Economic Development and Spillover Effects of Intermediate Goods and Services*

Marcos J Ribeiro†
FEARP/USP

Fernando Barros Jr§
FEARP/USP

Bruno Delalibera‡
Universitat de Barcelona

Luciano Nakabashi¶
FEARP/USP

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Abstract

This paper investigates the role of sectoral total factor productivity (TFP) and interdependence between sectors through the use of intermediate goods in economic development. Through a general equilibrium model, we show that shifting labor from less productive sectors, such as agriculture, to modern services has a significant impact on aggregate TFP. Additionally, we demonstrate that increasing TFP in the industry has a greater effect on reducing the worker income gap, at both the sectoral and aggregate levels, compared to other sectors of the economy. Our findings also suggest that in countries where industrial sector are highly efficient, a structural change that increases the share of the service sector in the economy, without a corresponding increase in productivity, would further widen the gap in GDP per worker.

Keywords: Production Networks; TFP; Economic Development.

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†Correspondence address: Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto da Universidade de São Paulo, Avenida Bandeirantes, 3900 - Vila Monte Alegre, Ribeirão Preto - SP, 14040-905. Email: mjribeiro@usp.br.

‡Email: brunodelalibera@gmail.com.

§E-mail: fabarrosjr@usp.br.

¶Email: luciano.nakabashi@gmail.com.

1 Introduction

Sectoral total factor productivity (TFP) and interdependence between sectors through the use of intermediate goods are two factors identified as crucial for understanding differences in development levels among countries (Jones, 2011b; Herrendorf and Valentinyi, 2012; Herrendorf et al., 2014; Inklaar et al., 2019; Fadinger et al., 2022). Interdependence between sectors via the use of intermediate inputs means that the effect of a productivity change in a specific sector spreads to other sectors of the economy. As in Jones (2011b), if one sector experiences an improvement in productivity efficiency, other sectors that use intermediate goods from that sector will benefit. In this paper, we address both factors; specifically, we study how changes in productivity in a specific sector spread to other sectors of the economy through intermediate goods and contribute to reducing income disparity compared to the United States. In this sense, our paper is related to studies that combine structural transformation and insights into the theory of production networks (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 based on Carvalho and Tahbaz-Salehi (2019) and Ferreira et al. (2021) to quantitatively assess the effects of changes in TFP and production structure on the income gap between countries. In our initial calibration, we demonstrated that the productivity of modern services is, on average, higher than that of other sectors of the economy. Additionally, we conducted two counterfactual exercises: in the first one, we introduced the sectoral TFP of the United States, one at a time, into the other countries; and in the second one, we introduced the elasticity of intermediate goods. Our findings indicate that increasing TFP in the industry has a more pronounced effect on GDP per worker and aggregate TFP, both at the sectoral and aggregate levels, compared to other sectors. Furthermore, we showed that introducing the elasticity of intermediate goods from the United States into other countries makes the sectoral share of these goods similar to that of the United States, on average; as a result, these economies become more service-oriented. However, many of these economies, such as China, are relatively more efficient in the industry, and this structural change, which forces them to produce more in the service sector, where they are less efficient, further increases the income gap.

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, which hinders the expansion of productivity in these countries. We find that on average, the TFP of modern services is higher than that of other sectors. This suggests that reallocating workers from less productive sectors, such as agriculture, to this sector could lead to 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, a 1% increase in TFP translates, on average, into a reduction of 0.4% in the aggregate TFP gap.

Other studies highlight the role of sectoral linkages through the input-output matrix in sectoral and aggregate product growth. 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 have shown that the increase in TFP in a specific sector leads to an increase in the production of intermediate goods within that same sector. Consequently, this results in a reduction in prices, which in turn increases the demand for intermediate goods 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 the greatest capacity to drive 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 demonstrate that increasing productivity in the industry has a greater average impact on reducing the GDP per worker gap, both at the sectoral and aggregate levels, compared to other sectors. A 1% increase in TFP in the industry resulted in an average reduction of 1.62% and 1.2% in the GDP per worker gap at the sectoral and aggregate levels, 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, on average, does not benefit economies, especially because many of these economies direct resources from where they are most efficient to where they are least efficient, 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 TFP in modern services have a greater average impact on GDP per worker compared to traditional services. However, variations in the TFP of traditional services have a very similar average impact on aggregate TFP 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 show that the traditional services sector is more central than 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.[1] 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).

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.[2]

Based on International Standard Industrial Classification of All Economic Activities (ISIC 4) we have classified the 56 sectors identified in the Socio-Economic Accounts (SEA) into three broad sectors: agriculture, industry, and services.[3] 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 in-

[1]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).

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

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

clude 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.[4] 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

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. This measure is defined as the ratio of GDP per worker in the United States to that of 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). Some papers assume that GDP per worker is a measure of labor productivity.[5]

