Economic Development and Spillover Effects of Intermediate Goods and Services*

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Abstract

In this paper we study the spillover effects of intermediate goods and services on income. We show that the share of intermediate inputs decreases in industry and agriculture as the countries' level of development increases, and the opposite occurs in modern and traditional services. We also show that there is a structural change underway in economies that is causing industry to lose share in intermediate goods while the traditional and especially modern services sector gains share. We develop a general equilibrium model to quantitatively evaluate the effects of productivity

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changes and changes in the productive structure on the income gap in developed and developing countries. We then show that closing productivity gaps in industry has a greater average impact on GDP per worker and aggregate productivity, when compared to other sectors. Furthermore, we show that in countries with highly efficient agricultural and/or industrial sectors, a structural change that makes services sector gain share in the economy, without the necessary increase in productivity, would further increase the GDP gap per worker.

Keywords: Intermediate Goods; Production Networks; Productivity.

JEL: O47; O11; C68.

1 Introduction

Sectoral total factor productivity (TFP) and interdependence between sectors through the use of intermediate goods are two of the factors identified as key to understanding differences in countries' levels of development (Jones, 2011b; Herrendorf and Valentinyi, 2012; Herrendorf et al., 2014; Inklaar et al., 2019; Fadinger et al., 2022). The interdependence between sectors through the use of intermediate inputs means that the effect of a productivity change in a specific sector spills over into other sectors of the economy.[1] As in Jones (2011b), if a sector experiences an improvement in productive efficiency, the other sectors that use intermediate goods from that sector will benefit. In this paper, we address both factors, specifically, we study how productivity changes in a specific sector spill over to other sectors of the economy through intermediate goods and contribute to reducing the income gap relative to the United States.[2] In this sense, our paper is related to studies that combine structural transformation and insights into production network theory (Jones, 2011a,b; Herrendorf et al., 2014; Carvalho, 2014; Barrot and Sauvagnat, 2016; Atalay, 2017; Ferreira et al., 2021).

We explore the World Input-Output Database (WIOD) dataset from 2014 that covers 43 countries and 56 sectors and we categorized this sectors into four major sectors: agriculture, industry, modern and traditional services. We find that there are gaps in GDP per worker, at the sectoral and aggregate level, between the sample countries and the United States. These gaps are largest in agriculture and smallest in the traditional services sector. Furthermore, we show that the share of intermediate inputs decreases in industry and agriculture as the countries' level of development increases, and the opposite occurs in modern and traditional services. We also show that there is a structural change underway in economies that is causing industry to lose share in intermediate goods while the traditional and especially modern services sector gains share.

Then, we developed a general equilibrium model to quantitatively evaluate the effects of productivity changes and changes in the productive structure on income gaps in

[1] In this paper we use productivity and total factor productivity as synonyms.

[2] Income gaps are calculated as the ratio between GDP per worker in the United States and other countries.

countries. In our baseline calibration, we show that the productivity of modern services is on average higher than that of other sectors of the economy. Also, we conducted two counterfactual exercises; in the first, we insert the sectoral productivity of the United States, one at a time, in the other countries; and in the second, we insert the elasticity of intermediate goods. Our findings show that closing productivity gaps in industry has a greater effect on GDP per worker and aggregate productivity, both at the sectoral and aggregate levels, compared to other sectors. Furthermore, we show that inserting the elasticity of United States intermediate goods in other countries makes the sectoral share of intermediate goods similar to that of the United States, on average; and consequently these economies become more service-oriented. However, many of these economies, for example China's, are more efficient in industry and this structural change that forces them to produce more in the services sector, where they are not as efficient, further increases the gap in GDP per worker.

Some studies have examined the contribution of structural transformation to increased productivity. Bah and Brada (2009) examined nine transition economies and found that the productivity of the manufacturing sector surpassed that of services in all countries, suggesting that reallocating labor to the service sector could reduce aggregate productivity. Duarte and Restuccia (2010) studied 29 countries from 1956 to 2004, concluding that during structural transformation, shifting labor from agriculture to manufacturing increases aggregate productivity, while a shift to services decreases it. Ferreira and Silva (2015) focused on nine Latin American countries, noting that despite low productivity and growth in the traditional services sector, it has absorbed a significant amount of labor, hindering productivity expansion in these countries. We find that, on average, the productivity of modern services is higher than in other sectors. This implies that moving workers from less productive sectors, for example agriculture, to this sector could result in greater gains in GDP per worker and aggregate productivity.

Herrendorf et al. (2022) suggests that moving workers to manufacturing is not the best solution for the economic development of countries; however, improving labor productivity in manufacturing can contribute to aggregate productivity growth in poor countries.

We advance on this topic by showing that in the case of industry, closing the average sectoral productivity gap of 30.58% led to an average reduction of 20.96% in the productivity gap at the aggregate level. This effect is proportionally greater than in other sectors.

Other studies highlight the role of sectoral linkages through input-output and their relationship with aggregate output, and this affects the GDP per worker on aggregate level. Several of them suggest that idiosyncratic microeconomic shocks that propagate through sectoral production networks within a specific economy can help explain the origins of fluctuations in aggregate output (Barrot and Sauvagnat, 2016; Atalay, 2017; Baqaee, 2018; Boehm et al., 2019; Frohm and Gunnella, 2021). Our findings corroborate this literature. We show that closing the productivity gap in a specific sector causes an increase in the production of intermediate goods in that sector. Consequently, this results in a reduction in prices, which in turn increases the demand for intermediate production factors in this sector. We also calculate the Bonacich-Katz centrality index, which measures the importance of a sector as a supplier to the economy and provide evidence that, on average, the industry plays a central role in the productive structure of countries, that is, it is the sector with greater capacity to boost demand for intermediate goods in other sectors, especially in less developed countries.

Rodrik (2016) documents that there is a tendency of premature deindustrialization in low and middle-income countries, that is, low and middle-income countries are becoming service economies without having gone through adequate industrialization experience. According to him, premature deindustrialization has negative effects on economic growth, mainly because industry is a technologically dynamic sector, absorbs a large amount of unskilled labor, and is a tradable sector, that is, it does not have many restrictions on demand in domestic markets populated by low-income consumers. In our counterfactual exercise, we show that closing the productivity gap in industry has a greater average impact on the GDP gap per worker, both at the sectoral and aggregate levels, when compared to other sectors. The 30.58% reduction in the sectoral productivity gap, in industry, led to a 75.72% and 47.39% reduction in the GDP per worker gap at the sectoral and aggregate levels, on average, respectively.

We also analyzed what would happen to the economies of the sample countries if their production structures converged with those of the United States. Specifically, what we do is predict what would happen to economies if industry actually lost share and they became more service-oriented. We show that this change only benefits the modern services sector and that in countries with highly efficient agricultural and/or industrial sectors, this structural change leads to a reduction in the amount of labor and the production of intermediate goods. Therefore, these sectors start to produce less, which, in turn, results in even greater income gaps.

Furthermore, our study is also related to the literature that addresses the importance of the service sector in economic development. Eichengreen and Gupta (2013) emphasizes that the share of modern services in GDP has been increasing since the 1970s, and this is related to technological advances that have allowed greater complementarity between traditional and modern services. We show that changes in productivity in modern services have a greater average impact on GDP per worker compared to traditional services. However, variations in the productivity of traditional services have a greater average impact on aggregate productivity compared to modern services. This effect is related to the fact that traditional services have a large share of added value and labor. We also demonstrate that the traditional services sector is more central that modern services and has a greater capacity to stimulate demand from other sectors.

In addition to this introduction, this paper is organized as follows. Section 2 presents the dataset that we used in our analysis and some stylized facts on value added per worker gaps between countries, and the trend of the sectoral share of intermediate goods in economies. Section 3 presents our general equilibrium model. Section 4 explains how this model is calibrated for 39 countries. The calibration results, comparison of the model with some empirical facts, and the two counterfactual exercises are presented in Section 5. Finally, Section 6 brings our concluding remarks.

2 Datasets and Stylized Facts

In this section, we present the dataset used in the paper and some stylized facts observed from this dataset. We begin the section by describing the World Input-Output Database (WIOD) and the Socio Economic Accounts (SEA). We then discuss the gaps in GDP per worker at the sectoral and aggregate levels. And finally, we discuss the share of intermediate goods in economies and the trends in sectoral production.

2.1 Dataset

In this paper, we utilize data sourced from the World Input-Output Database (WIOD). This dataset offers a time series of input-output matrices (IO) that spans 2000 to 2014, and covers 43 countries and 56 sectors.[3] Additionally, WIOD provides data pertaining to input quantity, prices, and volumes, including information on value added, capital stock, workers, and hours worked. These datasets are available within the Socio-Economic Accounts (SEA). For a more comprehensive introduction to this database, see Timmer et al. (2015).

