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REGIONAL ECONOMY AND INEFFICIENCY: A THEORETICAL MODEL TO EXPLAIN INEQUALITIES

Economia Regional e Ineficiência: um Modelo Teórico para Explicar Desigualdades.

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ABSTRACT

This paper seeks to develop a theoretical model in which regional inequality results from inefficiency. To this end, we explore the differences between economic units observed and ideal productivity. This work is based on misallocation and economic growth models. The main conclusions are: i) It is essential to control productive heterogeneity to prevent bias in the results; ii) There is a strong relationship between efficiency and productivity; iii) Resources are concentrated in regions with higher efficiency; iv) Efficiency and productivity are sources of regional inequalities; v) efficiency improvements generate long-term income equality; and vi) idiosyncratic tax regimes cause inefficiencies, based on distortions in the marginal products of capital and labor, contributing to income inequality between regions.

KEYWORDS: Regional Economy; Productivity; Efficiency; Inequality; Theoretical Model

RESUMO

Este artigo busca elaborar um modelo teórico no qual a desigualdade regional é resultado da ineficiência. Para isso são exploradas diferenças entre produtividade observada e ideal de unidades econômicas. A base teórica vem dos modelos de misallocation e crescimento econômico. As principais conclusões são: i) a heterogeneidade produtiva deve ser controlada para não viesar os resultados; ii) existe forte relação entre eficiência e produtividade; iii) os recursos são concentrados em regiões mais eficientes; iv) eficiência e produtividade são fontes de desigualdades regionais; v) melhorias de eficiência geram igualdade de renda de longo prazo; e vi) regimes fiscais idiossincráticos causam ineficiências, a partir de distorções sobre os produtos marginais de capital e trabalho, contribuindo para a desigualdade de renda entre as regiões.

PALAVRAS-CHAVE: Economia Regional; Produtividade; Eficiência; Desigualdade, Modelo Teorico.

Classificação JEL: C02; E13

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1 INTRODUCTION

The economic performance of different regions is a topic of extensive discussion in the literature. It is often attributed to productivity as a central factor in explaining income disparities. There is a consensus among influential authors, including Coe and Helpman (1995), Islam (1995), Keller (1997), Klenow and Rodríguez-Clarence (1997), Benhabib and Spiegel (2002), and Hsieh and Klenow (2009), on the relationship between productivity and resource allocation. The collective findings of these authors demonstrate how productive inefficiency can result in reduced aggregate productivity and the emergence of economic inequalities between regions. Furthermore, these authors' models highlight the direct association between the misallocation of resources and a loss of economic efficiency, thereby providing the reader with a sense of reassurance and confidence in the presented information.

In light of the contributions made by Hsieh and Klenow (2009), the existing literature on productivity has placed a greater emphasis on the relationship between productivity and efficiency. A significant body of literature posits a direct relationship between inefficiency in resource allocation and aggregate economic productivity. Consequently, during the initial two decades of the 2000s, a number of studies were published which linked resource misallocation, productivity and productive efficiency. This gave rise to a theoretical current which was centered on the problem of misallocation (Hsieh and Klenow, 2009; Banerjee and Moll, 2010) 1.

This theoretical approach gauges economic efficiency by comparing the outputs of disparate production units, operating under the assumption that an optimal pattern of resource allocation exists. Accordingly, the greater the discrepancy between the allocation of resources and this optimal standard, the lower the productivity at the microeconomic level, the more inefficient the production and use of resources, and consequently, the lower the aggregate productivity of the economy (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008; 2013; Adamopoulos et al., 2017).

