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REVISITING KALDOR'S LAWS: THE SYMBIOSIS BETWEEN MANUFACTURING AND SERVICES IN ECONOMIC GROWTH

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CENTRO DE DESENVOLVIMENTO E PLANEJAMENTO REGIONAL

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REVISITING KALDOR'S LAWS: THE SYMBIOSIS BETWEEN MANUFACTURING AND SERVICES IN ECONOMIC GROWTH

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Abstract: This paper revisits Kaldor's Laws, considering that both manufacturing and services, as well as their interaction (symbiosis), contribute to economic growth. To investigate this question, we constructed a symbiosis indicator and tested it econometrically using panel data models for a sample of 41 countries between 2000 and 2014. The results show that the services sector and the symbiosis between manufacturing and modern services are subject to Kaldor's Laws. It is concluded that the modern services sector is important for economic growth during this period and that the new stage of structural change is characterized by increased returns to scale (expanded Kaldor-Verdoorn Law).

Keywords: Modern services; Increasing Returns; Kaldor's Laws; Symbiosis; Economic Growth

JEL Classification: O1; O4; L80

Area 6 - Growth, Economic Development, and Institutions

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1.Introduction

The literature on structural change affirms manufacturing production at the center of the debate on economic growth (Lewis, 1954; Kaldor, 1966; McMillan & Rodrik, 2014). It is widely accepted that industrialization has been the main driver of economic dynamism. Kaldor's growth laws highlight the central relationship between the industrial sector and economic growth. The main arguments are the presence of increasing returns to scale, both static and dynamic, as well as the effects on the generation and dissemination of technologies in the economy resulting from advances in manufacturing (Kaldor, 1966; Thirlwall, 1983).

Kaldor's Laws can be understood as a series of stylized facts and historical regularities, compatible with empirical and analytical flexibility across several phases of the structural change process. The sectoral correlations identified economic growth patterns and the impact of changes in productive structures on economic performance (Felipe et al., 2009).

With the deindustrialization process that began in the mid-1970s, the modern services sector gained significant importance, explaining increases in productivity, employment, and national income. This sector can be defined as "a set of dynamic activities based on the generation and diffusion of technical and scientific knowledge, applied throughout the productive structure through digital means, with the aim of increasing productivity and/or adding value to production" (Pereira, 2021, p. 7).

In the late 1990s and early 2000s, modern services, especially information and communication technology (ICT) and knowledge-intensive business services (KIBS), developed significantly, paving the way for the most modern forms of production organisation we have today (Colecchia & Schreyer, 2002; Sharpe & Arsenault, 2008). In many cases, a relationship of integration or symbiosis has been observed between these services and manufacturing (Di Berardino & Onesti, 2018; Giovanini & Arend, 2019; Giovanini et al., 2020; Pereira et al., 2024).

The productive reconfiguration manifests in a range of manufactured products with embedded software that have become ubiquitous in the modern era, such as smartphones, cars with onboard computers, and agricultural vehicles that operate in networks and transmit real-time data on field conditions. Additionally, automated production lines integrate mechanical, electro-electronic, and computational systems worldwide. They modernize production units and contribute to more efficient and less polluting processes. The symbiosis between modern services and manufacturing has opened the door to Industry 4.0. The integration between these sectors demonstrates that the traditional boundaries among agriculture, industry, and services are becoming increasingly blurred.

Little attention has been paid to this issue in the literature. This article intends to fill this gap by measuring the role of modern services and their integration with manufacturing in economic growth in the light of Kaldor's laws. The proliferation of technologically sophisticated everyday products is concrete evidence that justifies the need to examine this issue both theoretically and empirically.

Thus, the objective of this article is to revisit Kaldor's Laws, assuming that not only manufacturing but also services and the symbiosis between manufacturing and modern services contribute to economic growth. In order to confirm this hypothesis, we built a symbiosis indicator and tested it econometrically using panel data models for a sample of 41 countries between 2000 and 2014.

This data spam is justified by the period in which the integration between manufacturing and services opens room for a new productive reconfiguration and by data availability. The originality of this paper lies in revisiting Kaldor's Laws by including the analysis of modern services and their interaction with manufacturing. Using a new symbiosis indicator and data from 41 countries between 2000 and 2014, the study offers new perspectives on productive reconfiguration and updates the debate on economic growth.[4]

The article is divided into six parts, including this introduction. The second and third sections present Kaldor's Laws and review the literature on deindustrialization, modern services, and the symbiosis between these sectors, respectively. The fourth section discusses the database and methodological procedures. The fifth section is dedicated to the discussion of the results. Finally, the sixth section presents the concluding remarks.

2.Structural Change and Kaldor's Growth Laws

The process of structural change is central to the study of economic growth and development (Lewis, 1954; Kaldor, 1966; McMillan & Rodrik, 2014). The literature emphasizes that structural change is the result of the transfer of labor and capital between different sectors of the production system (Duarte & Restuccia, 2010). Moreover, it can increase or decrease economic growth, as it depends on the increase (and level) of productivity in the sectors to which resources are reallocated (McMillan et al., 2014).

Thus, the dynamics of structural change are generally described as a course that begins in agriculture, briefly passes through traditional services, and advances to the industrialization stage. In this stage, the most significant transformations occur, marked by increases in productivity, accelerated innovation, and rising per capita income. Therefore, sustained growth requires a dynamic industrial base, where the reallocation of capital and employment within the manufacturing sector contributes to long-term growth (Nixson, 1990; Rodrik, 2006).

Kaldor's Laws help understand the role of manufacturing in economic growth because they can be understood as stylized facts or historical regularities within the framework of economic development theories. The merit of Kaldor's proposal lies in the flexibility to transpose the implications of manufacturing dynamics to various sectoral scenarios. In other words, the propositions in terms of laws are compatible at the sectoral level and, therefore, are useful in analyzing and comparing economic growth patterns across economies at different stages of development (Felipe et al., 2009).

2.1. Kaldor's Laws

The canonical model developed by Kaldor (1966) and systematized by Thirlwall (1983) empirically highlight the importance of manufacturing for economic growth. The first law proposes that there is a strong relationship between the growth of manufacturing output and GDP growth (Thirlwall, 1983, p. 347). The specification testing the first law is expressed as:

$$g_{nm} = \alpha + \beta g_m + u \qquad (1)$$

[4] According to Wang et al., (2016, p. 2), "The core idea of Industry 4.0 is to use the emerging information technologies to implement IoT and services so that business process and engineering process are deeply integrated making production operate in a flexible, efficient, and green way with constantly high quality and low cost".