Our analysis focuses on data from 2014.[4] We exclude countries with populations of fewer than one million inhabitants, namely Luxembourg and Malta, from our sample. Additionally, due to a lack of available data, we excluded Taiwan and Croatia, resulting in a sample size of 39 countries. We provide the names and acronyms of each country in Table A1 in Appendix A. Furthermore, to facilitate cross-country comparisons of monetary values, we employ Purchasing Power Parity (PPP) data provided by the Organization for Economic Cooperation and Development (OECD); this indicator is measured in terms of national currency per US dollar.[5]

Based on International Standard Industrial Classification of All Economic Activities (ISIC 4) we have classified the 56 sectors identified in the Socio-Economic Accounts

[3]It is important to emphasize that we utilize the updated 2016 version of WIOD, as outlined by Timmer et al. (2016). This latest version provides an annual time series of World Input-Output Tables (WIOTs) spanning from 2000 to 2014 (compared to 1995-2011 in the 2013 version) and covers 43 countries (compared to 40 in the 2013 version).

[4]We highlight that in Subsection 2.2.2 where we analyze the trend in sectoral production, we use data from 2000 to 2014.

[5]This indicator can be accessed on the OECD website: https://data.oecd.org.

(SEA) into three broad sectors: agriculture, industry, and services.[6] The agriculture sector encompasses activities such as 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 divide it into two: modern services and traditional services. We consider modern services to be the sectors within services that have the highest added value per worker. Modern services include financial services, real estate activities, insurance, scientific research, management consultancy, among others. In contrast, traditional services include educational services, healthcare, postal and courier activities, transportation, public administration and defense, and other related activities.[7] 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 instance, employees in the educational services sector typically possess different skills and exhibit different levels of productivity compared to those in the tourism sector. Our sector classification can be seen in Table D1 in Appendix D.

2.2 Stylized Facts

2.2.1 GDP per worker Gaps

According to Herrendorf et al. (2022), one of the channels for driving economic growth is to reallocate labor to sectors where productivity gaps are smaller, at the aggregate and sectoral level. In this context, agriculture, typically the least productive sector, plays a crucial role in explaining cross country income gaps, since less developed countries allocate a significant part of the workforce in this sector. In India, Indonesia, and China, the labor share in agriculture is 45%, 31%, and 24%, respectively. In this sense, the

[6]ISIC can be view in United Nations website: https://unstats.un.org.

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

income gaps between the least developed and the most developed countries would tend to decrease if the labor force was reallocated from agriculture to the more productive sectors of the economy.

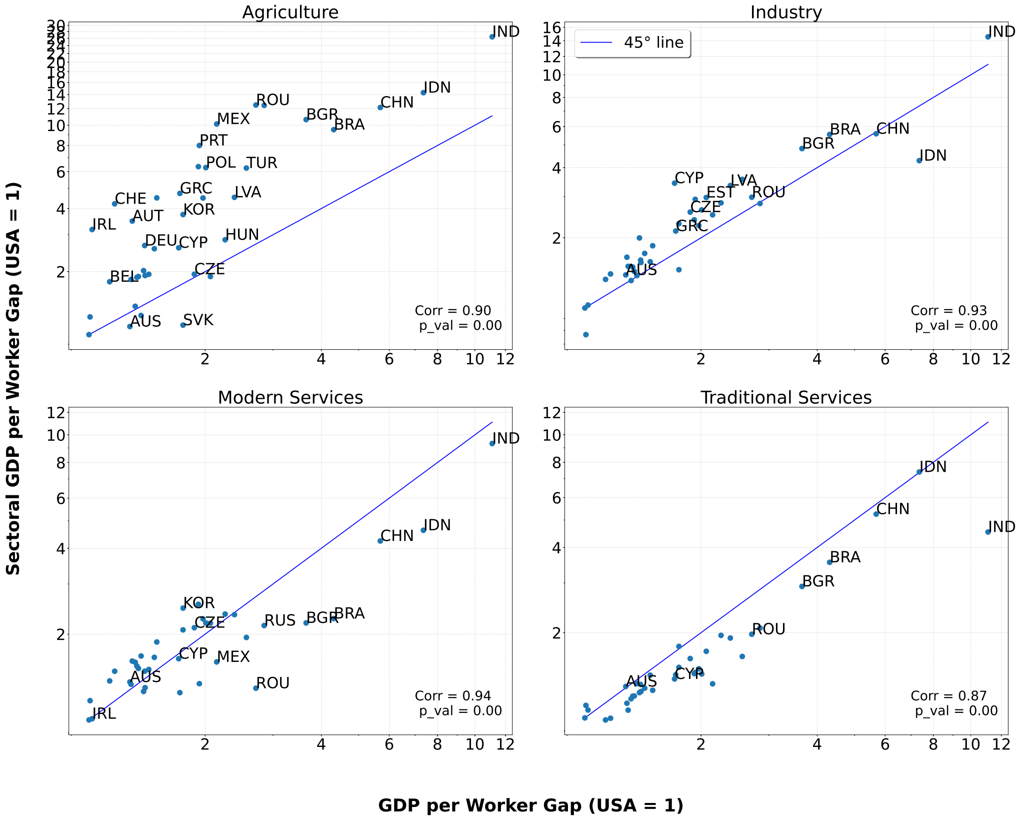
In this section, we document the gaps in GDP per worker, both at the sectoral and aggregate levels, between the countries in the sample and the United States.[8] This measure is defined as the ratio of GDP per worker in the United States to that of the other countries. We use the United States as a reference because this country is one of the countries that comes closest to the technological frontier (Herrendorf et al., 2022).

Figure 1 presents the results, with points below (above) the 45-degree line indicating countries where the gap in aggregate GDP is greater (lower) than the gap in sectoral GDP. We highlight two facts. Firstly, the GDP gap in agriculture is larger than in other sectors in most countries. The average gap in agriculture is 5.2, indicating that the value added per worker in the United States is on average 5.2 times higher than in the other countries. In developing countries, the gaps are even greater; for example, India, Indonesia, and China have gaps of 26.46, 14.3, and 12.5, respectively. Furthermore, on average, the gap in agriculture is greater than in the aggregate, which is 2.28. This result is consistent with findings by Restuccia et al. (2008); Herrendorf and Valentinyi (2012); Gollin et al. (2014); Herrendorf et al. (2022). In industry, the gap is smaller than in agriculture, on average 2.66, but it is larger than in the aggregate.

Secondly, the GDP per worker gap in the traditional and modern service sectors are, on average, 1.82 and 2.05, respectively, that is, lower than the GDP per worker gap at the aggregate level. In this sense, if workers move from agriculture to the service sector, especially traditional services, the gap in value added per worker at an aggregate level would tend to reduce more than if these workers moved to industry, for example.

[8] Some papers assume that GDP per worker is a measure of labor productivity (Restuccia et al., 2008; Herrendorf and Valentinyi, 2012; Gollin et al., 2014; Herrendorf et al., 2022).

Figure 1: GDP per Worker Gap, Aggregated and Sectorial - 2014



Notes: This figure is on logarithmic scale. Points below (above) the 45-degree line indicating countries where the gap in aggregate GDP is greater (lower) than the gap in sectoral GDP.

However, aggregate productivity gains resulting from labor reallocation can be exhausted, as most labor is already allocated to the most productive sectors of the economy. An alternative channel to fill these gaps and achieve economic growth is improvement in productive efficiency. Productivity changes in a sector increase its production and reduce costs, which in turn, through intermediate goods, affect other sectors of the economy. In this context, two important questions emerge. And if instead of reallocating labor there was an increase in productivity in these sectors, which one has the greatest capacity to reduce the income gaps? And in the context in which intermediate inputs create networks between sectors, which one has the greatest capacity to stimulate the production of the others? We address these questions in the following sections.