Other studies have concentrated on regional inequalities, as evidenced by the work of Marinho (2002) and Schettine and Azzoni (2018). In the view of Schettine and Azzoni (2018), regional inequalities are the consequence of relative inefficiency, resulting in a bias

[1] For further details, please see the following sources: Jones (2011); Restuccia & Rogerson (2008, 2012); Restuccia (2012); Moll (2014); Da-Rocha et al. (2016); Adamopoulos et al. (2017).

towards more significant investments in the country's more efficient and wealthier regions, to the detriment of the less efficient and, therefore, more backward regions. Regional inequalities represent a traditional field of macroeconomic discussion, in which a number of additional hypotheses have been proposed to explain regional inequalities. These include institutional asymmetries (Acemoglu et al., 2001; 2012), infrastructure inequalities (Schettine and Azzoni, 2015), and technological and vulnerability inequalities (Lima & Urraca-Ruiz, 2020; Lima et al., 2024). The formulation of regional infrastructure policies has the potential to mitigate these inequalities, as evidenced by the positive impacts of the construction of oil refineries in the Brazilian Northeast, as demonstrated by Ribeiro et al. (2018).

However, the objective of this study is to elucidate the phenomenon of regional inequalities through the lens of an economic inefficiency model, contingent upon the hypothesis of misallocation of productive resources. This study aims to examine the potential for increased productivity by investigating the discrepancy between the efficient marginal product and the observed one. This analysis will elucidate how this differential can explain the observed differences in efficiency and productivity across economic units. This research aims to address some of the key questions surrounding regional inequalities, including: What are the reasons behind the relationship between economic inefficiency and relative backwardness? What are the mechanisms through which inefficiency impedes the formation of productive investments? What are the links between regional heterogeneities and inefficiency and regional inequality? Furthermore, what policies would be most effective in reducing inequalities in productivity and income?

To answer these questions, this article develops a theoretical model for regional economies with inefficiency. In the baseline model, we completely abstracted from any direct causes of misallocation, focusing our attention on how exogenous productive inefficiencies generate income losses across regions. Thus, the deviation between observed and potential output was characterized solely by efficiency differences, without introducing their causes into the core of the analysis. In this way, we ensured a clear baseline on how capital and labor allocation failures affect regional inequalities. This strategy allows us to isolate the role of technological and institutional inefficiencies, while maintaining the flexibility to introduce the political dimension as an endogenous source of this mismatch. We then discuss how idiosyncratic fiscal policies can distort the marginal products of representative firms and lead to inequalities in efficiency, productivity, and income between two regions. Thus, income

inequality becomes endogenous to the current fiscal policy, as we demonstrate that inefficiencies are a function of fiscal distortions.

This research is based on the seminal human capital model proposed by Lucas (1978), as well as the contributions made by Adamopoulos et al. (2017) and Schelkle (2017), which have been adapted to a regional context. Some authors have demonstrated that specifications pertaining to human capital exert a positive and variable influence on the relative efficiency of regions (Tsekeris and Papaioannou, 2017). The principal contribution of our research is to introduce productive heterogeneity as a crucial element in understanding the inefficient distribution of resources and income disparities. As Mohan et al. (2022) have observed, these characteristics are intrinsic to the regional context and exert a pervasive influence on economic efficiency, irrespective of the technology in question. The theoretical model developed employs an indirect approach to addressing productivity differentials (see Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Schelkle, 2017; Restuccia and Rogerson, 2017). Assuming possible differences in marginal productivities as exogenous, we explore the relationship between productive efficiency and resource allocation. Our findings suggest that more productive regions attract more resources, widening regional inequalities. Furthermore, the model offers a tool for quantifying productivity losses due to inefficiency and suggests that efficiency improvements can generate significant economic gains in the long term.

2 LITERATURE REVIEW

The discussion on productivity and efficiency, a crucial element in the advancement and expansion of economies, represents a pivotal topic in the field of economic theory. This literature, which has been addressed by various authors at different times, serves as a testament to the diverse perspectives and insights that contribute to our understanding of the topic. As Manuelli and Seshadri (2014, p. 2736) observe, "Perhaps no question has attracted as much attention in the economic literature as the question of why some countries are richer than others".