Where g_{nm} is the growth rate of the other sectors of the economy, g_m is the growth rate of manufacturing, and u is an error term. The subscript m indicates that the data refer to the manufacturing sector.

Kaldor (1966) and Thirlwall (1983) argue that this relationship is explained by two reasons: First, by the displacement of labor from other sectors with open or disguised unemployment, such that it does not imply a reduction in the output of these sectors. Second, by the existence of static and dynamic increasing returns, which lead to productivity growth in response to total output growth.

Since differences in growth rates are explained by differences in productivity growth, Kaldor draws on Young's (1928) study to test whether economies of scale and increasing returns derive from the expansion of manufacturing. Thus, Kaldor's second law establishes that there is a strong positive relationship between the growth rate of manufacturing productivity (g_{pm}) and the growth of manufacturing output (g_m). The specification testing the second law is expressed as:

$$g_{pm} = a + \beta g_m + u \qquad 0 < \beta < 1 \qquad (2)$$

where g_{pm} is the growth rate of productivity, g_m is the growth rate of output, a is the autonomous growth rate of productivity, and the coefficient β is called the Verdoorn coefficient. This specification, which investigates the relationship between productivity growth and manufacturing output growth, became known as Verdoorn's Law.

Given $g_{pm} = g_m - e_m$ = equation (3), where e is the employment growth rate, it is noted that g_m appears on both sides of the equation. This characterizes the existence of a spurious correlation between g_{pm} and g_m. Kaldor proposes a new specification for Verdoorn's Law by replacing the productivity growth rate in Equation 2 with Equation 3 (Braga & Marquetti, 2007), such that:

$$e_m = -a + (1 - b)g_m + u \qquad \text{or} \qquad e_m = a^* + b^* g_m + u. \qquad (3)$$

where $a^* = -a$ and $b^* = 1 - b$. The econometric test should detect whether b^* is statistically significant and 0 or 1. Thus, the Kaldor-Verdoorn Law allows us to understand how demand contributes to productivity growth, as it investigates the extent to which manufacturing output growth induces productivity growth in this sector. By establishing the systemic connection between manufacturing expansion, which occurs through economic growth, it is possible to generalize the extent of manufacturing growth to the rest of the economy, which leads to the third law.

The third law argues that the faster the growth of industrial production, the faster the rate of labor transfer from the non-industrial sector to manufacturing, such that overall productivity growth is positively related to output and employment growth in manufacturing and negatively associated with employment growth outside the manufacturing sector. The specification testing the third law is expressed as[5]:

$$g_{pnm} = \alpha + \beta g_m - \gamma e_{nm} + u \qquad (4)$$

[5] For the specification form see Mamgain (1999, p. 298)

where gp_{nm} is the productivity growth rate in the non-manufacturing sector, $g_m$is the manufacturing output growth rate, e_{nm} corresponds to the employment growth rate in the non-manufacturing sector, and u is an error term.

Manufacturing growth has been a key feature since the Industrial Revolution, which is why Kaldor's Laws highlight the importance of this sector to the economy. Over the last fifty years, however, virtually all countries have undergone significant changes in their productive structures. The deindustrialization of advanced economies and, to some extent, of developing countries has stimulated several debates among researchers and policy-makers. The rise of the service sector raises the question of whether this sector might also be subject to Kaldor's laws. The next section reviews the literature on the modern services sector and its integration with manufacturing.

3.Deindustrialization and the Symbiosis Between Manufacturing and Modern Services

Since the 1970s, there has been a decline in the share of manufacturing in employment and in the generation of national income in the developed countries. It is defined as deindustrialization (Rowthorn & Ramaswamy, 1997, 1999; Tregenna, 2009). For developed countries, this singularity is considered natural because manufacturing reached full maturity and was able to create a society with a high standard of living and a dynamic productive structure that generates and disseminates innovations across the economy.

For other countries, deindustrialization is considered premature, because before manufacturing could provide the economic and social benefits mentioned above, some developing countries entered a process of deterioration of their productive structures (Dasgupta & Singh, 2006; Rodrik, 2016; Palma, 2019). In any case, the consequences of deindustrialization are well known. These include the deterioration of the labor market, increased balance of payments constraints, lower overall productivity and reduced opportunities for innovation.

Along with deindustrialization, the service sector has also gained prominence in economic debates. As Palma (2005, 2019) argues, deindustrialization is characterized by a relative decline in industrial employment, followed by an absolute decline, while the service sector becomes the main source of labor absorption.

The services sector was not always considered important for economic growth. Indeed, it was treated as a residual one, encompassing all activities that has not belong to agriculture or industry. Baumol (1967) defined services as responsible for the so-called "cost disease," whereby the growth of this sector would imply a reduction in total productivity due to the substitution of the dynamic sector (manufacturing) by the less dynamic sector.

However, due to the new stage of structural change that began in the 1970s, researchers have sought to understand the role of modern services in the economy. Studies show that services significantly changed their role in economic growth from the 1980s onward. In the United States and Europe, capital stock growth was higher in the services sector than in manufacturing, particularly in ICT activities (Roach, 1988; Ark, 2003).

Thus, the economic growth and productivity gains achieved by manufacturing since the 1970s can, at least in part, be explained by the emergence of modern services, especially those resulting from new communication technologies and knowledge provision (Aboal & Tacsir, 2015; Lodefalk, 2014).

By the late 1990s and early 2000s, ICT and KIBS activities developed and paved the way for the most modern forms of productive organization we have today (Colecchia & Schreyer, 2002; Sharpe & Arsenault, 2008).

In other words, service activities, particularly those considered modern, assumed a transversal position in the productive structure, as they ensured the diffusion of information technologies through the use of computing and the dissemination of software in financial and operational production management (Dunning, 1989; Pavitt & Bell, 1993). In other words, we can assume that the modern services sector has a pervasive character in the current productive structure of economies (Giovanini et al., 2020).

KIBS, for example, provide knowledge to manufacturing and contribute to innovation generation (Miles, 2008; Muller & Zenker, 2001). ICTs increase productivity, make the production process more efficient, and accelerate trade by decentralizing productive activities, which is why Global Value Chains (GVCs) have benefited significantly in recent decades (Dasgupta & Singh, 2006; Di Meglio et al., 2018).

In these terms, modern services also help minimize balance of payments constraints, as they add value and contribute to product differentiation by generating innovation and ensuring external competitiveness (Castellacci, 2008; Cainelli & Mazzanti, 2013; Arbache, 2014).