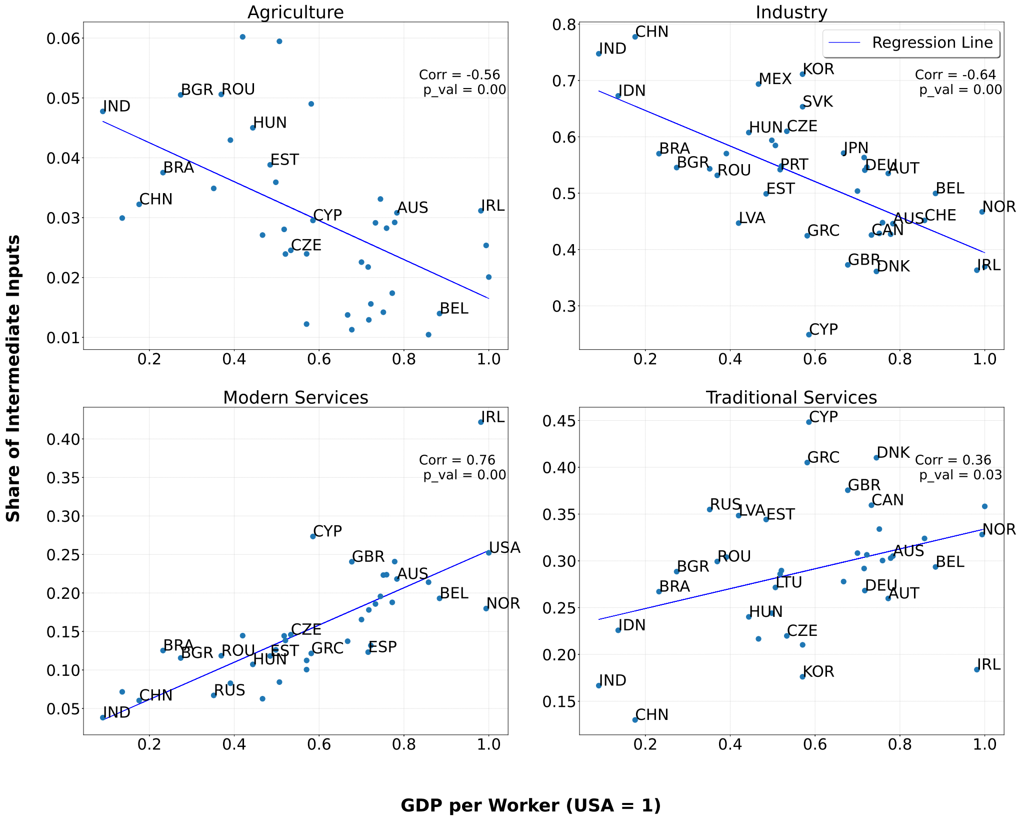
2.2.2 Intermediate Inputs

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 networks between then, acting as a shock propagation mechanism, that is, a positive (negative) shock in the productivity of an important sector has a positive (negative) impact on all other sectors (Jones, 2011a; Carvalho and Tahbaz-Salehi, 2019; Boehm et al., 2019; Fadinger et al., 2022).

In Figure 2, we illustrate the cross-country distribution of the share of intermediate inputs on the supply side by sector. It is worth noting that the share of intermediate goods tends to decrease in the agriculture and industry sectors as the level of development increases. Conversely, in the service sector, the share of intermediate goods tends to rise with increasing development levels.[9] This observation is consistent with the literature on structural change, which provides evidence that both value added and the share of employment in the service sector increase as countries develop (Herrendorf et al., 2014; Herrendorf and Schoellman, 2018; Sposi, 2019).

[9]The sectoral gross output, value added and labor share exhibits a pattern similar to that depicted in Figure 2.

Figure 2: Share of Intermediate Inputs by Sector - 2014



Apparently, the services sector, especially modern services, has greater importance in the productive structure of more developed countries, while agriculture and industry has greater importance in less developed countries. However, industry tends to lose importance as economies specialize in the service sector. Rodrik (2016) documents that there is a tendency to premature deindustrialization in low- and middle-income countries, that is, low- and middle-income countries are becoming service economies.

To verify whether deindustrialization has been faster in recent periods, Rodrik (2016) used 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; however, our objective is to analyze the trend in sectoral share of intermediate inputs. Our specification is the following:

[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.

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

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 data 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 time fixed effects, D05, D08, D11, and D14. These parameters shows the share of intermediate inputs of each period relative to the excluded period 2000 – 2002. Columns 1 and 2 present the estimates for agriculture and industry and indicate that both sectors, especially industry, have been losing share in total intermediate inputs as time progresses. Columns 3 and 4 present the estimates for modern and traditional services and point to a contrary pattern to the first two sectors, that is, as in Rodrik (2016), as time progresses, the share of both sectors in the total of intermediate inputs increases, that is, these economies are becoming service sector-oriented economies.[11]

[11] In Table C1 in Appendix C we show that the share of sectoral value added presents a similar pattern to the share of sectoral intermediate inputs.

Table 1: Panel Regression Models, 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	-0.064^{***}	0.052^{**}	0.079^{***}	-0.067^{***}
Ln GDP per Capita Squared	0.007^{***}	0.0002	-0.014^{***}	0.006^{*}
Ln Population	-0.336^{***}	-0.639^{***}	1.373^{***}	-0.398^{**}
Ln Population Squared	0.011^{***}	0.016^{**}	-0.040^{***}	0.013^{**}
D05	-0.003^{***}	-0.002	0.002	0.003
D08	-0.005^{***}	0.003	0.003	-0.001
D11	-0.003^{***}	-0.017^{***}	0.010^{***}	0.010^{***}
D14	-0.003^{**}	-0.018^{***}	0.010^{***}	0.011^{***}
Country Fixed Effects	✓	✓	✓	✓
Observations	585	585	585	585
R^2	0.562	0.262	0.265	0.114
Adjusted R^2	0.525	0.199	0.203	0.038
F Statistic (df = 8; 538)	86.458^{***}	23.852^{***}	24.287^{***}	8.630^{***}

Notes: Statistical significance is indicated at the $***p < 0.01$, $**p < 0.05$, and $*p < 0.1$ levels. 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 dummy that indicates the period goes from 2000 to 2002.

If economies actually converge towards a structure in which the service sector, both modern and traditional, are more important than the others, would this lead to a reduction in the income gap between countries? To answer this question and the others raised in Section 2.2.1, we developed a general equilibrium model in which we make explicit the importance of productivity and intermediate goods in the production function. We calibrate the model and conducted a series of counterfactual exercises.

3 Theoretical Framework

In this section, we present our theoretical framework, based on Carvalho (2014) and Ferreira et al. (2021), to study the effects of sectoral productivity changes and its spillover effects through intermediate goods on the final output of the economies. Our model has four sectors: agriculture, industry, traditional and modern services, and in the production function we make explicit the relationship between them through intermediate goods. In this context, the productivity changes in one sector spills over into the others. First, we describe the production technology and the firm's problem, then the representative consumer preferences. Next, we present the equilibrium conditions and the optimal solution of the model, and finally, we discuss how productivity changes affect the production chain and the final product of the economy.

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 how much to employ labor and how much to use each of the intermediate goods. The production technology is given by:

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

where Q_i is the gross product of sector i, A_i is the total factor productivity, L_i is the amount of labor employed and X_{ij} is the matrix of intermediate goods where the columns indicate the sector of destination of the goods and services while the rows indicate the sector of origin. Furthermore, σ_i is the elasticity of the good of sector i with respect to labor and β_{ij} is the elasticity of the set of intermediate goods i with respect to the specific intermediate good j. Specifically, a high β_{ij} indicates that sector i produces more intermediate inputs for sector j, while $\beta_{ij} = 0$ indicates that input i is not needed in the production of good j, we also assume that for all i $\sum_{j \in N} \beta_{ij} = 1$.

The firm's problem can be written as:

$$\max_{X_{ij}, L_i} \quad p_i Q_i - w L_i - \sum_{j \in N} p_j X_{ij}, \tag{3}$$
$$\text{st:} \quad Q_i = A_i L_i^{\sigma_i} \left(\prod_{j \in N} X_{ij}^{\beta_{ij}} \right)^{1-\sigma_i},$$

where w is the amount of wage. From the first order conditions of the problem we have:

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

$$L_i = \frac{\sigma_i p_i Q_i}{w}. \tag{5}$$

3.2 Consumers

The economy is populated by an infinite number of homogeneous individuals who inelastically supply an amount of labor L. The representative individual has preference CES over the consumption of N goods offered in the economy and chooses consumption c_i to solve the following problem:[12]

$$\begin{aligned} &\max \quad \left[\sum_{i \in N} c_i^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \\ &\text{st:} \quad \sum_{i \in N} p_i c_i = wL, \end{aligned} \tag{6}$$

where the parameter θ is the elasticity of substitution between the goods, and w is the amount of wage. The first order conditions of the problem give us the optimal consumption:

$$c_j = \frac{1}{p_j^{\theta}} \frac{wL}{\sum_i p_i^{1-\theta}}. \tag{7}$$

[12]This type of preference function is common in the literature and can be view in Hsieh and Klenow (2009) and Hsieh et al. (2013).

3.3 Equilibrium

3.3.1 Conditions

A competitive equilibrium is a set of prices p_i, wages w, and allocations $c_i, Y_i, L_i, Q_i, X_{ij}$ such that:

1. w and c_i solve the consumer problem, taking p_i as given.

2. w, L_i, and X_{ij} solve the firm's problem, taking p_i as given.