In his 1956 work, Solow sought to address this question, emphasizing the pivotal role of physical capital accumulation in explaining income disparities between countries. Ellery Jr. (2014) also notes the significant role of the exogenous technological factor (also known as the Solow residual or "size of our ignorance"). The author notes that this variable is

currently employed in the calculation of total factor productivity (TFP), wherein the following assumptions are typically made: "Firstly, the factors of production are utilized in a technically efficient manner and compensated based on their marginal products. Secondly, the production process is conducted using a technology that exhibits constant returns to scale, with the marginal cost determining the price" (ELLERY JR., 2014, p. 62).

Subsequent to Solow's (1956) foundational work, other scholars have investigated the subject of economic growth and proposed alternative theories that diverge from those initially put forth by the author. For example, Lucas (1988) posits that the accumulation of physical capital alone is insufficient to account for a nation's economic growth process. He suggests that the model should also consider human capital. Mankiw et al. (1992) expanded Solow's model to incorporate the accumulation of human and physical capital. The authors discovered that incorporating human capital into the model resulted in a notable impact on both physical capital accumulation and population growth, which in turn influenced countries' income levels.

Coe and Helpman (1995) construct a measure of total factor productivity to verify the effects of capital stocks and foreign R&D on this measure of productivity. The theoretical novelty of their study concerns the measurement of TFP growth that is not directly associated with the accumulation of inputs in a given economy. This allows for an investigation of how growth may be affected by factors other than inputs, as well as the mechanisms through which these factors influence the economy's performance and growth.

Additionally, the work of Hsieh and Klenow (2009) examines TFP as a factor influencing national income disparities. However, the approach places emphasis on the impact of resource misallocation on TFP. The work of Hsieh and Klenow (2009) represents a significant contribution to the growing literature on resource misallocation. In conjunction with Restucia (2013), they provide a framework for estimating the impact of misallocation on income disparities between economies through the inefficiency resulting from misallocation. In this context, studies examining the relationship between misallocation, productivity, efficiency, and growth have gained prominence and contributed significantly to the economic literature.

Hsieh and Klenow (2009) defend the proposition that discrepancies in income between economies are attributable to dissimilarities in TFP. The authors contend that attributing these results to productivity alone is insufficient; rather, it is imperative to comprehend the factors that give rise to the observed variation in productivity across economies. In their theoretical discussion, the authors posit that this variation can be

attributed to both differences in technology and the misallocation of resources. Accordingly, the authors present a model demonstrating how the misallocation of resources at the firm level can have consequences for aggregate productivity, efficiency, and GDP per capita.

For Banerjee and Moll (2010), the issue of misallocation or misuse of resources has become a prominent topic in economic literature. In their view, they state:

> There is growing interest in the view that underdevelopment may be not only a matter of a lack of resources, such as capital, skilled labor, entrepreneurship, or ideas but also a consequence of the misallocation or misuse of available resources (BANERJEE and MOLL, 2010, p. 189).

Furthermore, the authors illustrate various methodologies for addressing the issue of misallocation and inefficient utilization of resources. The authors highlight that this issue has already been addressed in light of frictions in the credit market and their impact on the dispersion of marginal productivity of capital, income dispersion from marginal productivity of labor and capital (a consequence of external distortions such as tax regimes or institutions), the dispersion of firm sizes in the economy, and the correlation between firm size and average output. Additionally, they cite the use of calibration exercises where parameters are imposed for potential misallocation scenarios, followed by an evaluation of the consequences of such a scenario. Nevertheless, they caution that all forms of measurement are subject to limitations. They propose, however, that it is feasible to quantify the extent to which misallocation has contributed to the income disparities observed across economies.

In addition, Jones (2011, p.02) posits that the path with the most significant potential for explaining differences in income between economies is the misallocation of resources. He considers this theoretical current to be "one of the most important developments in the growth literature of the last decade".

The author posits that the observed low productivity at the macro level can be attributed to misallocation at the micro level. In the author's own words,

> Given an economy's stock of physical capital, labor, human capital, and knowledge, how these aggregate quantities of inputs are allocated [...] determines the economy's overall production level. The best allocation will maximize welfare and [...] production in the long run. Other allocations result in lower production levels and, therefore,

> appear in the aggregate as a lower level of total factor productivity (JONES, 2011, p. 02).