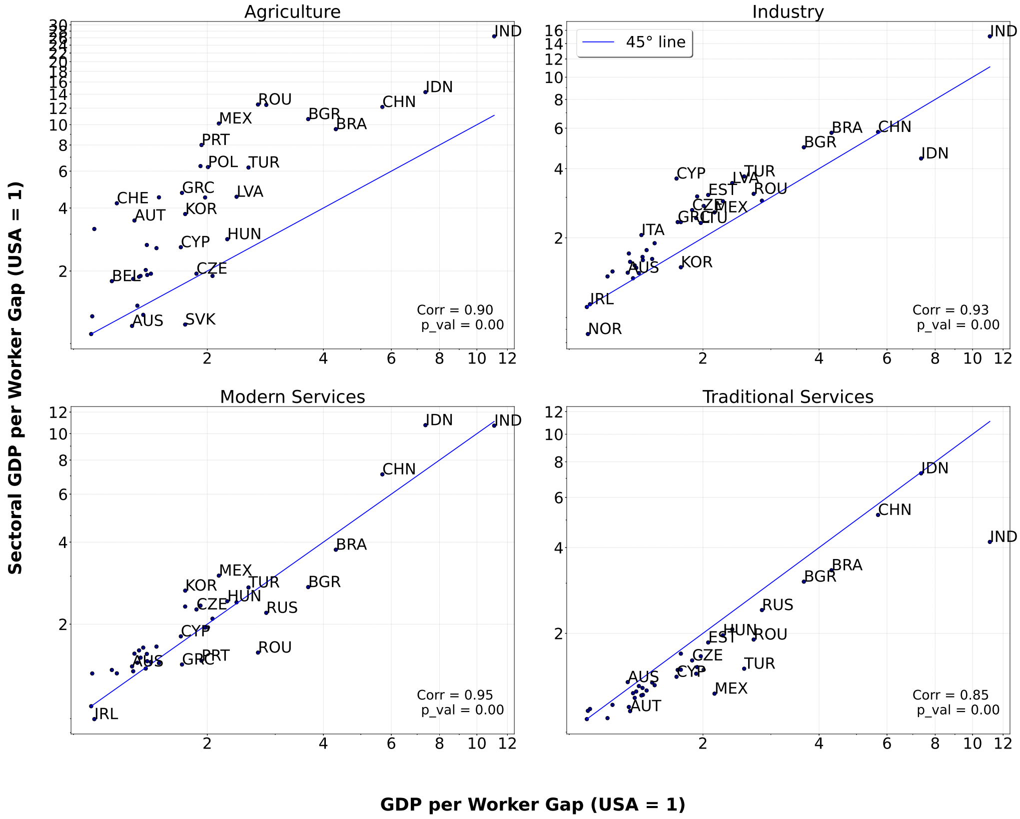
Figure 1 presents the results, with points below (above) the 45-degree line indicating countries where the gap in aggregate GDP is greater (lower) than the gap in sectoral GDP. We highlight two facts. Firstly, the GDP gap in agriculture is larger than in other sectors in most countries. The average gap 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. Furthermore, on average, the gap in agriculture is greater than in the aggregate, which

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

[5] See: Restuccia et al. (2008), Herrendorf and Valentinyi (2012), Gollin et al. (2014) and Herrendorf et al. (2022).

is 2.28. This result is consistent with the findings of Restuccia et al. (2008), Herrendorf and Valentinyi (2012), Gollin et al. (2014), and Herrendorf et al. (2022). In industry, the gap is smaller than in agriculture, on average 2.75, but is larger than in the aggregate. Secondly, the GDP per worker gap in the traditional and modern service sectors are, on average, 1.83 and 2.43, respectively.

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.

Aggregate total productivity factor (TFP) depends on sectoral productivity and labor share, and one of the channels to fill these gaps is to reallocate labor to sectors where productivity is higher. In this context, agriculture, normally the least productive sector, plays a crucial role in explaining income differences between countries, since less developed countries allocate a significant part of the workforce in this sector.[6] Therefore, income disparities between the least developed and most developed countries would tend to

[6]In India, in Indonesia and China, the percentage of labor in agriculture is 45%, 31% and 24%, respectively

decrease if the labor force was reallocated from agriculture to the most productive sectors of the economy (Restuccia et al., 2008; McMillan and Rodrik, 2011; Herrendorf et al., 2022).

However, aggregate TFP 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 improved sectoral productive efficiency. In this context, important questions emerge. Which sector would most boost aggregate TFP and income growth in the event of labor reallocation from agriculture? And if instead of reallocating labor there was an increase in TFP in these sectors, which one has the greatest capacity to reduce the income gaps? In the context in which intermediate inputs create networks between sectors, which 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 more developed countries, intermediate goods production is more focused on service sectors, while in less developed countries, production is more focused on agriculture and industry. For example, the correlation between GDP per worker and the share of intermediate goods from agriculture and industry is -0.56 and -0.66, respectively. On the other hand, the correlation with the traditional services and modern services sectors is 0.43 and 0.66, respectively.[7] This observation is consistent with the literature on structural change (Eichengreen and Gupta, 2013; Herrendorf et al., 2014; Herrendorf and

[7] We consider data from 2014.

Schoellman, 2018; Sposi, 2019).

Although industry has great importance in the productive structure of less developed countries, it tends to lose share as economies specialize in the services sector. Rodrik (2016) documents that there is a trend towards 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.[8]

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:

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

where II_{jt}^{share} is the share of intermediate inputs of country j in period t, pop is the population, y_{jt} is the GDP per capita, also there are quadratic terms for $\ln pop_{jt}$ and $\ln y_{jt}$, C_j are country fixed effects, D_T are period dummies, and ϵ_{jt} is an error term. Here, we use 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

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

for 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.[9]

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	-0.184^{***}	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: 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.

[9] 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.

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 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 Model

In this section we provide an overview of the model. First, we describe the problem of the firm and the representative consumer. Next, we present the equilibrium conditions and the optimal solution of the model, and finally, we discuss how changes in productivity affect the production chain and the economy's final product.

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 (TFP), L_i is the amount of labor employed and X_{ij} is the matrix of intermediate goods where the columns indicate the sector of the origin of goods and services while the rows indicate the sector of destination. 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 j produces more intermediate inputs for sector i, while $\beta_{ij} = 0$ indicates that input j is not needed in the production of good i, we also assume that for all i $\sum_{j \in N} \beta_{ij} = 1$.

The firm's problem can be written as:

$$
\begin{aligned}
\underset{X_{ij},L_i}{\text{Max}} \quad & p_i Q_i - wL_i - \sum_{j\in N} p_j X_{ij}, \\
\text{st:} \quad & Q_i = A_i L_i^{\sigma_i} \left(\prod_{j\in N} X_{ij}^{\beta_{ij}} \right)^{1-\sigma_i},
\end{aligned} \tag{3}
$$

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 Stone-Geary over the consumption of N goods offered in the economy and chooses consumption c_i to solve the following problem:[10]

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

where $\bar{c}_i$ are the minimum level of the consumption, α_i are nonnegative weights, p_i are prices and w is the amount of wage. We also assume that $\sum_i^N \alpha_i = 1$.