3. Markets clear conditions:

   (a) The demand for labor by firms must be equal to the supply of individuals:

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

   (b) The consumption of each good must be equal to the supply of the product intended for consumption:

$$Y_i = c_i, \qquad \forall i \in N. \tag{9}$$

   (c) The supply of product must equal the demand of firms and individuals:

$$Q_i = Y_i + \sum_{j \in N} X_{ij}, \qquad \forall i \in N. \tag{10}$$

3.3.2 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: $Q_i = wL_i/(\sigma_i p_i)$, and replace in Equation (4) to get the demand of X_{ij} in terms of L_i:

$$X_{ij} = wL_i \left(\frac{1 - \sigma_i}{\sigma_i} \right) \frac{\beta_{ij}}{p_j}. \tag{11}$$

Replacing Equation (11) in Equation (2) we have:

$$Q_i = wA_iL_i\left(\frac{1-\sigma_i}{\sigma_i}\right)^{(1-\sigma_i)}\prod_{j\in N}\left(\frac{\beta_{ij}}{p_j}\right)^{(1-\sigma_i)\beta_{ij}}. \quad (12)$$

To get the solution of equilibrium we can use Equations (9), (11) and (12) to rewrite Equation (10) as:

$$G_iL_i = \sum_{j\in N} B_{ij}L_i + c_i. \quad (13)$$

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 (13) by G_i, transform the system of equations into matrix form and solve to find the amount of labor L_i in each sector:

$$\mathbf{L} = \left[\mathbf{I} - \hat{\mathbf{B}}\right]^{-1}\hat{\mathbf{c}}, \quad (14)$$

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

To obtain prices, we substitute Equation (12) into (5) and take the logarithm, which implies:

$$\ln p_i - \Theta_i p_j = -\ln A_i - \Phi_i. \quad (15)$$

We define $\Theta_i = (1-\sigma_i)\sum_j \beta_{ij}$ and $\Phi_i = \ln(1-\sigma_i)^{\sigma_i}\sigma_i^{\sigma_i} + (1-\sigma_i)\sum_j \beta_{ij}\ln\beta_{ij}$. This system of equations can be written in matrix form and solved to find a price vector $\hat{\mathbf{p}}$:

$$\hat{\mathbf{p}} = -\left[\mathbf{I} - \boldsymbol{\Theta}\right]^{-1}\left[\hat{\mathbf{A}} + \boldsymbol{\Phi}\right]. \quad (16)$$

We then have a vector of sectoral prices that depend on productivity, and constants.

3.4 Propagation Channels

Production technology, given by Equation (2), takes into account an important characteristic of the productive structure of any economy, which is the interdependence between sectors through the use of intermediate goods. This network allows the impact of a productivity changes in a specific sector to spill over to other sectors of the economy.

For example, if a specific sector experiences an improvement in efficiency for a certain reason (innovation, factor reallocation, technological advancement, etc.) and increases its productivity, the sectors that use its goods and services start producing more.

Suppose that there are only two sectors in the economy, A and B. If the productivity of sector A experiences a positive shock, the quantity of intermediate goods produced by sector A increases and the price decreases. The price reduction has a positive impact on the sector B, which starts to demand more inputs from A and consequently increases its production. As a result, the prices of goods produced by sector B decrease, leading sector A to demand more goods from sector B. The magnitude of the effect of the initial shock will depend on the elasticity of the set of intermediate goods with respect to the intermediate good j, β_{ij}, and the elasticity of good in sector i with respect to labor, σ_i.

4 Calibration

In this section, we describe the steps of the empirical investigation. First, we discuss how we calibrate the constant parameters of the model presented in the previous section. Then we detail how we calibrate the model and present the result of the adjustment.

4.1 Exogenous Calibration

We need to define four parameters of the model, θ, β_{ij}, σ_i and L. The elasticity of substitution in utility function, θ, we follow Hsieh and Klenow (2009) and Hsieh et al. (2013) and set $\theta = 3$. The remaining parameters are calculated using input-output matrices (IO) and Socio Economic Accounts (SEA) data. The elasticity of the set of intermediate goods with respect to the intermediate good j, β_{ij}, is calculated directly using the input-output matrix for each country. Specifically, β_{ij} represents the share of intermediate goods of sector i used in the production of sector j. The elasticity of good in sector i with respect to labor, σ_i, is given by the ratio between the compensation of the employees and the gross output of the industry.[13] Finally, the total amount of labor, L, is

[13]The calculation of σ_i is a direct consequence of Equation (5).

associated with the number of people engaged in production in each respective country.

4.2 Endogenous Calibration

We calibrated the model for 39 countries in the sample with data from 2014. Our calibration strategy consists of selecting values for sectoral productivity A_i in such a way that the added value per worker resulting from the equilibrium of the model coincides with the added value per worker present in the data. We define the following objective function for our numerical routine:

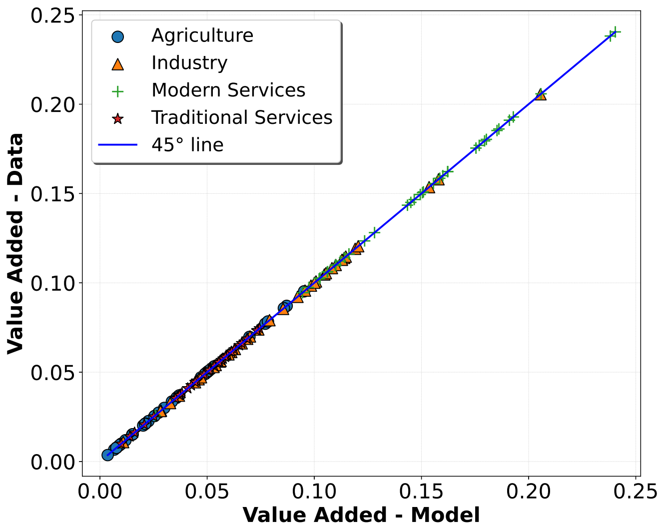
$$\mathfrak{R} = \sum_{i=1}^{N} \left(\frac{VA_i^M - VA_i^T}{VA_i^T} \right)^2, \tag{17}$$

where VA is the value added per worker and the superscripts M and T indicate the model and target statistics. The value added per worker from the model, VA_i^M, is calculated as follows:

$$VA_i^M = \frac{p_i^{USA} c_i}{L_i^M}, \tag{18}$$

where p_i^{USA} is USA prices of good i, c_i is the consumption, and L_i^M is the labor amount. Calibration is performed for each country independently of the others. In all, we calibrated 156 parameters, 39 countries multiplied by 4 sectors. Figure 3 shows the added value present in the data (y-axis) and the added value resulting from the equilibrium of the model (x-axis). The model fits well with the empirical data, as the points are well fitted to the 45-degree line.

Figure 3: Model Adjustment to Data



5 Results

In this section, we present the results of the paper. Initially, we discuss calibrated productivity and show that some model results are in line with empirical facts. We then discuss the results of two counterfactual exercises that we implemented. In the first exercise, we imputed the sectoral productivity of the United States in other countries, verified the effects on the gap in GDP per worker at the sectoral and aggregate level, and discussed how this affects the production chain through intermediate goods. Furthermore, we discuss the effects of this exercise on aggregate productivity. In the second exercise, we do something similar to the first, the difference is that instead of productivity we impute the elasticity of intermediate goods, in the United States, in other countries, and discuss the effects on price gaps, amount of work, intermediate goods, and GDP per worker.

5.1 Total Factor Productivity

In Figure 4, we present calibrated sectoral productivity alongside GDP per worker.[14] As expected, the productivity of the four sectors is positively associated with the level

[14] The calibrated sectoral productivity for each country can be seen in Appendix B.

of development in the countries, which means that the more developed countries tend to be more productive in all sectors. The relationship between sectoral productivity and GDP per worker is direct, meaning that a potential positive shock in productivity can contribute to its rise.