The reason for the relevance of modern services is that they can be divided into two types: 1) value-added services and 2) cost services. Value-added services enhance the production process, increase productivity, and improve the return on invested capital. These are concentrated in developed countries, where the supply of human capital and technological development is greater. Cost services, commonly found in developing countries, contribute to corporate competitiveness and increased productive efficiency but do not aid in product differentiation (Pilat & Wölfl, 2004; Arbache, 2015; Giovanini et al., 2020, 2021).

The literature has advanced in understanding how modern service activities operate within the economic system. Studies assume a symbiotic relationship between manufacturing and modern services as a new form of productive restructuring that positively affects economic performance. Research indicates that services have been extensively utilized by industry and that manufacturing and economic success depend on the interaction between these sectors (Di Berardino & Onesti, 2018; Giovanini & Arend, 2019; Giovanini et al., 2020; Pereira et al., 2024).

In the case of more advanced economies, the productive structure is characterized by a significant number of firms involved in the production of integrated goods and services, with a future trend toward increased interaction (Barreto et al., 2017; Ennis et al., 2018; Cadestin & Miroudot, 2020). This is why a range of products with embedded software, which have become ubiquitous in the modern era, are being created. Examples include smartphones, cars with onboard computers, and agricultural vehicles linked in networks, monitored by GPS, and generating and transmitting real-time data.

Moreover, the symbiosis between manufacturing and services enables the construction of automated production lines that integrate mechanical, electro-electronic, and computational systems across various economies worldwide. It modernizes production units and contributes to less polluting and more efficient production processes. It is also directly responsible for the development of Industry 4.0.

In summary, services contribute to productivity and economic growth, as they are also subject to Kaldor's Laws (Dasgupta & Singh, 2006; Ariu et al., 2016; Di Meglio et al., 2016, 2018; Giovanini & Arend, 2017; Ledesma & Moro, 2020). In this sense, the next section discusses the methodological aspects that will allow us to investigate whether the services sector and its symbiosis with manufacturing can be understood in light of Kaldor's Laws.

4.Database and Methodological Procedures

The database consists of a sample of 41 countries for the available period from 2000 to 2014 (Appendix A). The data come from the WIOD Socio-Economic Accounts and Input-Output Matrices, covering 56 sectors. We use this database for three reasons. First, due to its level of disaggregation, which allows for a more precise grouping of service activities within the classification typically labeled as modern services.

Broadly, the literature on the topic presents classifications: i) according to the technological standard, developed by Eichengreen and Gupta (2013), where services are divided into traditional and modern; ii) based on functionality, where services are divided into cost services and value-added services (Arbache, 2014); iii) by destination, divided into final consumption and business (Singelmann, 1978; Machado et al., 2015); and iv) according to the OECD classification, where services are divided into professional business services and traditional businesses.

The second reason is that it provides data on the inputs and outputs of sectors in an economy, which will be used to build the symbiosis efficiency indicator. These data are typically used to construct technical coefficients of production. These coefficients measure how much a given economic activity needs to consume from other activities to produce an additional monetary unit of output (Miller & Blair, 2009). The indicator is expressed as:

$$a_{ij} = Z_{ij}/X_j \tag{5}$$

where a_{ij} is the direct input coefficient and denotes the monetary amount of input from sector i required to produce one monetary unit of final output from sector j. The variable Z_{ij} is intermediate consumption (inputs), and X_j is the value of production (output).

Finally, the third reason is that it allows for a discussion of the issue of productive efficiency in symbiosis. The concept of efficiency is broad, and it is common to confuse productive efficiency with the concept of productivity. Productivity can be understood as the ratio between output and input, while efficiency is the ratio between the maximum potential output, given the input (Debreu, 1951; Lovell, 1993 [1957]).

The potential is defined in terms of production possibilities. The productivity of a system is, therefore, an indicator of productive efficiency, as the higher the productivity of a productive system, the more efficient it is. The efficiency captured by productivity can be understood as an indicator that measures how much the productive system is capable of producing (output) with a unit amount of input.

Note that the productive efficiency indicator measured by productivity (the ratio between output and input) is essentially the inverse of the technical coefficient of production. This opens the opportunity to make a slight modification to the indicator captures not only the efficiency of the production system but also the interaction between manufacturing and modern services.

Despite the difficulty of attempting to synthesize complex interactions such as the relationship between manufacturing and modern services, it can be an indicator of symbiosis efficiency between manufacturing and modern services.

The symbiosis efficiency index between manufacturing and modern services measures how much the productive system can generate in output from the consumption of modern services by manufacturing and manufactured goods by the modern services sector. To achieve this index, we aggregate all manufacturing activities into a single group called manufacturing. From service activities, we extract a group called modern services (see Appendix B). We then isolate the portion of manufactured goods consumed by modern services to generate their output. Next, we extract the portion of modern services consumed by manufacturing to form its output. Thus,

$$efsy = Out_{sym}/In_{sym} \quad (6)$$

where $efsy$ is the efficiency of symbiosis between manufacturing and modern services. The variable Out_{sym} is the sum of the output of the manufacturing and services sectors $(Out_{manu} + Out_{serv})$. In_{sym} is the sum of two variables, namely: i) manufactured products consumed as inputs for the modern services sector, and ii) modern services consumed as inputs for manufacturing. Thus, the mentioned variable is $(In_{manu} + In_{serv})$.

We chose this strategy because it allows us to incorporate the efficiency index into the econometric tests. Moreover, from a perspective of economic growth, the crucial factor is not just the presence of symbiosis between the manufacturing and services sectors, since most countries exhibit some degree of interaction between these sectors. The main determinant of growth is the productive efficiency of this symbiosis, as it ensures the attainment of increasing returns to scale.

In line with Karaomerioglu and Carlsson (1999) and Hauge and Chang (2019), we aggregate the inputs and outputs of the manufacturing and services sectors. These authors argue that certain activities classified as services were previously part of the internal structure of firms. Based on their hypothesis, it is reasonable to consider manufacturing and services as an interconnected entity in our study. This approach effectively captures the essence of the symbiosis between the two sectors. Consequently, the analysis of symbiosis requires considering manufacturing and services as a unified whole (Karamerioglu & Carlsson, 1999).

Chart 1 summarizes the variables and indicators used in this study.

Chart 1 – Variables and Indicators

Description of the indicators	Variables	Source
Gross Domestic Product of the Economy	g_{PIB}	WIOD
Gross Domestic Product of Manufacturing	g_m	WIOD
Gross Domestic Product of Modern Services Sector	g_s	WIOD
Manufacturing Productivity (VA/PO)	P_m	WIOD
Modern Services Productivity (VA/PO)	P_s	WIOD
Productivity of Other Sectors (VA/PO)	P_{nm}	WIOD
Efficiency of Symbiosis Between Manufacturing and Modern Services	ES_{ms}	WIOD

Source: Authors' elaboration. Note: VA = value added and PO = employed persons.