The first order conditions of the problem give us the optimal consumption:

$$
c_i = \bar{c}_i + \frac{\alpha_i}{p_i} \left(w - \sum_{j=1}^{4} p_j \bar{c}_j \right). \tag{7}
$$

[10]This type of preference function is common in the literature and can be view in Herrendorf et al. (2013) and Herrendorf et al. (2014).

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

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

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

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

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:

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

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:

$$\ln p_i - \Theta_i p_j = -\ln A_i - \Phi_i. \tag{15}$$

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 $\hat{\mathbf{p}}$:

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

We then have a vector of sectoral prices that depend on TFP, 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 TFP 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 TFP, 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 TFP of sector A experiences a positive change, the amount of intermediate goods produced by sector A increases and the price decreases. The price reduction has a positive impact on the sector B, which begins 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 variation will depend on β_{ij}, and 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, α_i, β_{ij}, σ_i, and L. All parameters are calculated using input-output matrices (IO) and Socio-Economic Accounts (SEA) data. We calculated the weights of consumption in the utility function, α_i, as the ratio of consumption of good i in relation to total income. 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 j used in the production of sector i. 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.[11] Finally, the total amount of labor, L, is associated with the number of people engaged in production in each respective country.

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

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, and agricultural subsistence consumption, $\bar{c}_{agr}$, in such a way that the value added per worker and the labor share of agriculture, resulting from the equilibrium of the model, coincide with the values present in the data.[12] We define the following objective function for our numerical routine:

$$D = \sum_{i=1}^{N} \left(\frac{VA_i^M - VA_i^T}{VA_i^T} \right)^2 + \left(\frac{Lsh_{agr}^M - Lsh_{agr}^T}{Lsh_{agr}^T} \right)^2 \tag{17}$$

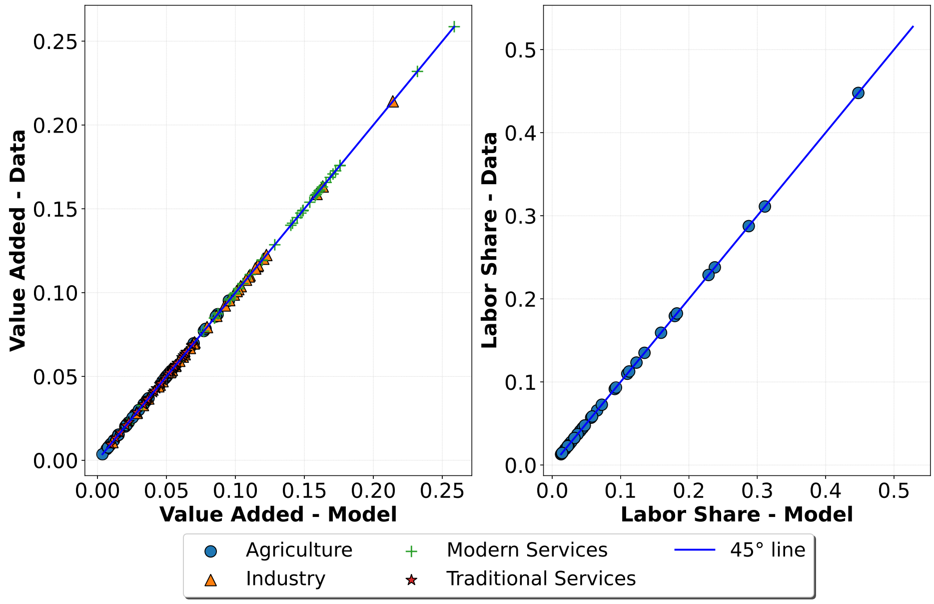
where VA is the value added per worker, Lsh_{agr} is the labor share of agriculture, and the superscripts M and T indicate the model and target statistics. The value added per worker from the model, VA_i^M, is calculated as follows:

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

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, and, in all, we calibrated 195 parameters. Figure 2 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.

[12] Note that we only calibrate subsistence consumption in agriculture, in other sectors we consider it as zero.

Figure 2: Model Adjustment to Data



Notes: We consider only labor share from agriculture.

5 Results

In this section, we present the results of the paper. Initially, we discuss the calibrated TFP and demonstrate that some model outcomes are aligned with empirical facts. Next, we address the results of two counterfactual exercises that we conducted. In the first exercise, we apply the sectoral TFP of the United States to other countries, analyze the impacts on the GDP per worker gap at both sectoral and aggregate levels, and explore their implications on the production chain through intermediate goods. Additionally, we examine the effects of this exercise on aggregate TFP. In the second exercise, we follow a similar procedure to the first one, except that instead of TFP, we apply the elasticity of intermediate goods from the United States to other countries, and discuss the resulting effects on the GDP per worker gap.

5.1 Total Factor Productivity

In Figure 3, we present calibrated sectoral TFP alongside GDP per worker.[13] As expected, the productivity of the four sectors is positively associated with the level of

[13]The calibrated sectoral TFP for each country can be seen in Appendix A.

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 3: Total Factor Productivity