Figure 4: Total Factor Productivity

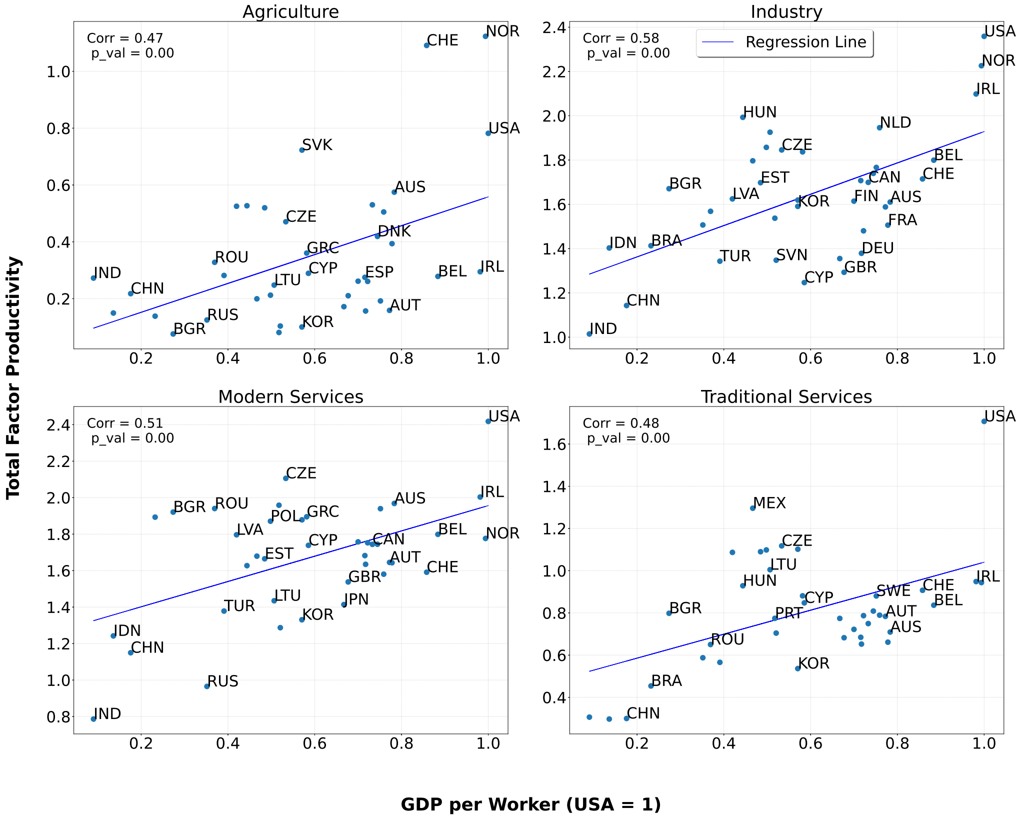


Table 2 provides descriptive statistics for the calibrated productivity. It is observed that, on average, the modern services sector is the most productive sector, followed by the industry. This result comes from the fact that modern services encompass the subsectors of real estate activities, financial services, and insurance and reinsurance, and all of these subsectors have value added per worker well above average.

Table 2: Descriptive Statistics of Calibrated Sectoral Productivity

Sectors	Mean	Std	Min	25%	50%	75%	Max
Agriculture	0.35	0.25	0.08	0.18	0.28	0.49	1.12
Industry	1.64	0.28	1.01	1.45	1.62	1.80	2.36

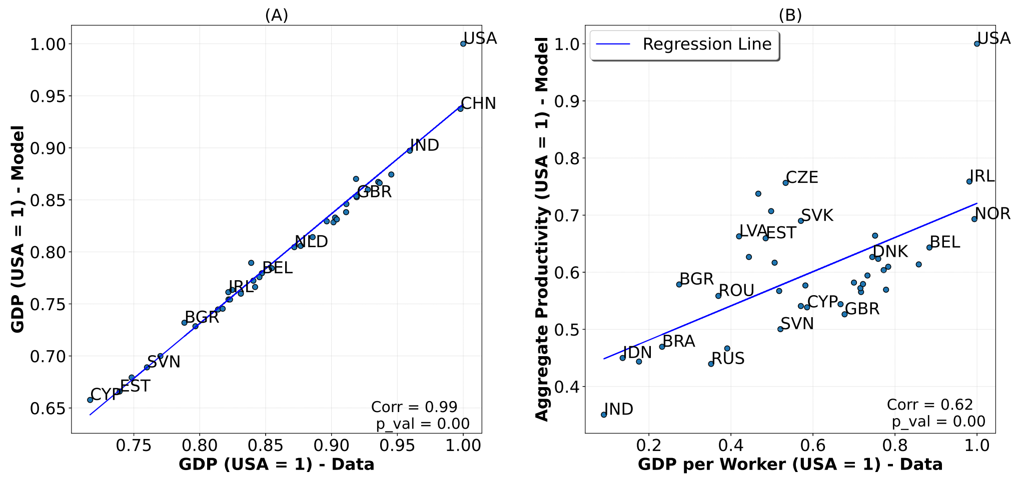
Continued on next page

Table 2: Descriptive Statistics of Calibrated Sectoral Productivity (Continued)

Sectors	Mean	Std	Min	25%	50%	75%	Max
Modern Services	1.67	0.31	0.79	1.56	1.74	1.89	2.42
Traditional Services	0.81	0.27	0.30	0.67	0.79	0.94	1.71

Figure 5 (A) compares GDP data with GDP and productivity values generated by our model. It is observed that the GDP of the calibrated model fits well with the GDP of the data, and the correlation between these two sets of data is close to unity and statistically significant at the confidence level 1%. Figure 5 (B) compares aggregate productivity and GDP per worker from the data, it is observed that aggregate productivity also has a positive correlation with the level of income of the countries.[15] Note that India, Russia, and China are the countries with the lowest aggregate productivity, while the United States, the Czech Republic, and Ireland are the most productive. Our model also replicates well other important characteristics of economies, for example, the share of intermediate goods, gross product, and labour.[16]

Figure 5: Comparison Between Data and Model Results



Note: We have logarithmized GDP to improve the scale of the figure.

5.2 Effects of the Sectoral Productivity Changes

In this section, we conduct a counterfactual exercise in which we insert the sectoral productivity of the United States, one at a time, into each respective sector of other

[15] Aggregate productivity is the sum of sectoral productivity weighted by labor share in each sector.

[16] See Figure A1 in the Appendix for a detailed comparison of these shares between the model and observed data.

countries. We then assess the effects of these productivity shocks on GDP per worker and aggregate productivity and discuss the key channels through which these changes propagate.

5.2.1 GDP per Worker

To investigate which sectors have the greatest capacity to boost economies and reduce the gap in GDP per worker, in relation to the United States, given an improvement in productive efficiency, we conducted the following counterfactual exercise: (i) We calculate the productivity gap and the GDP per worker gap at the sectoral and aggregate level;[17] (ii) We insert the sectoral productivity of the United States, one at a time, in each of the analyzed sectors, that is, we reduced the sectoral productivity gap between the United States and the other countries to zero;[18] (iii) We repeat step (i) and measure the percentage change in the productivity gap and the GDP gap per worker at the sectoral and aggregate level. This exercise allows us to measure how much the reduction in the sectoral productivity gap reduces the gap in per capita GDP between the United States and other countries at the sectoral and aggregate level.

Figure 6 illustrates the results of this exercise at the aggregate level. The x-axis presents the percentage change in the GDP gap per worker, while the y-axis presents the percentage change in the productivity gap. Points below the 45-degree line indicate that the reduction in the productivity gap has led to a less than proportional reduction in the GDP per worker gap. Note that in all sectors, except agriculture, the reduction in the output gap per worker was more than proportional in most countries. It is also noted that there is a positive correlation between both variables, that is, where there have been greater reductions in the productivity gap, there have also been greater reductions in the GDP per worker gap.

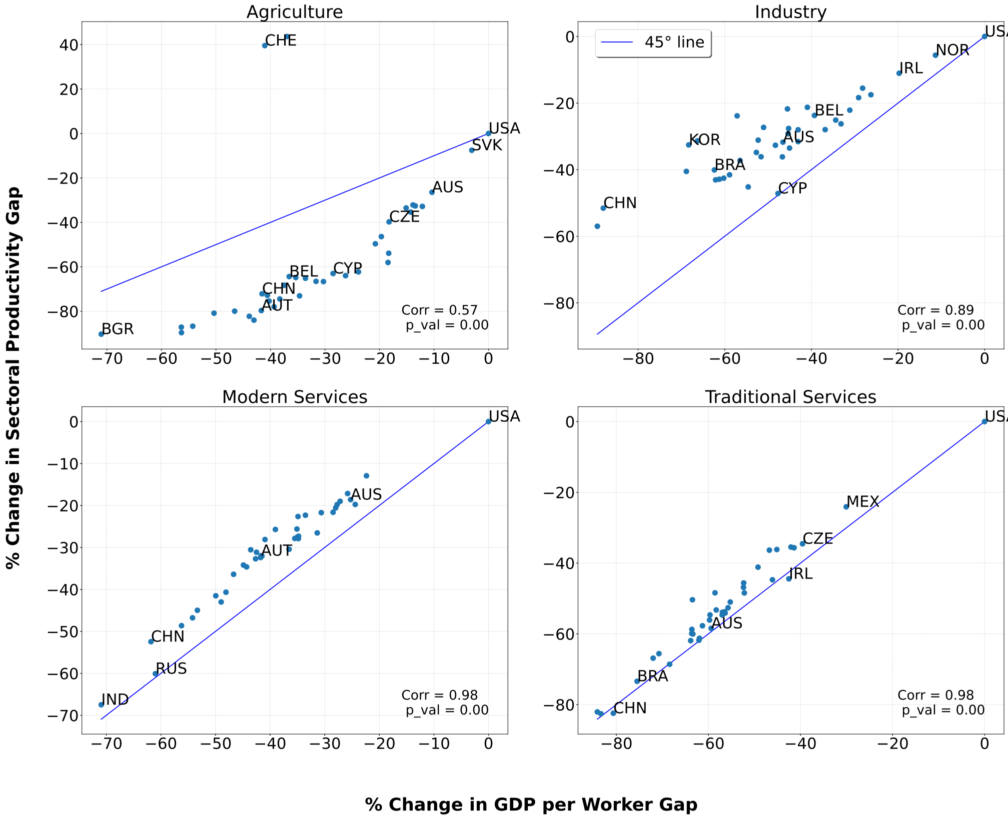
The countries that benefit the most from closing the sectoral productivity gap, in

[17] Recall that the GDP per worker gap is calculated as the ratio between the GDP per worker of the United States and that of the other countries in the sample. The productivity gap is calculated in a similar way.