4.1. Empirical Strategy

Following Di Meglio et al. (2018) with some modifications, the equation to be estimate is

$$g_{nm,it} = \alpha + \beta_1 g_{m,it} + \beta_2 g_{s,it} + u_{it} \quad (7)$$

where $g_{nm,it}$ is the growth rate of Gross Domestic Product (GDP) of country i in period t for all sectors except manufacturing and modern services; $g_{m,it}$ is the growth rate of manufacturing, where $a > 0$, $\beta_1 > 0$ and $\beta_2 > 0$, $g_{s,it}$ is the growth rate of modern services, whereas u_{it} is a random term. This equation shows that economic growth is explained by manufacturing growth and that the modern services sector exhibits the same characteristics as the manufacturing sector, contributing to aggregate output growth.

The second law of Kaldor is tested using the following equation:

$$g_{pm,it} = a + \beta_1 g_{m,it} + \beta_2 g_{s,it} + u_{it} \qquad (8)$$

where $g_{pm,it}$ is labor productivity of the industrial sector in country i in period t, defined as value added divided by the number of workers. This equation is also adjusted and used to verify whether the modern services sector exhibits economies of scale:

$$g_{ps,it} = a + \beta_1 g_{m,it} + \beta_2 g_{s,it} + u_{\text{it}} \qquad (9)$$

where $g_{ps,it}$ is the labor productivity of the modern services sector in country i in period t, where $\text{a} > 0$, $\beta_1 > 0$ and $\beta_2 > 0$.

The third Kaldor law posits that an increase in manufacturing output is favorable to economic growth, which fosters manufacturing productivity. This is disseminated to other sectors of the economy. As follows:

$$g_{pnm,it} = \alpha_0 + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 e_{nms,it} + u_{it} \qquad (10)$$

where $g_{pnm,it}$ is the productivity of the whole economy, excluding manufacturing and modern services, $e_{nms,it}$ is employment growth, excluding manufacturing and modern services, where $\alpha_0 > 0$, $\beta_1 > 0$, $\beta_2 > 0$, and $\beta_3 > 0$

In addition to the regressions employed to ascertain the presence of the laws proposed by Kaldor, as delineated in equations (7), (8), (9), and (10), we also estimate supplementary regressions, incorporating the symbiosis efficiency variable, ES_{ms}, as an explanatory variable.

$$\text{g}_{PIB,\text{it}} = \alpha + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 ES_{ms} + \epsilon_{it} \qquad (11)$$
$$g_{pm,it} = a + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 ES_{ms} + \epsilon_{it} \qquad (12)$$
$$g_{ps,it} = a + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 ES_{ms} + \epsilon_{\text{it}} \qquad (13)$$
$$g_{pnm,it} = \alpha_0 + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 e_{nms,it} + \beta_4 ES_{ms} + \epsilon_{it} \qquad (14)$$

The estimation of panel data regressions can be performed using different analysis techniques. Among the most commonly are the Pooled, fixed effects, and random effects models. The first law of Kaldor is used to demonstrate the differences between these statistical techniques.

One possible approach involves the implementation of the pooled Ordinary Least Squares method using equation (7), with the data for countries and years arranged in a stacked format.

According to Gujarati and Porter (2011), an important assumption of the classical linear regression model is that there is no correlation between the explanatory variables and the error term. To understand how the error term may be correlated with the explanatory variables, consider that the correct model includes a variable I_{it} that measures specific factors associated with the productive structure of each country and that influence the growth rate of other sectors:

$$\text{g}_{nm,\text{it}} = \alpha + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \beta_3 I_{it} + u_{it} \qquad (15)$$

Of the variables included in Equation (15), only I_{it} is time-invariant, varying between countries. Although it is time-invariant, it is not directly observable, and therefore, it is not possible to measure its contribution to the growth of other sectors. However, its contribution can be measured indirectly by rewriting Equation (15):

$$g_{nm,\mathrm{it}} = \alpha + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \alpha_i + u_{it} \qquad (16)$$

where α_i, called the unobserved effect, reflects the impact of I_{it} on the growth rate of other sectors. Since α_i is not directly observable, one possibility is to include it in the error term u_{it}, and consider the error term $v_{it} = a_i + u_{it}$:

$$g_{nm,\mathrm{it}} = \alpha + \beta_1 g_{m,it} + \beta_2 g_{s,it} + v_{it}. \qquad (17)$$

The term a_i, included in the error term v_{it}, may be correlated with any of the explanatory variables. Thus, $cov\ (v_{it}, v_{is}) = \sigma_u^2;\ t \neq s,$ is different from zero, and therefore, unobserved heterogeneity induces autocorrelation, making the OLS estimates biased and inconsistent.

The least squares model with dummy variables for fixed effects (MQVD) can be used to capture the effect of heterogeneity between countries:

$$g_{nm,\mathrm{it}} = \alpha_{1\mathrm{i}} + \beta_1 g_{m,it} + \beta_2 g_{s,it} + u_{it} \qquad (18)$$

where the subscript i has been added to the intercept to capture heterogeneity between countries using fixed effects.

An alternative to the fixed effects model is the estimation of the random effects model. The underlying logic of this model is that the error term, rather than dummy variables, can be used to identify unobservable time-invariant factors. For this, we start from equation (16) and, instead of estimating $\alpha_{1\mathrm{i}}$, we assume that it is a random variable with mean α_1. Thus, the intercept for country i can be formalized as:

$$\alpha_{1\mathrm{i}} = \alpha_1 + \epsilon_i \qquad (19)$$

where ϵ_i has a mean of zero and variance σ_ϵ^2. In other words, countries share a common mean value for the intercept, with individual differences reflected in the error term ϵ_i.

Substituting equation (19) into equation (18) yields:

$$g_{nm,\mathrm{it}} = \alpha_1 + \beta_1 g_{m,it} + \beta_2 g_{s,it} + \epsilon_i + u_{it} \qquad (20)$$

thus:

$$g_{nm,\mathrm{it}} = \alpha_1 + \beta_1 g_{m,it} + \beta_2 g_{s,it} + w_{it} \qquad (21)$$

where the error term $w_{it} = \epsilon_i + u_{it}$ is composed of two terms, an idiosyncratic shock, ϵ_i, and a related error term from the time series and cross-section, u_{it}, which varies across countries and time. It is worth noting that w_{it} is not correlated with the explanatory variables, since ϵ_{it} is a component of w_{it}. Equation (21) is known as the random effects model, which assumes that unobserved characteristics are random and uncorrelated across countries. The composite error term, w_{it}, is not correlated with the explanatory variables and assumes the following properties: $\epsilon_i \sim N(0, \sigma_\epsilon^2)$, $u_{it} \sim N(0, \sigma_u^2)$, $E(\epsilon_i u_{it}) = 0$; $E(\epsilon_i \epsilon_j) = 0 \ (i \neq j)$; $E(u_{it} u_{is}) = E(u_{it} u_{ij}) = E(u_{it} u_{js}) = 0$; $(i \neq j;\ t \neq s)$.