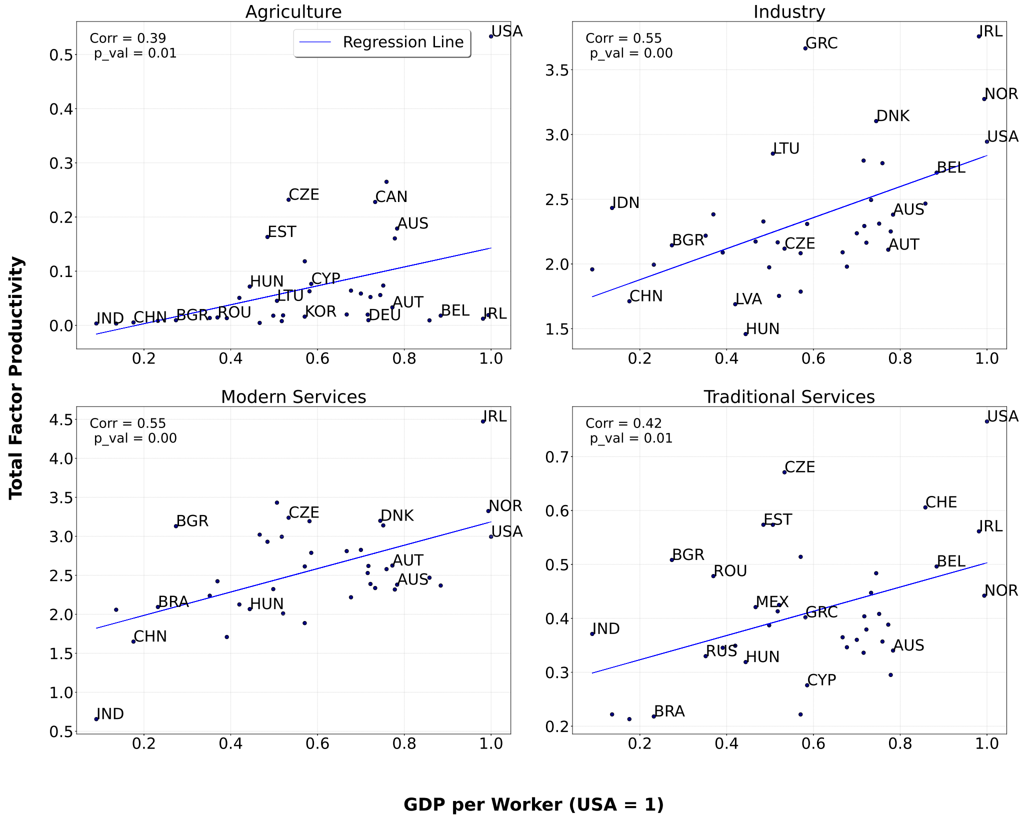


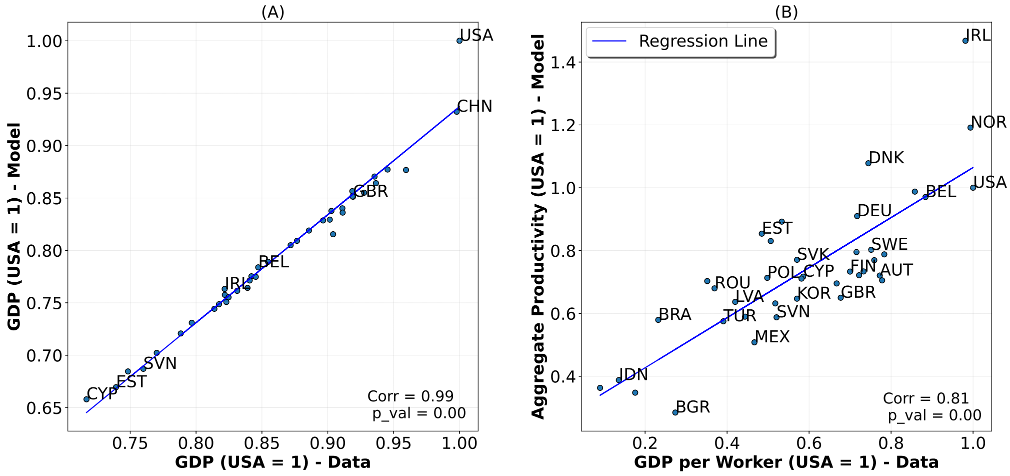
Table 2 provides descriptive statistics for the calibrated TFP. On average, the modern services sector is the most productive sector, followed by the industry. This result comes from the fact that modern services cover subsectors that have added value per worker well above the average, for example, real estate activities, financial services, and insurance and reinsurance. This finding suggests that reallocating labor from agriculture to modern services has a more positive effect on aggregate productivity than if labor were directed to industry, for example.

Table 2: Descriptive Statistics of TFP

Sectors	Mean	Std	Min	25%	Median	75%	Max
Agriculture	0.07	0.10	0.00	0.01	0.02	0.07	0.53
Industry	2.34	0.50	1.46	2.09	2.24	2.48	3.76
Modern Services	2.57	0.63	0.66	2.23	2.53	2.99	4.47
Traditional Services	0.41	0.12	0.21	0.34	0.39	0.48	0.77

Figure 4 (A) compares GDP data with GDP and TFP 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 4 (B) compares aggregate TFP and GDP per worker from the data, it is observed that aggregate TFP also has a positive correlation with the level of income per worker of the countries.[14] Note that Bulgaria, India, Russia, and China are the countries with the lowest aggregate TFP, while Ireland, Norway, Denmark and the United States are the most productive.[15]

Figure 4: Comparison Between Data and Model Results



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

5.2 Counterfactual 1

In this section, we analyze what would happen to the economies of the sample countries if their production structures converged to that of the United States. Thus, we

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

[15] Our model also replicates well other important characteristics of economies, for example, the share of intermediate goods, gross product, and labour. See Figure A1 in the Appendix for a detailed comparison of these shares between the model and observed data.

conduct a counterfactual exercise in which we insert the elasticity of the set of intermediate goods i in relation to the specific intermediate good j, β_{ij}, of the United States into the other countries. Specifically, by doing this, we make the importance of good j in the production of good i equal to that of the United States.

In Table 3, we present the average sectoral shares of intermediate inputs and labor before and after this counterfactual exercise, along with those of the United States. It is observed that the average share of intermediate inputs before the exercise is higher in the industry (72.15%), followed by modern services (19.23%). On the other hand, the labor share is higher in traditional services (46.45%), followed by the industry (32.94%). However, after the exercise, the shares of intermediate inputs and labor become more similar to those of the United States. In other words, the industry loses its share and economies become more service-oriented, with modern and traditional services gaining a larger share. Note that what we did was reduce the gap in the share of intermediate inputs and labor to almost zero.