[18] The productivity of United States in agriculture, industry, modern services, and traditional services is 0.78, 2.36, 2.42, 1.71, respectively.

general, are the less developed countries, especially in industry and both traditional and modern services. In India, for example, reductions of 57%, 82%, and 67% in the productivity gaps of these three sectors resulted in aggregate reductions of 89%, 84%, and 71% in the GDP gaps per worker, respectively.

Figure 6: Percentual Changes in per Worker GDP Gap Given a Percentual Change in Productivity Gap



Note: Points below the 45-degree line suggest that reducing the productivity gap results in a less than proportional decrease in the GDP per worker gap.

Table 3 presents the average results of this counterfactual exercise. The first column of the table displays the average percentage reduction in the productivity gap. The second and third columns show the average percentage reduction in the GDP gap per worker at the sectoral and aggregate level, respectively. The last two columns are the ratios between columns three and four, and column two. Both columns illustrate the proportional effect of variations in the productivity gap on the variation in the GDP gap per worker, at the sectoral and aggregate levels, respectively. In agriculture, for instance, the 55.3% reduction in the productivity gap resulted in average reductions of 87.28%

and 31.72% in the GDP gap per worker at the sectoral and aggregate level, respectively. On the other hand, in industry, the average reduction of 30.58% in the productivity gap reduced 75.72% and 47.39%, on average.

When we look at column four, we notice that the sectoral GDP per worker gap responds more than proportionally to variations in the sectoral productivity gap. If we combine with the results provided in the fifth column, we note that there is a clear order of the average impact of sectoral productivity changes on the GDP per worker gap at sectoral and aggregate levels. The impact of productivity changes in the industrial sector is greater than in the modern services sector, which in turn exceeds the impact in traditional services and is ultimately greater than in the agricultural sector.

Table 3: Average Percentage Change in Gaps in Productivity and GDP per Capita

	(1)	(2)	(3)	(4)	(5)
	% Change in Gaps				
Sectors	Productivity	**Sectoral** Per Worker GDP	Per Worker GDP	Ratio 1 (2)/(1)	Ratio 2 (3)/(1)
Agriculture	-55.30	-87.28	-31.72	1.57	0.57
Industry	-30.58	-75.72	-47.39	2.47	1.55
Modern Services	-30.89	-54.52	-39.11	1.76	1.27
Traditional Services	-52.76	-82.99	-56.70	1.57	1.07

5.2.2 Intermediate Goods as Channels for Propagating Changes in Productivity

This effect in GDP per worker gap can be attributed to two main factors. First, by increasing the productivity of a sector there is a reallocation of workers in the economy; that is, the positive variation in the productivity of a sector is associated with a positive variation in labor share. The shift of labor from low productivity sectors, for example agriculture, to high productivity sectors such as modern services and industry is a driver to further increase the final product of economies.

Second, interdependence between sectors causes the effect of the impact of a productivity change on a specific sector to spread to other sectors of the economy. For example, in the sector that receives the productivity change, prices decrease, so there is greater demand for intermediate goods. Hence, sectors that use the now more productive goods and services as intermediate inputs will also benefit indirectly, and so on. In Table 4 we present the average percentage change in intermediate inputs after sectoral productivity shocks, the columns of the table indicate the sector that received the shock, while the rows indicate the average percentage change in intermediate inputs of the respective sector.

We highlight two facts. First, a productivity change in a specific sector has a greater effect on the supply of intermediate goods within that same sector. For example, closing the productivity gap in relation to the United States in agriculture results in an average increase of 530.31% in the supply of intermediate goods within the same sector. Second, productivity shocks in the industry and traditional services sectors were the ones that most stimulated the supply of intermediate goods, both for themselves and for other sectors of the economy, on average.

Table 4: Average Percentage change in Intermediate Inputs After Sectoral Productivity Shock

Sectors	Agriculture	Industry	Modern Services	Traditional Services
Agriculture	530.31	155.91	5.42	52.59
Industry	13.82	391.65	11.11	86.02
Modern Services	0.26	71.42	115.63	89.93
Traditional Services	2.32	62.90	13.98	335.39

This high effect of productivity changes in industry and traditional services, in the production chain, can be attributed to the fact that both sectors are, on average, the most central. Central sectors are those that are most closely linked in production networks with other sectors, which implies that positive productivity changes in these sectors tend to have a greater impact on the production chain and GDP compared to more peripheral sectors.

To measure how central a sector is, we calculated the Bonacich-Katz centrality index, which measures the importance of a sector as a supplier to the economy and has been applied in the recent literature on the diffusion of macroeconomic shocks (Acemoglu et al., 2012; Carvalho, 2014; Grassi and Sauvagnat, 2019). The centrality index is, on average, higher in traditional service sectors and industry, 0.75 in both. Agriculture and modern services have a Bonacich-Katz centrality index, on average, equal to 0.32 and 0.41, respectively.[19]

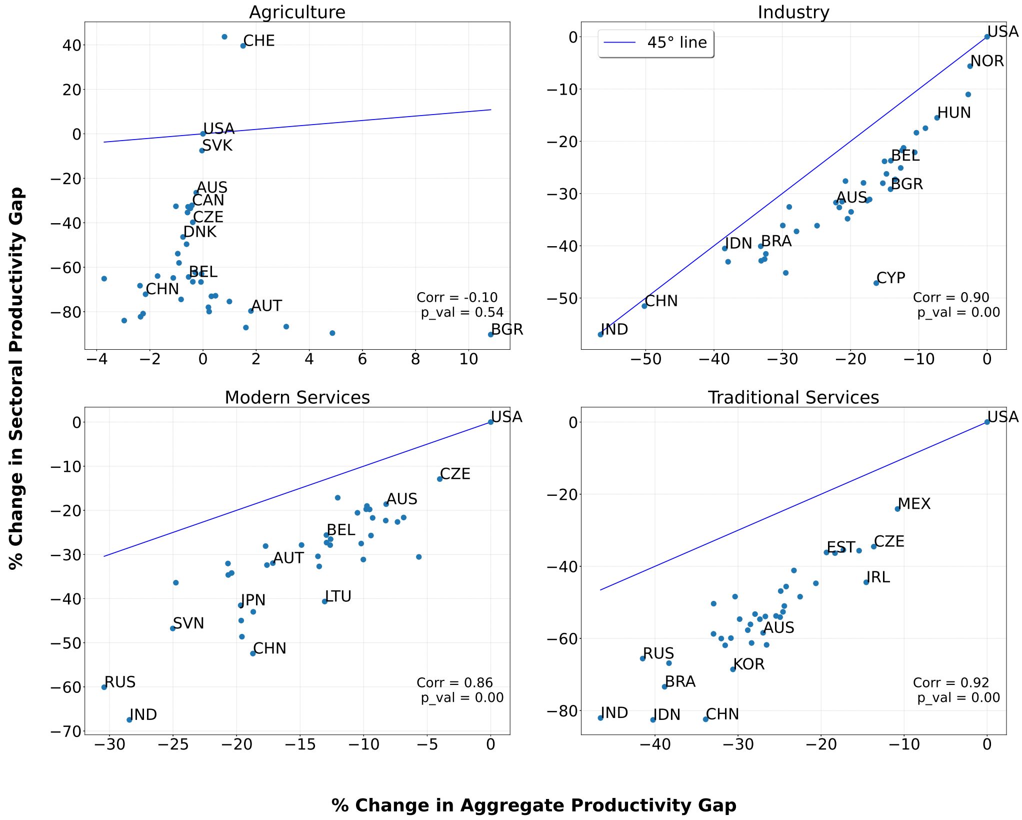
5.2.3 Aggregate Productivity

In section 5.2.1, we assessed the effects of productivity changes on GDP per worker at both the sectoral and aggregate levels. In this section, we examine the effects of the same exercise on aggregate productivity. Aggregate productivity is simply the sum of productivities, weighted by labor share.