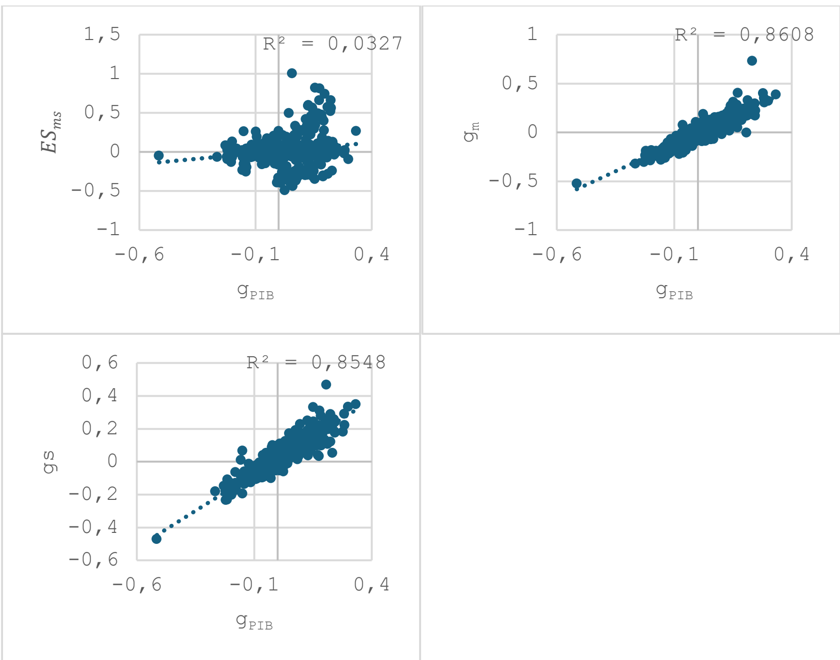
5.Results

Figure 1 provides a formal representation of the findings concerning the correlation between the variables under scrutiny. The correlation between the GDP growth rate of manufacturing(g_m) and the GDP growth rate (g_{PIB}) is significant with a coefficient of 0.861. Similarly, a strong positive correlation is observed between (g_m) and manufacturing productivity (P_m) with a coefficient of 0.718. Additionally, a notable correlation is seen between (g_m) and the productivity of other sectors of the economy (P_{nm}) , with a coefficient of 0.706. However, a moderate correlation is exhibited only for the productivity of the modern services sector (P_s) with a correlation coefficient of 0.440. The GDP of the modern services sector (g_s) exhibits robust correlation with GDP, with a magnitude of 0.855, and with the productivity of other sectors, with a magnitude of 0.782. Additionally, it exhibits a moderate correlation with manufacturing GDP, with a magnitude of 0.589, and with the productivity of the modern services sector, with a magnitude of 0.640.

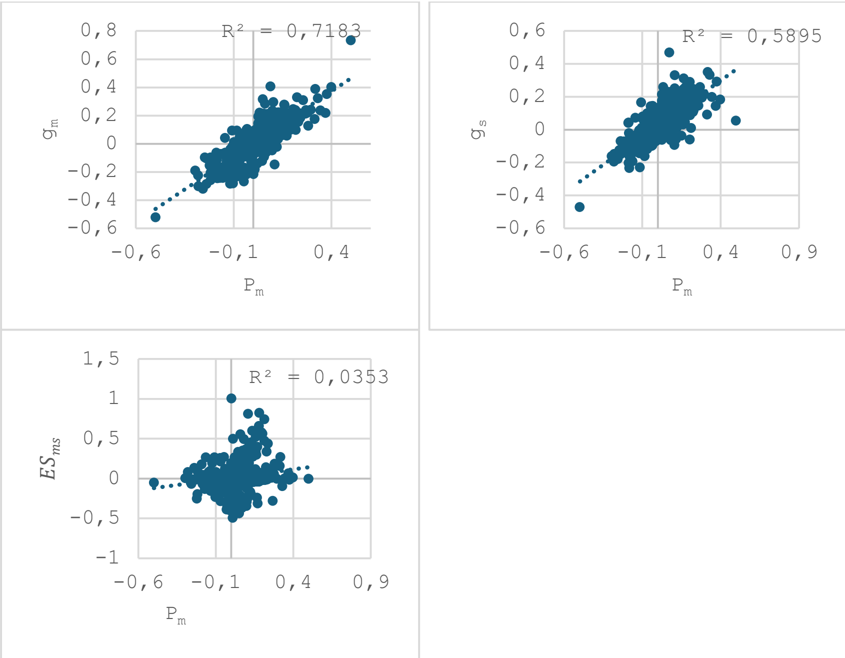
The productivity of the manufacturing sector (P_m) also exhibits a very strong correlation with the productivity of other sectors (P_{nm}), 0.970. However, the symbiosis indicator (ES_{ms}) has a weak correlation with all other variables in view, with the highest correlation found for manufacturing productivity, at only 0.035.