Table 3: Counterfactual 1 - Average Percentage Share of Intermediate Inputs and Labor

	Intermediate Inputs			Labor		
Sectors	Before	After	USA	Before	After	USA
Agriculture	0.18	0.22	0.59	2.51	1.92	1.65
Industry	72.15	53.06	50.46	32.94	23.04	22.55
Modern S.	19.23	29.59	30.94	18.30	18.61	21.25
Traditional S.	8.44	17.13	18.01	46.25	56.43	54.55

Table 4 demonstrates the average percentage change in the sectoral GDP gap per worker in three different scenarios: when exclusively modifying the parameter β_{ij}, when modifying only the TFP and, finally, when change both simultaneously. It is noticeable that, in the first scenario, there was a considerable increase in GDP gaps per worker in all sectors.

This negative average effect on economies can be explain by the fact that if β_{ij} increases, the dependency of sector i on input j increases. This means that sector i now uses a larger proportion of input j for its production. As a result, the demand for intermediate inputs X_{ij} increases. According to Equation (4), this implies that, to maintain equilibrium, the relative price p_i/p_j must also adjust, leading to an increase in the price p_i if p_j remains constant or also increases. This pressure on the prices of intermediate inputs translates into higher costs for the sectors that depend on them, resulting in higher prices for the final goods. Consequently, this reduces the quantity consumed of each good c_i.

In China, for example, the industrial sector supplies many inputs to itself. However, structural changes have led to increased dependency on the service sector. Although more labor has been directed to the service sector, it is not enough to meet the demand for goods. Consequently, the prices of goods and services provided by the service sector increase. This rise in costs causes the Chinese industrial sector to produce less, making final goods more expensive, which in turn leads to a reduction in consumption.

In the second scenario, as expected, we noticed a reduction in the gap. In the third scenario, it is noted that there was also a reduction in the gap, this is due to the fact that along with the structural change there was an increase in productivity that means the sectors produce more intermediate inputs and are able to meet demand. These findings suggest that structural change alone, without the appropriate increase in TFP, is not capable of reducing income gaps between countries.

Table 4: Counterfactual 1 - Average Percentage Change Sectoral GDP per Worker Gap

	% Change in sectoral GDP per worker gap		
Sectors	Change β_{ij}	Change TFP	Change Both
Agriculture	44.84	-91.43	-92.58
Industry	35.46	-78.27	-78.03
Modern Services	80.83	-71.56	-61.69
Traditional Services	58.26	-78.68	-72.23

5.3 Counterfactual 2

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 GDP per worker gap at the sectoral and aggregate level;[16] (ii) We then enter the United States sectoral TFP, one at a time, into each of the sectors analyzed;[17] (iii) We calculate the percentage change in TFP; (iv) We repeat step (i), and measure the percentage change in the GDP gap per worker at the sectoral and aggregate level. We then analyze the effects on GDP per worker, intermediate goods, and aggregate productivity.

5.3.1 GDP per Worker

First, we will analyze the effects on GDP per worker. This allows us to assess the extent to which an increase in sectoral TFP reduces the gap in GDP per worker between the United States and the other countries, both at the sectoral and aggregate levels. Figure 5 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 TFP. It is also noted that there is a negative correlation between both variables, that is, where there have been greater increases in TFP, there have also been greater reductions in the GDP per worker gap.

[16] 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 .

[17] United States TFP in agriculture, industry, modern services, and traditional services is 0.54 , 2.94 , 2.99, 0.76, respectively.

Figure 5: Counterfactual 2 - Percentual Changes in GDP per Worker Gap

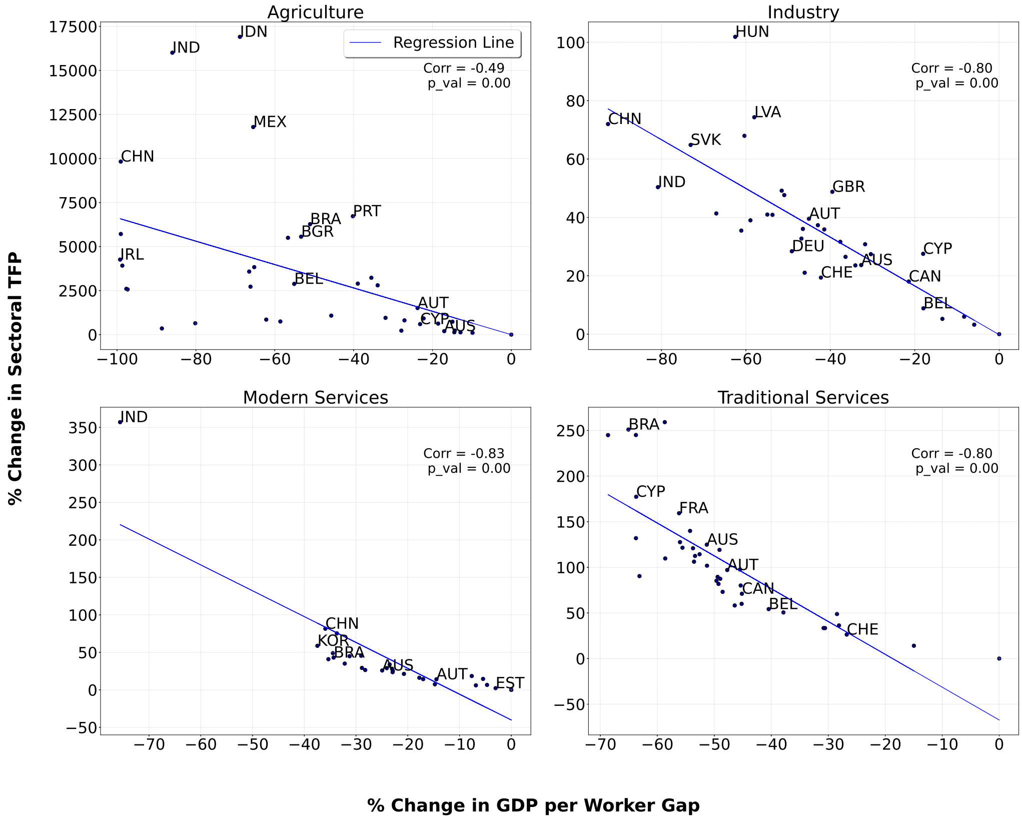


Table 5 presents the average results of this counterfactual exercise. The first column of the table shows the average percentage change in TFP. The second and third columns show the average percentage reduction in the GDP gap per worker at the sectoral and aggregate level, respectively. The last two columns are the ratios between columns three and four, and column two. Both columns illustrate the proportional effect of variations in TFP on the variation in the GDP gap per worker, at the sectoral and aggregate levels, respectively. In agriculture, for example, the 3,432.02% increase in TFP resulted in average reductions of 88.18% and 51.76% in the difference in GDP per worker at the sectoral and aggregate level, respectively. When analyzing proportional effects, we find that a 1% increase in TFP translates, on average, into a decrease of 0.03% and 0.02% in the GDP per worker gap at the sectoral and aggregate level, respectively.