Figure 7 illustrates the results. The x-axis shows the percentage change in the aggregate productivity gap, while the y-axis presents the percentage change in the productivity gap. Points below the 45-degree line indicate that the reduction in the productivity gap led to a less than proportional reduction in the aggregate productivity gap. It is noticeable that in all sectors, except agriculture, there is a strong positive correlation between the percentage changes in sectoral and aggregate productivity gaps. In other words, we have a result analogous to that of the previous section, where a greater reduction in the sectoral productivity gap also led to a greater reduction at the aggregate level.

[19] In Appendix B we provide the method for calculating the Bonacich-Katz centrality index.

Figure 7: Percentual Changes in Aggregate Productivity Gap Given a Percentual Change in Sectoral Productivity Gap



Points below the 45-degree line indicate that the reduction in the productivity gap led to a less than proportional reduction in the aggregate productivity gap.

Table 5, analogous to the table presented in the previous section, shows the average results of the exercise. Industry had a greater proportional effect (see column 5), that is, a 30.58% reduction in the sectoral productivity gap led to a 20.96% reduction in the productivity gap at the aggregate level.

Table 5: Average Percentage Change in Gaps in Sectoral and Aggregate Productivity

	(1)	(2)	(3)	(4)	(5)
	% Change in Gaps				
Sectors	Productivity	**Sectoral** Weighted Productivity	Aggregate Productivity	Ratio 1 (2)/(1)	Ratio 2 (3)/(1)
Agriculture	-55.30	-74.92	-0.03	1.35	0.00
Industry	-30.58	-41.63	-20.96	1.36	0.68
Modern Services	-30.89	-44.15	-14.26	1.42	0.46

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Table 5: Average Percentage Change in Gaps in Sectoral and Aggregate Productivity (Continued)

	(1)	(2)	(3)	(4)	(5)
Traditional Services	-52.76	-58.72	-26.56	1.11	0.50

When we compare this exercise with the one from the previous section, we notice an interesting particularity in the services sector. The modern services sector has a greater average impact on GDP per worker gap when subjected to productivity changes compared to traditional services. On the other hand, the traditional services sector has a greater average impact on aggregate productivity when subjected to productivity changes, compared to modern services. This is due to the fact that, on average, the traditional services sector concentrates most of the labor share; therefore, it has a greater weight in the calculation of aggregate productivity, and this causes productivity changes in this sector as well have greater weight.[20]

In the case of agriculture, productivity changes have little effect on aggregate productivity. This is because in this sector, labor participation and productivity are relatively small compared to other sectors. As can be seen in Table 5, on average a reduction of 55.3% in the sectoral productivity gap only resulted in a reduction of 0.03% in the aggregate. Column 6 shows that the proportional effect was close to zero.

5.3 Changing Elasticity of Intermediate Goods

In this section, we analyze what would happen to the economies of the sample countries if their production structures were to converge to that of the United States. Therefore, we conduct a counterfactual exercise similar to that in the previous section. However, in this new exercise, instead of inserting the productivity of the United States to the other countries, we insert the elasticity of the set of intermediate goods with respect to the intermediate good j, β_{ij}. Specifically, by proceeding in this way, we are making the importance of good i in the production of good j equal to that of the United States.

In Table 6, we present the sectoral average shares of intermediate inputs before and

[20] On average, traditional services concentrates 44% of labor share.

after the exercise, along with those of the United States. It can be seen that the average share of intermediate inputs before the exercise is higher in the industry (53%), followed by traditional services (26%). However, after the exercise, the share of intermediate inputs becomes more similar to that of the United States. In other words, the industry loses its share, and economies become more service-oriented, with both modern and traditional services gaining a larger share. Note that what we did was reduce the gap in the share of intermediate inputs to almost zero.

Table 6: Share of Intermediate Inputs

	Average		
Sectors	Before Change	After Change	USA
Agriculture	0.01	0.01	0.01
Industry	0.53	0.34	0.36
Modern Services	0.21	0.30	0.28
Traditional Services	0.26	0.35	0.35

Table 7 presents the average percentage change in the sectoral gaps in prices, labor, intermediate inputs, and GDP per worker given this counterfactual exercise. It is noticeable that there has been a considerable increase in the gaps in labor, intermediate inputs, and sectoral GDP in agriculture and industry. In other words, this structural change that altered the importance of intermediate inputs in production resulted in a negative average effect on the economies.

This is due to the fact that the structural change was carried out without the necessary increase in productivity. Specifically, in countries with highly efficient agricultural and/or industrial sectors, the structural change led to a reduction in the quantity of labor and intermediate inputs, and consequently they began to produce less, resulting in an increased gap.

In the modern services sector, the opposite occurred, which means that the structural change benefited this sector. In this case, the quantity of labor and intermediate inputs increased and the gap in sectoral GDP decreased. Finally, the traditional services sector underwent little change, but there was an increase in the gap in sectoral GDP.

Table 7: Average Percentage Change in Gaps

Sectors	Prices	Labor	Intermediate Inputs	GDP per Worker
Agriculture	-8.21	64.30	118.19	79.15
Industry	-14.45	59.74	149.25	84.37
Modern Services	3.04	-27.87	-30.67	-22.07
Traditional Services	-8.51	-10.21	-1.31	10.59

6 Final Remarks

In this article we develop a general equilibrium model to quantitatively evaluate the effects of productivity changes and changes in the productive structure on the income gap in developed and developing countries. We used WIOD data from 2014 and calibrated the model for 39 countries. We conducted two counterfactual exercises, in the first we imputed the productivity of the United States in other countries and evaluated the effects on the income gap per worker, on aggregate productivity, and on the supply of intermediate inputs. In the second exercise, we impute the elasticity of intermediate goods in other countries and evaluate the effects on prices, supply of intermediate goods, number of workers, and sectoral income per worker.

Our findings show that productivity in modern services is, on average, higher than in other sectors. However, closing the manufacturing productivity gap, relative to the United States, results in a greater average reduction in the gaps in income per worker and aggregate productivity gaps. Furthermore, industry is, on average, the most central sector; therefore, this sector has a greater capacity to transmit productivity changes and, consequently, to stimulate production in other sectors.

We also show that if economies became more service-oriented, without the necessary increase in productivity, this would further increase the income gap per worker. This arises from the fact that some countries have a very productive agricultural and/or industrial sector, therefore, a structural change that causes these countries to produce more intermediate inputs in the service sectors causes these economies to move resources from more productive sectors to the services sector, which in turn harms economic development. A future avenue of research is to identify the drivers that cause economies to become more service-oriented.

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Appendix A Model Results

Table A1: Sectoral Productivity

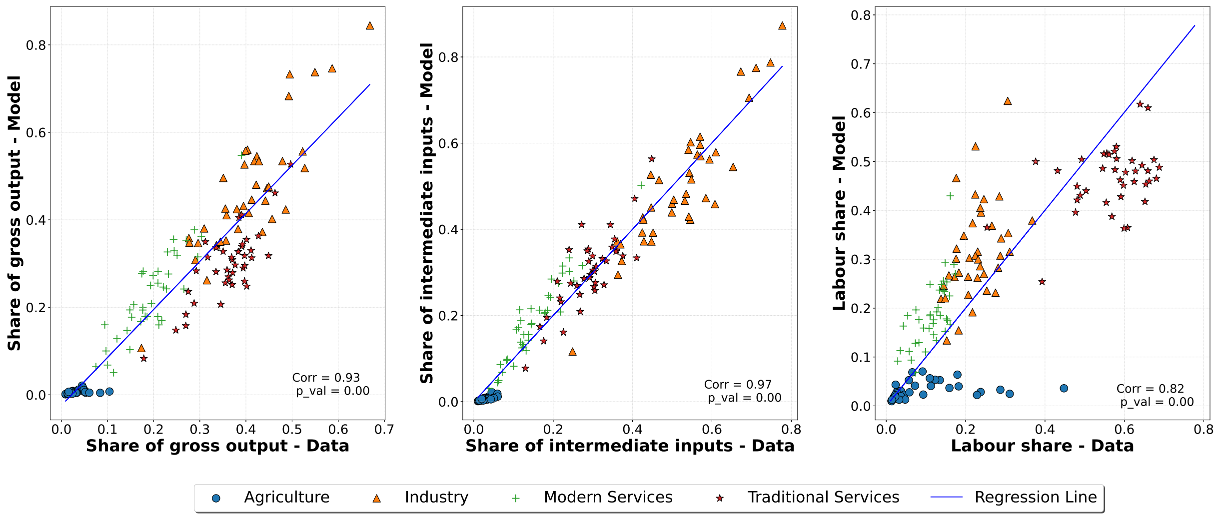
Country	Code	Agriculture	Industry	Modern Services	Traditional Services
Australia	AUS	0.57	1.61	1.97	0.71
Austria	AUT	0.16	1.59	1.64	0.78
Belgium	BEL	0.28	1.80	1.80	0.84
Brazil	BRA	0.14	1.41	1.89	0.45
Bulgaria	BGR	0.08	1.67	1.92	0.80
Canada	CAN	0.53	1.70	1.74	0.75
China	CHN	0.22	1.14	1.15	0.30
Cyprus	CYP	0.29	1.25	1.74	0.85
Czech Republic	CZE	0.47	1.85	2.11	1.12
Denmark	DNK	0.42	1.74	1.74	0.81
Estonia	EST	0.52	1.70	1.66	1.09
Finland	FIN	0.26	1.61	1.76	0.72
France	FRA	0.39	1.51	1.64	0.66
Germany	DEU	0.16	1.38	1.63	0.65
Greece	GRC	0.36	1.84	1.90	0.88
Hungary	HUN	0.53	1.99	1.63	0.93
India	IND	0.27	1.01	0.79	0.31
Indonesia	IDN	0.15	1.40	1.24	0.30
Ireland	IRL	0.29	2.10	2.00	0.95
Italy	ITA	0.26	1.48	1.75	0.79
Japan	JPN	0.17	1.36	1.41	0.77
Latvia	LVA	0.53	1.62	1.80	1.09
Lithuania	LTU	0.25	1.93	1.43	1.00
Mexico	MEX	0.20	1.80	1.68	1.30
Netherlands	NLD	0.51	1.95	1.58	0.79
Norway	NOR	1.12	2.23	1.78	0.94
Poland	POL	0.21	1.86	1.87	1.10
Portugal	PRT	0.08	1.54	1.96	0.77
Republic of Korea	KOR	0.10	1.59	1.33	0.54
Romania	ROU	0.33	1.57	1.94	0.65
Russian Federation	RUS	0.13	1.51	0.97	0.59
Slovakia	SVK	0.72	1.62	1.88	1.10
Slovenia	SVN	0.10	1.35	1.29	0.70
Spain	ESP	0.28	1.71	1.68	0.68
Sweden	SWE	0.19	1.77	1.94	0.88
Switzerland	CHE	1.09	1.71	1.59	0.91