Figure 1 -- Scatter plots and correlation between the variables under analysis

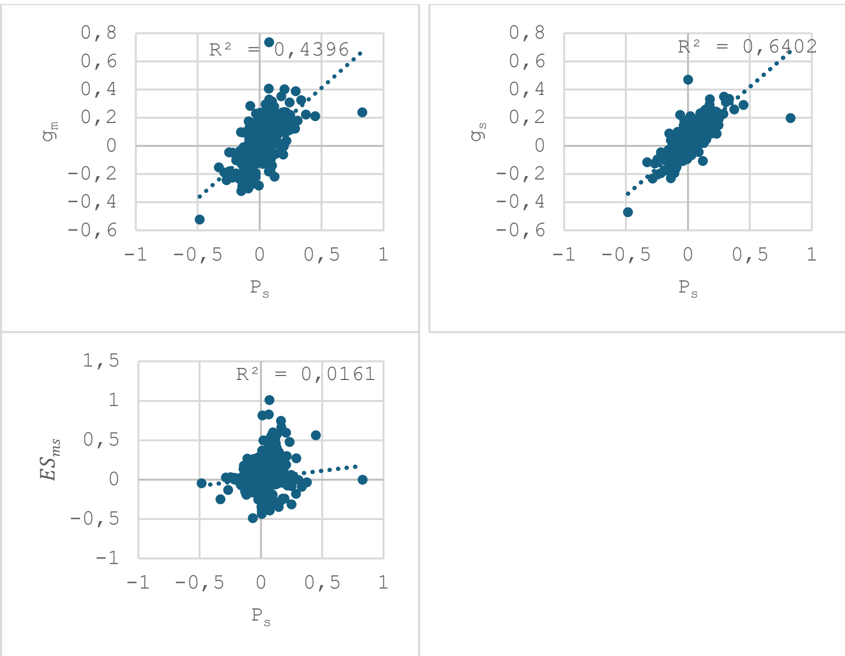
First Law of Kaldor



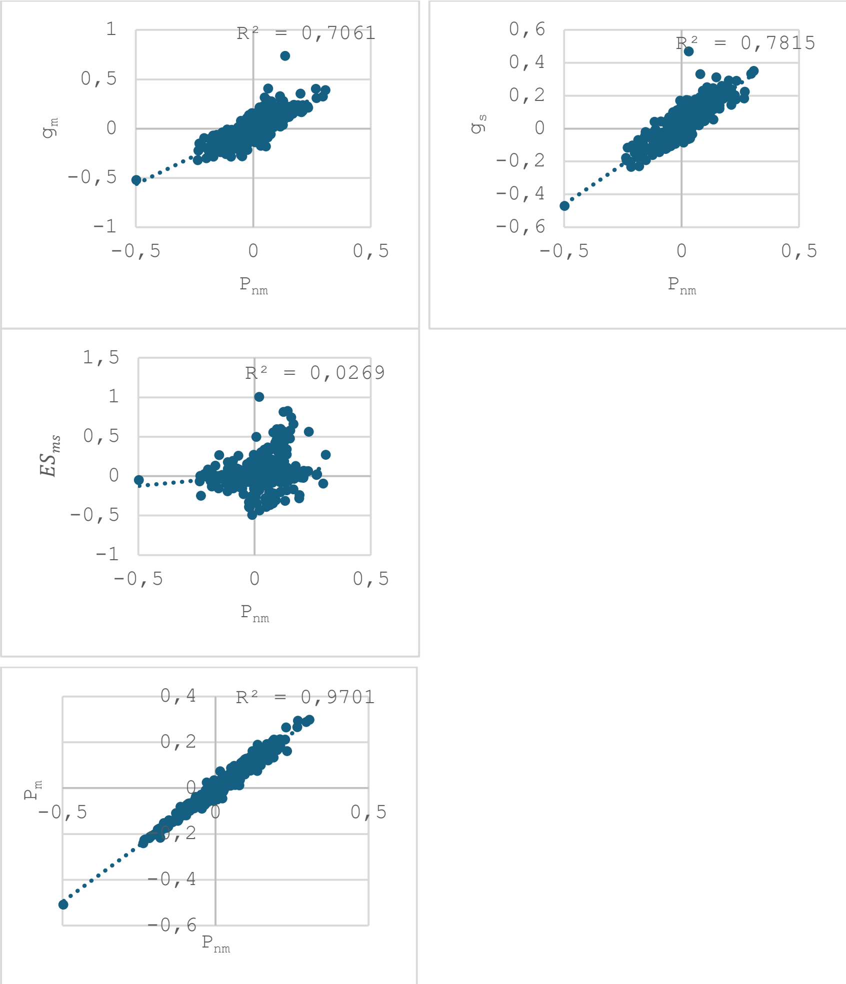
Second Law of Kaldor



Second Law of Kaldor - services



Third Law of Kaldor



Source: Prepared by the authors

Table 1 provides a comprehensive overview of the outcomes obtained from the stationarity tests of Im, Pesaran, and Shin (2003), Levin, Lin, and Chu (2002), Harris and Tsavalis (1999), and the Fisher-type test proposed by Maddala and Wu (1999), Choi (2001), and Hadri (2000). The results of the analysis indicate that the variables are stationary when expressed in growth rate form at the 1% significance level.

Table 1 - Stationarity Tests

Variable	IPS[1]	p-value	Levin	p-value	Harris	p-value	Fisher[2]	p-value	Hadri	p-value
g_{PIB}	-7,125	0,000	-12,152	0,000	-16,418	0,000	7,684	0,000	4,121	0,000
g_m	-8,473	0,000	-15,293	0,000	-21,985	0,000	8,650	0,000	3,883	0,000
g_s	-7,203	0,000	-11,831	0,000	-16,566	0,000	7,320	0,000	3,800	0,000
ES_{ms}	-11,852	0,000	-25,397	0,000	-32,195	0,000	20,354	0,000	2,517	0,006
p_m	-9,058	0,000	-16,599	0,000	-22,002	0,000	8,332	0,000	3,168	0,001
p_s	-9,537	0,000	-17,396	0,000	-23,218	0,000	9,251	0,000	2,656	0,004
P_{nm}	-7,475	0,000	-12,562	0,000	-17,038	0,000	9,353	0,000	3,573	0,000

Source: Prepared by the authors.

Notes: 1. Statistic $Z_{\tilde{t}-bar}$, 2. Statistic χ^2 P_m proposed by Choi (2001), Augmented Dickey-Fuller test.

The models are estimated with the addition of cross-variables for g_m, g_s, and g_p for the period after the 2009 crisis. Table 2 shows the variables are not statistically significant. Only the binary variable for the year 2009 is statistically significant. The results found for the Chow test are statistically significant at the 0.01 significance level and show that the fixed effects estimation is more appropriate than the pooled estimation.

The Hausman test, Table 2, indicates that the random effects model is the one that exhibits the best specification for the four distinct regressions estimated, at the 95% confidence level. That is, no time-invariant factors specific to each country are observed, only a common factor for all countries.

Table 2 -- Results found for the Chow and Hausman tests

	Law 1		Law 2		Law 2 - Services		Law 3	
Description	**Test**	**P-Value**	**Test**	**P-Value**	**Test**	**P-Value**	**Test**	**P-Value**
Chow	3,09	0,000	1,77	0,000	1,67	0,000	2,00	0,000
Hausman test	1,4	0,705	0,75	0,443	0,65	0,911	1,61	0,807

Source: Prepared by the authors

In turn, the Variance Inflation Factor (VIF), Table 3, shows that the estimated regressions do not exhibit multicollinearity, given that the VIF is below 10 for all explanatory variables.