If we combine with the results provided in the fourth and fifth columns, we note that there is a clear order of the average impact of sectoral TFP 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 5: Counterfactual 2 - Average Percentage Change in GDP per Worker Gap

	(1)	(2)	(3)	(4)	(5)
	Average % Change				
Sectors	TFP	**Sectoral** GDP Per Worker gap	GDP Per Worker gap	Ratio 1 (2)/(1)	Ratio 2 (3)/(1)
Agriculture	3432.02	-88.18	-51.76	-0.03	-0.02
Industry	36.98	-60.07	-44.50	-1.62	-1.20
Modern Services	40.45	-33.62	-23.80	-0.83	-0.59
Traditional Services	106.20	-68.31	-48.72	-0.64	-0.46

5.3.2 Intermediate Goods as Channels for Propagating Changes in Productivity

The effect of sectoral TFP changes on 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 a 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 6 we present the average percentage change in intermediate inputs after counterfactual exercise, 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, inserting the TFP of the United States industry into the industry of other countries resulted in an average increase of 416.24% in the supply of intermediate goods within the same sector. Secondly, given the change in the TFP, industry and traditional services were the sectors that most stimulated the supply of intermediate goods in other sectors of the economy, on average.

Table 6: Counterfactual 2 - Average Percentage Change in Supply of Intermediate Inputs

Sectors	Agriculture	Industry	Modern Services	Traditional Services
Agriculture	1285.73	63.97	3.81	30.15
Industry	85.38	416.24	10.45	88.06
Modern Services	74.20	98.02	103.83	100.80
Traditional Services	69.09	93.01	8.52	328.13

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.[18]

5.3.3 Aggregate Productivity

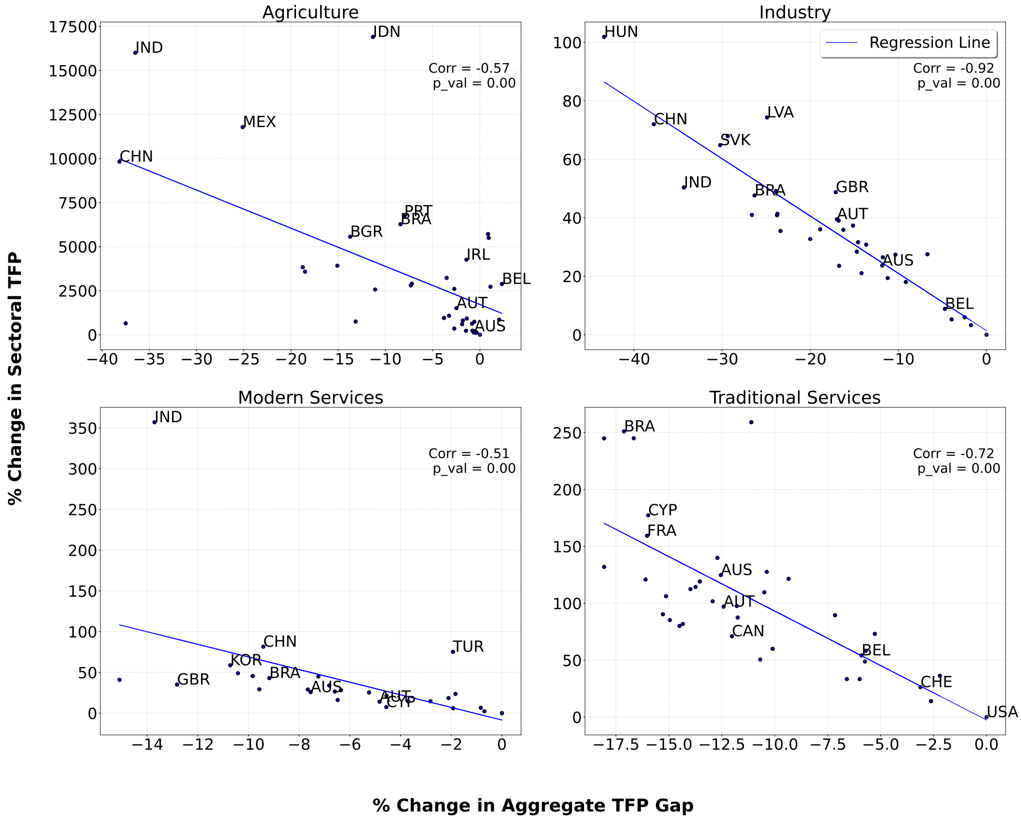
In Section 5.3.1, we evaluated the effects of TFP changes on GDP per worker at both the sectoral and aggregate levels. In this section, we examine the effects of the same exercise on aggregate TFP. The aggregate TFP is simply the sum of sectoral TFPs,

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

weighted by labor share.

The Figure 6 presents the results of the analysis. On the x-axis, we have the percentage change in the aggregate TFP gap, while on the y-axis we have the percentage change in the sectoral TFP. A negative correlation is observed between these two variables in all sectors. In other words, the observed pattern is consistent with the results discussed in the previous section, where significant increases in sectoral TFP resulted in steeper reductions at the aggregate level.