Continued on next page

Table A1: Sectoral Productivity (Continued)

Country	Code	Agriculture	Industry	Modern Services	Traditional Services
Turkey	TUR	0.28	1.34	1.38	0.57
United Kingdom	GBR	0.21	1.29	1.54	0.68
United States	USA	0.78	2.36	2.42	1.71

Figure A1: Comparison Between Data and Model Results



Appendix B Bonacich-Katz Centrality Index

In this section, we describe how to calculate Bonacich-Katz centrality index that measure the importance of a sector as supplier to economy. According to Grassi and Sauvagnat (2019) Bonacich-Katz centrality index can be defined by:

$$b_i = \beta_i + \sum_j b_j \Sigma_{ji}, \tag{19}$$

where $\beta_i = \frac{C_i+G_i+I_i+X_i}{GDP}$ is the importance of sector i as supplier to final demand, and is known as Domar Weights, and $\Sigma_{ji} = \frac{X_{ij}}{Q_i}$, where Q_i is the gross product and X_{ij} is the input output matrix.[21] 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

[21] We highlight that C_i, G_i, I_i and X_i are consumption, government spend, investments and net exports, respectively.

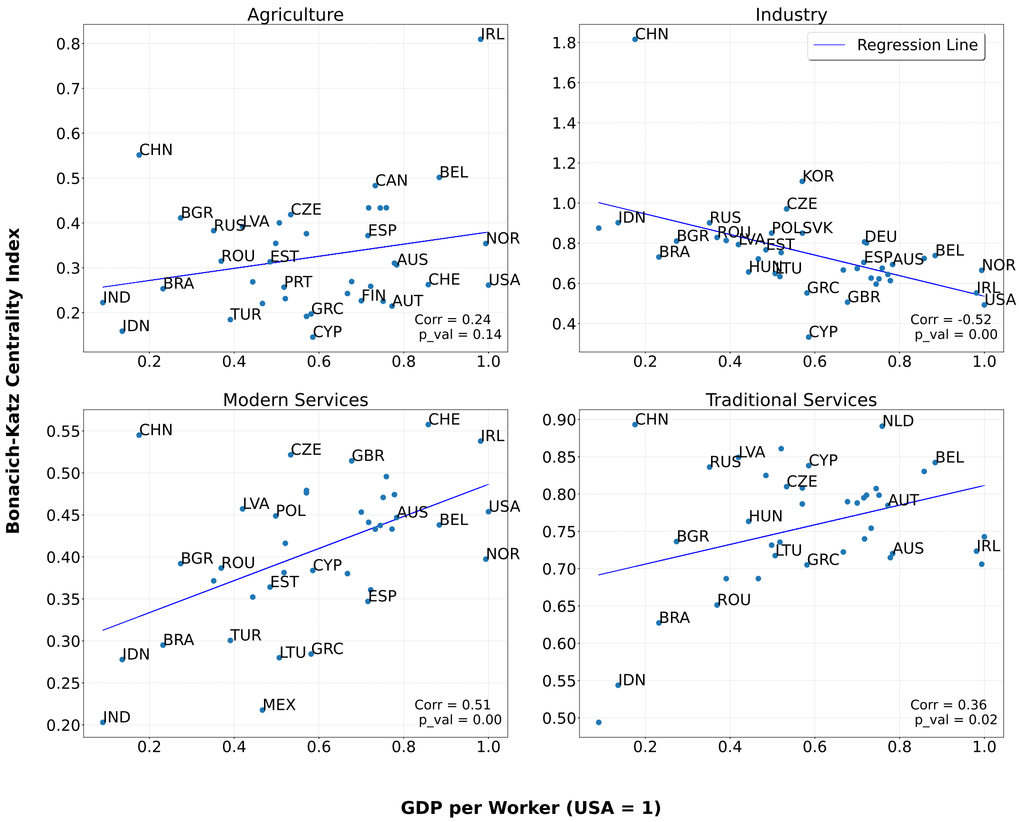
centrality of its customer sectors. This equation is a system with four equations with four unknowns, that is, the Bonacity-Katz centrality index for each sector. The solution of this system can be written as follows.

$$b' = \beta'(I - \Sigma)^{-1} = \beta' + \beta'\Sigma + \beta'\Sigma^2 + \beta'\Sigma^3 + \cdots + \beta'\Sigma^k + \cdots , \qquad (20)$$

where b' is the centrality vector and $(I - \Sigma)^{-1}$ is the Leontief inverse matrix.

In Figure B1 we present this measure together with GDP per worker. The Bonacich-Katz centrality index of traditional and modern services is positively associated with the countries' level of development; the correlation of the centrality index of these subsectors with GDP per capita is 0.31 and 0.54, respectively, both statistically significant at 1%. On the other hand, the industry centrality index is negatively correlated with the countries' income level, and in agriculture there is no statistically significant relationship.

Figure B1: Bonacich-Katz Centrality Index - 2014



Appendix C Sectoral Trends

Table C1: Panel Regression Models, Sectoral Share of Value Added - 2000:2014

	Dependent Variable: Share of Added Value			
	(1)	(2)	(3)	(4)
	Agriculture	Industry	Modern Services	Traditional Services
Ln GDP per Capita	−0.081***	−0.008	0.108***	−0.019
Ln GDP per Capita Squared	0.010***	0.010***	−0.021***	0.001
Ln Population	−0.294***	−0.950***	1.176***	0.068
Ln Population Squared	0.011***	0.027***	−0.037***	−0.0002
D05	−0.005***	−0.007***	0.008***	0.005***
D08	−0.010***	−0.013***	0.021***	0.003
D11	−0.011***	−0.032***	0.031***	0.012***
D14	−0.011***	−0.041***	0.037***	0.015***
Country Fixed Effects	✓	✓	✓	✓
Observations	585	585	585	585
R^2	0.552	0.464	0.455	0.203
Adjusted R^2	0.514	0.418	0.409	0.135
F Statistic (df = 8; 538)	83.009***	58.253***	56.172***	17.119***

Notes: Statistical significance is indicated at the $***p < 0.01$, $**p < 0.05$, and $*p < 0.1$ levels. 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 dummy that indicates the period goes from 2000 to 2002.

Appendix D Sectoral Classification

Table D1: 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	Traditional Services
Air transport	Modern Services
Warehousing and support activities for transportation	Traditional 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
Activities auxiliary to financial services and insurance activities	Modern Services
Real estate activities	Modern Services

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Table D1: Sectoral classification (Continued)

Sector names	Sector group
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	Modern Services
Other professional, scientific and technical activities; veterinary activities	Modern 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	Traditional Services

Notes： Adapted from World Input-Output Database.