Table 3 -- Variance Inflation Factor (VIF)

	g_m	g_s	g_p	ES_{ms}
VIF	4,75	4,3	4,28	1,03

Source: Prepared by the authors

The estimated coefficients regarding first law of Kaldor for the random effects model, show that the GDP growth rate of manufacturing (g_m), 0.291%, is statistically significant at 1% significance level. Similar to Dasgupta and Singh (2005, 2006), Felipe et al. (2009), and Di Meglio et al. (2018), this result confirms the validity of the first law of Kaldor for the sample composed of the 41 countries in the database. Manufacturing is the engine responsible for pulling the growth of other sectors (Table 4).

Table 4 -- Estimated Coefficients for the First Law of Kaldor

	Polled		Fixed Effects		Random Effects	
Variables	**Coef.**	**P-Value**	**Coef.**	**P-Value**	**Coef.**	**P-Value**
g_m	0,287*	0,000	0,293*	0,000	0,291*	0,000
g_s	0,613*	0,000	0,623*	0,000	0,620*	0,000
d_{2009}	-0,014**	0,097	-0,011	0,217	-0,012	0,154
α_1	-0,005*	0,027	-0,006*	0,003	-0,006*	0,019
R^2 Within	-	-	0,893	-	0,893	-
R^2 Between	-	-	0,672	-	0,671	-
R^2 Overall	0,876	-	0,876	-	0,876	-
Breusch-Pagan	-	-	1332*	0,000	61,23*	0,000

Source: The authors. Note: *(**) p-value smaller than 0.05(0.1).

The estimated coefficient for the GDP of the modern services sector, 0.620%, is also statistically significant at the 1% significance level, being responsible for promoting higher

GDP growth rates. As demonstrated by the modern services literature, this sector is responsible for supplying countries with advanced knowledge. With the advancement of ICTs, the productive structure has become more knowledge-intensive, making the presence of a structured and dynamic modern services sector necessary for countries to achieve higher economic growth rates.

The estimated coefficients for the second law of Kaldor for manufacturing, Table 5, are statistically significant at the 1% significance level, except for the linear coefficient. Growth in manufacturing value added and in the modern services sector contributes to growth in manufacturing productivity. More precisely, a 1% increase in manufacturing output implies a 0.591% increase in the productivity of this sector, while a 1% increase in modern services output results in a 0.326% increase in manufacturing productivity.

Table 5 -- Estimated Coefficients for the Second Law of Kaldor

	Polled		Fixed Effects		Random Effects	
Variables	**Coef.**	**P-Value**	**Coef.**	**P-Value**	**Coef.**	**P-Value**
g_m	0,623*	0,000	0,591*	0,000	0,612*	0,000
g_s	0,295*	0,000	0,326*	0,000	0,305*	0,000
d_{2009}	0,034*	0,004	0,030*	0,009	0,033*	0,003
α_1	0,000	0,932	0,000	0,776	0,000	0,920
R^2 Within	-	-	0,76	-	0,757	-
R^2 Between	-	-	0,68	-	0,688	-
R^2 Overall	0,750	-	0,75	-	0,750	-
Breusch-Pagan	-	-	1204,133,	-	6,140	-

Source: The authors. Note: *p-value smaller than 0.05.

The elasticity estimated for manufacturing, close to 0.60%, is like the results obtained by Felipe et al. (2009), Di Meglio et al. (2018) and Pieper (2003), who also found lower elasticities for the services sector. As highlighted by Di Meglio et al. (2018), these results are highly relevant as they show that the modern services sector also has increasing returns. The same mechanisms that make manufacturing the dynamic center of economic growth, identified by Kaldor, are likely to be present in the modern services sector.

An additional regression is estimated to check whether the productivity growth of the modern services sector is explained by the growth of its own GDP and the GDP of manufacturing, as showing in Table 6. That is, whether this sector can generate an endogenous and self-determined movement of productivity growth. Only the GDP growth rate of the modern services sector is statistically significant at the 95% confidence level. The manufacturing GDP growth rate is only significant at the 90% confidence level.

Table 6 -- Estimated Coefficients for the Second Law of Kaldor Applied to the Services Sector

	Polled		Fixed Effects		Random Effects	
Variables	**Coef.**	**P-Value**	**Coef.**	**P-Value**	**Coef.**	**P-Value**
g_s	0,749*	0,000	0,750*	0,000	0,750*	0,000
g_m	0,117**	0,079	0,123**	0,078	0,119**	0,069
d_{2009}	0,032*	0,029	0,034*	0,036	0,033*	0,026
α_1	-0,020*	0,000	-0,020*	0,000	-0,020*	0,000
R^2 Within	-	-	0,66	-	0,663	-
R^2 Between	-	-	0,46	-	0,458	-

R^2 Overall	0,648	-	0,65	-	0,648	-
Breusch-Pagan	-	-	1213*	-	7,290*	-

Source: The authors. Note: *p-value smaller than 0.05.

In contrast, the productivity of the modern services sector is less sensitive to manufacturing GDP growth than manufacturing productivity is to modern services GDP growth. More precisely, a 1% increase in manufacturing GDP results in a 0.119% increase in the productivity of the modern services sector, while a 1% increase in modern services GDP, as formalized in Table 5, results in a 0.326% increase in manufacturing productivity.

These results show that manufacturing tends to be more dependent on the modern services sector than vice versa. As demonstrated by Giovanini (2021), service activities exhibit a high degree of vertical integration, where a significant portion of the knowledge and manufacturing innovations observed by this sector originate from internal suppliers. Alternatively, although the acquisition of machinery, equipment, and other industrial inputs contributes to innovation in the services sector, this sector tends to be more dependent on inputs from other service activities, which explains the low contribution of manufacturing to its productivity growth.

The estimated coefficients for the third law of Kaldor for the growth rates of manufacturing productivity and the value added of manufacturing and modern services are statistically significant at the 95% confidence level, with a positive sign, as showing in Table 7. They corroborate the argument that both manufacturing and modern services contribute to the productivity growth of other sectors.

Table 7 -- Estimated Coefficients for the Third Law of Kaldor

Variables	Polled		Fixed Effects		Random Effects	
	Coef.	P-Value	Coef.	P-Value	Coef.	P-Value
e_{nms}	0,817*	0,000	0,808*	0,000	0,813*	0,000
g_m	0,072*	0,000	0,071*	0,000	0,072*	0,000
g_s	0,107*	0,000	0,114*	0,000	0,110*	0,000
d_{2009}	0,010*	0,002	0,009*	0,003	0,009*	0,001
α_1	0,001	0,255	0,001	0,303	0,001	0,324
R^2 Within	-	-	0,98	-	0,979	-
R^2 Between	-	-	0,96	-	0,965	-
R^2 Overall	0,978	-	0,98	-	0,978	-
Breusch-Pagan	-	-	1037	-	14,090	-

Source: The authors. Note: *(**) p-value smaller than 0.05(0.1).