Figure 6: Counterfactual 2 - Percentual Changes in Aggregate TFP Gap



The table 7, similar to the table presented in the previous section, presents the average results of the counterfactual. It is observed that industry demonstrated a more significant proportional effect than other sectors, indicating that a 1% increase in industry TFP results in an average reduction of 0.4% in the aggregate TFP gap (see column 3).

Table 7: Counterfactual 2 - Average Percentage Change in the Aggregate TFP Gap

	(1)	(2)	(3)
	Average % Change		
Sectors	TFP	Aggregate TFP gap	Ratio 1 (2)/(1)
Agriculture	3432.02	-7.52	-0.00
Industry	36.98	-14.90	-0.40
Modern Services	40.45	-3.81	-0.09
Traditional Services	106.20	-11.08	-0.10

When comparing this exercise with that of the previous section, an interesting particularity can be noted in the services sector. Modern services demonstrate a greater average impact on the GDP gap per worker when subject to changes in TFP, in contrast to traditional services. On the other hand, it is observed that traditional services exert a very similar average impact on aggregate productivity when subject to changes in sectoral TFP, compared to modern services (0.09 versus 0.1). This distinction occurs because, on average, the traditional services sector concentrates the majority of the workforce, which results in a significant weight in the calculation of aggregate TFP. Therefore, TFP changes in this sector also have a substantial influence on aggregate TFP, as indicated by the fact that, on average, traditional services hold 44% of the labor share.

In the case of agriculture, changes in TFP have little effect on aggregate TFP. This is because in this sector, labor share and TFP are relatively small compared to other sectors. As can be seen in Table 7, on average an increase of 3432.02% in sectoral TFP only resulted in a reduction of 7.52% in the aggregate. Column 3 shows that the proportional effect was close to zero.

6 Final Remarks

In this article we develop a general equilibrium model to quantitatively evaluate the effects of TFP 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 TFP of the United States in other countries and evaluated the effects on the income gap per worker, on aggregate TFP, 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 the income gap per worker.

Our findings show that TFP in modern services is, on average, higher than in other sectors. However, closing the manufacturing TFP 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 TFP, 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 TFP

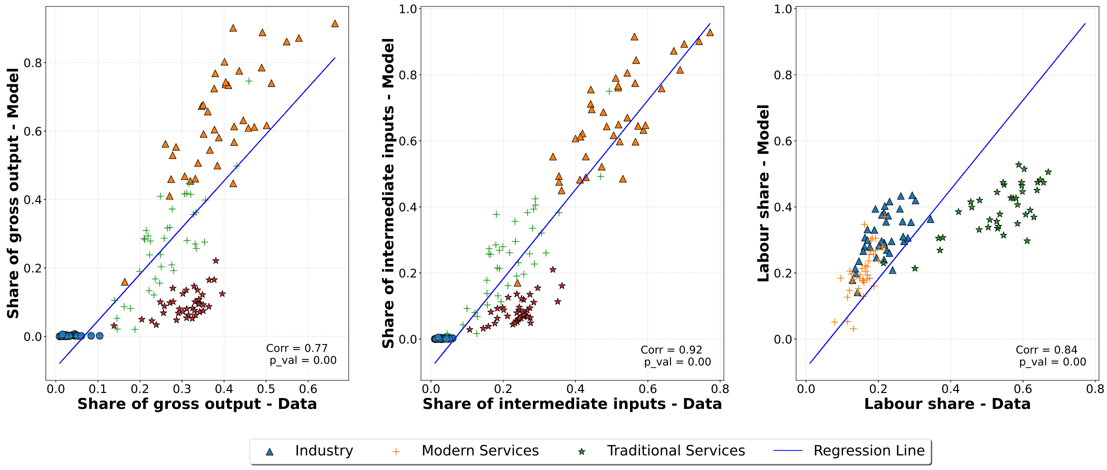
Country	Code	Agriculture	Industry	Modern Services	Traditional Services
Australia	AUS	0.18	2.38	2.38	0.34

Continued on next page

Table A1: Sectoral TFP (Continued)

Country	Code	Agriculture	Industry	Modern Services	Traditional Services
Austria	AUT	0.03	2.11	2.62	0.39
Belgium	BEL	0.02	2.71	2.37	0.50
Brazil	BRA	0.01	1.99	2.09	0.22
Bulgaria	BGR	0.01	2.14	3.13	0.51
Canada	CAN	0.23	2.49	2.34	0.45
China	CHN	0.01	1.71	1.65	0.21
Cyprus	CYP	0.08	2.31	2.79	0.28
Czech Republic	CZE	0.23	2.12	3.24	0.67
Denmark	DNK	0.06	3.10	3.20	0.48
Estonia	EST	0.16	2.33	2.93	0.57
Finland	FIN	0.06	2.24	2.83	0.36
France	FRA	0.16	2.25	2.32	0.30
Germany	DEU	0.01	2.29	2.62	0.40
Greece	GRC	0.06	3.67	3.19	0.40
Hungary	HUN	0.07	1.46	2.07	0.32
India	IND	0.00	1.96	0.66	0.37
Indonesia	IDN	0.00	2.43	2.06	0.22
Ireland	IRL	0.01	3.76	4.47	0.56
Italy	ITA	0.05	2.16	2.39	0.38
Japan	JPN	0.02	2.09	2.81	0.36
Latvia	LVA	0.05	1.69	2.13	0.35
Lithuania	LTU	0.05	2.85	3.43	0.57
Mexico	MEX	0.00	2.17	3.02	0.42
Netherlands	NLD	0.26	2.78	2.58	0.36
Norway	NOR	0.02	3.27	3.32	0.44
Poland	POL	0.02	1.97	2.32	0.39
Portugal	PRT	0.01	2.17	2.99	0.41
Rep. of Korea	KOR	0.02	2.08	1.89	0.22
Romania	ROU	0.01	2.38	2.42	0.48
Russia	RUS	0.01	2.22	2.24	0.33
Slovakia	SVK	0.12	1.79	2.61	0.51
Slovenia	SVN	0.02	1.75	2.01	0.42
Spain	ESP	0.02	2.80	2.53	0.34
Sweden	SWE	0.07	2.31	3.14	0.41
Switzerland	CHE	0.01	2.47	2.47	0.61
Turkey	TUR	0.01	2.09	1.71	0.35
United Kingdom	GBR	0.06	1.98	2.22	0.35
United States	USA	0.53	2.94	2.99	0.77

Figure A1: Comparison Between Data and Model Results



Note: We exclude labor share from agriculture.

