermediate input channels. While our approach emphasizes a general framework based on sectoral wedges, empirical studies provide complementary evidence by assessing the effects of specific reforms. These studies consistently find that developing economies, in particular, benefit significantly from services sector liberalization. For instance, Arnold et al. (2016) examine India's post-1991 reforms in banking, telecommunications, insurance, and transport, using panel data for approximately 4,000 manufacturing firms from 1993–2005. Their findings indicate that a one-standard-deviation increase in the liberalization index led to productivity gains 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 mainly foreign firms. The authors argue that these reforms enhanced manufacturing performance by improving service quality, expanding access (including in rural areas), enhancing reliability, and reducing upstream market power—thereby fostering innovation and downstream efficiency. Notably, these productivity gains occurred even after goods trade had already been liberalized, underscoring the unique role of services reforms as a driver of industrial growth.

Further macroeconomic evidence is provided by Lee and McKibbin (2018), who used a general equilibrium model to simulate the effects of sustained productivity growth in services across Asia. Their results show that such shocks raise long-run GDP and generate strong transitional effects through investment surges, labor reallocation, and intersectoral linkages. Similar insights arose from Duggan et al. (2013), who analyzed Indonesia's experience with relaxing foreign direct investment (FDI) restrictions in services such as transport and utilities following the Asian financial crisis. They find that these reforms accounted for approximately 8% of the total observed growth in manufacturing TFP. Simulations further suggest that reducing barriers in services to the levels observed 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 documented that liberalizing services FDI and lowering entry barriers systematically raise productivity in both services and manufacturing, with the largest effects observed in middle-income countries. Given the increasingly central role of services in input–output structures—particularly in emerging economies—reforming these sectors represents a high-yield strategy for sustaining growth. The evidence suggests that modern services, when enhanced through better infrastructure, digital connectivity, and regulatory capacity, serve as new engines of development. Comparable results have been reported for the Czech Republic (Arnold et al., 2011), Ukraine (Shepotylo and Vakhitov, 2015), Chile (Fernandes and Paunov, 2012), and other countries (Arnold et al., 2008; Tarr, 2012).

The policy implications are clear: governments should prioritize removing distortions in service industries (e.g., such as restrictive licensing, foreign equity limits, and bureaucratic red tape). Doing so strengthens intersectoral linkages and catalyzes broad-based productivity growth, positioning services as a key driver of structural transformation. These benefits are magnified 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" constraining downstream performance. Given the strong forward linkages of manufacturing and modern services, improvements in upstream sectors can generate widespread gains. This logic aligns with network-based development theories (Jones, 2011), which argue that removing constraints in low-productivity sectors produces economy-wide multiplier effects. Empirical support comes from Organization for Economic Cooperation and Development (OECD) studies showing that deregulation in energy, transport, and communication raised aggregate labor productivity by approximately 5% and manufacturing productivity by more than 10% (Andrews et al., 2025). In essence, manufacturers benefit disproportionately from reforms that alleviate upstream constraints.

For developing countries, the potential gains from addressing upstream distortions are especially large. Dabla-Norris et al. (2016) estimate that if countries in Africa, Asia, or Latin America reduced service 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 central role in amplifying these effects. Reducing sector-specific wedges to US levels can increase output by approximately 30% on average—and by 50% in developing economies—while accelerating the reallocation of resources toward modern, high-productivity services. These gains are not confined to individual sectors but are driven primarily by network spillovers. Enhancing productivity in one sector lowers costs and improves the availability of intermediate inputs for others, thereby elevating the entire production system. For example, reducing frictions in the services sector benefits manufacturing and agriculture indirectly through cheaper logistics, finance, and communication. This highlights the importance of adopting a network-oriented perspective in policy design. Reforms that strengthen intersectoral connectivity (e.g., investments in supply chain infrastructure, digital platforms, or logistics systems) can substantially amplify the returns to targeted policy interventions.

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) found that deep liberalization of services trade would raise welfare by approximately 3% on average, and by more than 8% in developing economies with highly connected production networks. Moreover, these reforms generate cross-border spillovers: advanced economies that supply 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 capture the compounded benefits of better-connected production systems.

6 Conclusion

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

We find sizable effects from reducing sectoral distortions to US levels, which effectively make production networks converge—particularly in lower-income countries. As sectors become more integrated, the use of intermediate inputs rises, aggregate gross output increases by 27% on average and by 50% in lower-income economies, and the productivity gap with the US narrows by roughly one-third. Service sectors become more central within production networks, accelerating structural transformation toward services—especially modern services. Eliminating distortions sector by sector highlights the significance of network effects. For instance, when distortions faced by modern service firms are removed, output per worker rises by at least 5% across all sectors, accompanied by substantial increases in intermediate input use.

Our analysis identifies key policy priorities for reducing income disparities and strengthening economic resilience. Given the pivotal role of services—particularly modern services—as providers of intermediate inputs, policymakers should prioritize measures that enhance sectoral productivity, such as investments in digital infrastructure, human capital development, and regulatory reforms to reduce market frictions. At the same time, strengthening intersectoral linkages through supply chain coordination, logistics improvements, and reduced transaction costs in intermediate goods exchanges can improve allocative efficiency and support sustainable economic growth.

Our framework abstracts from real-world complexities by assuming homogeneous workers and uniform wages across sectors. Extending the model to incorporate sectoral mobility frictions or worker heterogeneity would enhance realism but also increase analytical complexity, and is therefore left for future research. Since modern services typically generate higher value added and stronger demand for skilled labor, allowing for heterogeneity would likely amplify 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 labor L_i and then the prices p_i. First, to calculate labor, we rewrite Eq. (5) as $Q_i = (1+\tau_i^w)wL_i/(\sigma_i p_i)$, placing it into Eq. (4) to obtain the demand, X_{ij}, in terms of L_i:

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

By replacing Eq. (10) into Eq. (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 obtain the equilibrium, we use Eqs. (10) and (11) to rewrite Eq. (9):

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

Note that G_i and B_{ij} are simply Q_i and X_{ij} divided by L_i, respectively. Next, we divide both sides of Eq,. (12) by G_i, transform the system into matrix form, and solve to provide labor L_i for 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 Eq. (11) into Eq. (5) and take the logarithm:

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

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:

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

It can also be solved to find vector prices $\hat{\mathbf{p}}$:

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

where $\hat{\mathbf{p}}$ is the logarithm of vector prices, and $\mathbf{D}$ is a diagonal matrix, $\mathbf{D} = \text{diag}(1 - \sigma_i, \cdots, 1 - \sigma_N)$. By taking the exponential of $\hat{\mathbf{p}}$, we obtain a vector of sectoral prices that depend on TFP, including its constants.

A.2 Bonacich—Katz centrality index

The Bonacich–Katz centrality index measures the economic importance of a supply sector Grassi and Sauvagnat (2019):

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

where $\gamma_i = \frac{c_i}{C}$ is the importance of supply sector i based on final demand and $\Sigma_{ji} = \frac{X_{ij}}{Q_i}$.[23] Hence, a sector's centrality is equal to its importance based on the weighted sum of customer sector centralities. This produces a system of four equations and four unknowns:

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

where b' is the centrality vector.

Appendix B Numerical Exercises

Table B1 presents the effects of removing distortions in each economic sector. Column 2 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] 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 lists sectoral variations based on the main variables after removing sectoral distortions. (2) "Intermediates" refer to the intermediates-to-labor ratio, "output" 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 U.S. 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 the U.S.

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 nonmetallic 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 program 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 defense; 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 the World Input–Output database.