After estimating the four regressions for Kaldor's Laws, the Chow test is used to test the equality between the estimated coefficients for the GDP growth rate of manufacturing and modern services given the following hypotheses:

H0: $-\beta_1 + \beta_2 = 0$
H1: $-\beta_1 + \beta_2 \neq 0$

For the first law of Kaldor, the null hypothesis of equality between the estimated coefficients is rejected, regardless of the specification used. That is, the contribution of modern services' output to aggregate output growth of other sectors is statistically different from the contribution of manufacturing output. Thus, there is evidence that between 2000 and 2014, the growth of the modern services sector contributed more to the structural change process than manufacturing (Table 8)

Table 8 -- Test of Equality Between the Estimated Coefficients for the GDP Growth Rate of Manufacturing and Modern Services

Model	Law 1		Law 2		Law 2 - Services		Law 3	
	Test	P-Value	Test	P-Value	Test	P-Value	Test	P-Value
Pooled	7,05	0,011	20,03	0,000	18,46	0,000	2,23	0,143
Fixed Effect	5,57	0,023	9,58	0,004	17,05	0,000	4,88	0,033
Random Effect	6,41	0,011	16,11	0,000	18,28	0,000	3,42	0,064

Source: The authors. Note: *(**) p-value smaller than 0.05(0.1).

The null hypothesis of equality in the estimated coefficients for the second law of Kaldor for the GDP growth rate of manufacturing and the modern services sector is rejected at the 1% significance level. Therefore, the contribution of manufacturing output growth to the productivity growth of this sector is statistically greater than the contribution of modern services output. Similarly, the contribution of modern services output growth to the productivity growth of this sector is also statistically greater than the contribution of manufacturing output growth.

For the third law of Kaldor, the null hypothesis of equality in the coefficients for g_m and g_s is rejected only at the 5% significance level for the fixed effects model and at the 10% significance level for the random effects model. Thus, the contribution of g_s to the productivity growth of other sectors is statistically greater than the contribution of g_m. These results corroborate the argument that between 2000 and 2014, the growth in modern services output was the main factor responsible for explaining the aggregate productivity growth of the 41 countries in the sample.

Table 9 formalizes the results found for the regression estimated with the addition of the symbiosis efficiency variable (ES_{ms}) between manufacturing and modern services, which captures how much the productive system can generate in output from the consumption of modern services by manufacturing and manufactured goods by the modern services sector. This variable is statistically significant at the 5% significance level for the first and second laws of Kaldor and marginally significant at the 10% level for the third law. Only for the second law of Kaldor for the modern services sector is it not statistically significant. This result shows that greater interaction between manufacturing and modern services results in higher GDP growth rates, manufacturing productivity, and aggregate productivity.

Table 9 -- Regressions Estimated with the Addition of the Symbiosis Variable

	First Law			Second Law			Second Law - services			Third Law		
	Pooled	**Fixed**	**Random**	**Pooled**	**Fixed**	**Random**	**Pooled**	**Fixed**	**Random**	**Pooled**	**Fixed**	**Random**
e_{nms}	-	-	-	-	-	-	-	-	-	0,818*	0,808*	0,814*
g_s	0,284*	0,290*	0,287*	0,618*	0,584*	0,606*	0,117**	0,122**	0,119**	0,071*	0,069*	0,070*
g_m	0,613*	0,623*	0,618*	0,293*	0,325*	0,304*	0,749*	0,750*	0,750*	0,106*	0,113*	0,109*
ES_{ms}	0,019*	0,011*	0,015**	0,027*	0,030*	0,028*	-0,002	0,003	0,000	0,006**	0,008*	0,007**
d_{2009}	-0,014*	-0,012	-0,013	0,033*	0,030*	0,032*	0,032*	0,034*	0,033*	0,009*	0,009*	0,009*
α_1	-0,006*	-0,007*	-0,006	-0,001	-0,001	-0,001	-0,020*	-0,020*	-0,020*	0,001*	0,001*	0,001*
R^2 W	-	0,893	0,893	-	0,758	0,758	-	0,663	0,663	-	0,979	0,979
R^2 B	-	0,675	0,677	-	0,680	0,686	-	0,456	0,458	-	0,964	0,965
R^2 O	0,877	0,877	0,877	0,752	0,751	0,752	0,648	0,648	0,648	0,978	0,978	0,978
H#	-	11,68*	-	-	3,20	-	-	13,82*	-	-	11,18*	-
B-P##	-	1379*	56, 19*	-	1224*	6,63*	-	1215*	7,26*	-	1037*	15,45*

Source: The authors. Note: *(**) p-value smaller than 0.05(0.1); R^2W is the R^2 Within; R^2B, the R^2 Between; R^2O, the R^2 Overall; H, the Hausman test; and B-P, the Breusch-Pagan test.

6.Concluding Remarks

This paper revisits Kaldor's Laws by considering both manufacturing and modern services and their interaction (symbiosis) as influential for economic growth. The results confirm that manufacturing and modern services contribute to GDP growth, with the symbiosis between them playing a crucial role.

For the first law, it was observed that the GDP growth rate of manufacturing and modern services has a positive impact on economic growth. The analysis showed that between 2000 and 2014, the modern services sector made a greater contribution to structural change than manufacturing.

With regard to the second law, the growth of value added in both manufacturing and modern services had a positive impact on manufacturing productivity. However, the productivity of modern services responded more directly to the growth of its own sector than to the growth of manufacturing, suggesting an endogenous and self-determined dynamic.

For the third law, the results confirm that both manufacturing and modern services contribute to productivity growth in other sectors. Modern services had a statistically larger impact on overall productivity growth than manufacturing.
In addition, the analysis of the symbiosis indicator shows that the interaction between manufacturing and modern services is significant for the first two Kaldor laws and marginally significant for the third. This suggests that greater integration between these sectors leads to higher GDP growth rates, manufacturing productivity and total productivity.

In summary, the results suggest that the services sector, especially its interaction with manufacturing, is consistent with Kaldor's laws.

The symbiosis between modern services and manufacturing can be seen as a phenomenon of extended increasing returns to scale, or an extended Kaldor-Verdoorn law. This concept reflects a new stage of structural change, where integration between sectors promotes a more advanced and efficient production process, accelerating technological progress and innovation.

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