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.[19] This shows that the centrality of a sector is equal to the importance of that sector as a supplier to the final demand plus the weighted sum of the centrality of its customer sectors. This equation is a system with four equations with four unknowns, that is, the Bonacity-Katz centrality index for each sector. The solution of this system can be written as follows.

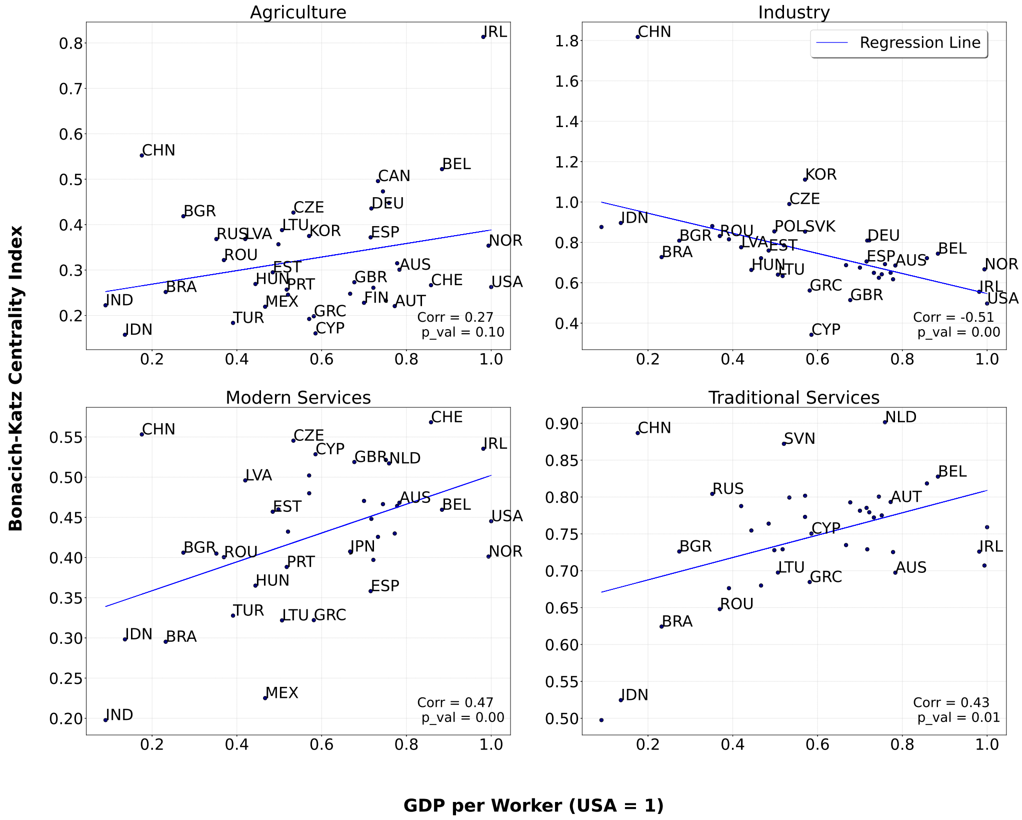
$$b' = \beta'(I - \Sigma)^{-1} = \beta' + \beta'\Sigma + \beta'\Sigma^2 + \beta'\Sigma^3 + \cdots + \beta'\Sigma^k + \cdots, \tag{20}$$

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

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 sectors with GDP per worker is 0.36 and 0.51, 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	-0.298^{***}	-0.116^{**}	0.312^{***}	0.101^{**}
Ln GDP per Capita Squared	0.014^{***}	0.009^{***}	-0.018^{***}	-0.006^{**}
Ln Population	-0.381^{***}	-1.016^{***}	0.701^{***}	0.696^{***}
Ln Population Squared	0.012^{***}	0.030^{***}	-0.023^{***}	-0.019^{***}
D05	-0.003^{***}	-0.011^{***}	0.009^{***}	0.004^{**}
D08	-0.007^{***}	-0.020^{***}	0.025^{***}	0.002
D11	-0.007^{***}	-0.042^{***}	0.036^{***}	0.013^{***}
D14	-0.007^{***}	-0.055^{***}	0.047^{***}	0.014^{***}
Country Fixed Effects	✓	✓	✓	✓
Observations	585	585	585	585
R^2	0.657	0.450	0.399	0.245
Adjusted R^2	0.627	0.403	0.347	0.181
F Statistic (df = 8; 538)	128.627^{***}	54.991^{***}	44.590^{***}	21.845^{***}

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	Modern Services
Air transport	Modern Services
Warehousing and support activities for transportation	Modern Services
Postal and courier activities	Traditional Services
Accommodation and food service activities	Traditional Services
Publishing activities	Modern Services
Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	Modern Services
Telecommunications	Modern Services
Computer programming, consultancy and related activities; information service activities	Modern Services
Financial service activities, except insurance and pension funding	Modern Services
Insurance, reinsurance and pension funding, except compulsory social security	Modern Services
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	Traditional Services
Scientific research and development	Modern Services
Advertising and market research	Traditional Services
Other professional, scientific and technical activities; veterinary activities	Traditional Services
Administrative and support service activities	Traditional Services
Public administration and defence; compulsory social security	Traditional Services
Education	Traditional Services
Human health and social work activities	Traditional Services
Other service activities	Traditional Services
Activities of households as employers; undifferentiated goods-and services-producing activities of households for own use	Traditional Services
Activities of extraterritorial organizations and bodies	Modern Services

Notes： Adapted from World Input-Output Database.