In this sense, Jones (2011) posits that although misallocation has a microeconomic genesis, it is discernible at the macroeconomic level due to the fact that the total quantities of the production aggregate elements reflect it. Nevertheless, he illustrates that TFP conveys the consequences of misallocation to aggregate variables, thereby demonstrating that misallocation is a mechanism that reduces productivity. Furthermore, the author posits that, in a more constrained sense, there are only two potential explanations for discrepancies in income over the long term: disparate allocation of resources or divergent production possibilities.

As stated by Restuccia and Rogerson (2013), the issue of misallocation has been primarily investigated through direct and indirect methods. As the authors posit,

> the essence of the direct approach is to choose one or more factors that are thought to be empirically essential sources of misallocation, attempt to obtain direct measures of these factors, and then use a model of heterogeneous production units to quantitatively assess the extent to which these factors generate misallocation and impact aggregate TFP (RESTUCCIA and ROGERSON, 2013, p. 05 - 06) .

As evidenced by Restuccia and Rogerson (2013), the direct approach may not be the most appropriate given the multitude of factors and channels that contribute to the poor allocation of resources. In employing the direct approach, researchers select a factor that is purported to be responsible for this suboptimal resource allocation and investigate the manner in which this factor gives rise to a specific impact. Nevertheless, the authors stress that it is not feasible to ascertain which factors are the most pertinent and which mechanisms are the most significant in the context of an inefficient allocation. Consequently, the direct approach is constrained by the fact that numerous factors exert influence on the allocation process, many of which are challenging to quantify.

In this context, the authors present the indirect approach as an alternative means of addressing the issue of misallocation. In regard to the indirect approach, the authors posit that "the starting point [...] is the observation that any factors that create a misallocation can be considered generators of wedges in the first-order conditions of optimization problems" (Restuccia and Rogerson, 2013, p. 10). Accordingly, the authors posit that the exogenous definition of wedges (distortions) represents the most viable approach to addressing

misallocation, while simultaneously accounting for essential and challenging-to-measure factors.

In their study, Da-Rocha et al. (2016) employed an indirect measurement strategy to assess the consequences of misallocation on output. The authors posit the existence of policy distortions on marginal productivities, which are typically attributed to idiosyncratic fiscal regimes. The authors develop an extension of the Hsieh and Klenow (2009) model to assess the impact of intermediate inputs on the degree of misallocation in the economy and its consequent effect on TFP. Additionally, they observe misallocation at the sectoral level (agriculture, services, and industry).

In a related study, García-Santana et al. (2016) examined the relationship between economic growth, productivity, and efficiency in the Spanish economy. The authors posit that a correlation exists between fluctuations in TFP and the level of efficiency. Therefore, they posit that the decline in TFP may be attributed to the misallocation of resources, noting that inefficiency in resource allocation increased concurrently with the decline in TFP.

Schelkle (2017) developed novel methodologies for assessing the impact of misallocated production factors on efficiency and productivity across diverse production units. He asserts that, based on his findings, it is feasible to conduct a comparative analysis of production units in a manner that is agnostic to the specific pairing, whether it be between firms, industries, sectors, or even countries. In his own words, Schelkle (2017, p.42) posits that "the theoretical framework, in its current or modified form, could be applied to misallocation in a multitude of contexts, including but not limited to the misallocation between firms, industries, sectors, or regions, as well as the comparison of the degree of misallocation between countries and periods".

In evaluating sectoral productivity and potential gains in per capita income resulting from improvements in this indicator, Veloso et al. (2017) assert the necessity of assessing the relative importance of the agricultural, industrial, and service sectors in productivity. They provide an extensive review of international literature, citing studies that demonstrate how the productivity of each sector fluctuates in accordance with the level of economic development. Upon applying their model to data from the Brazilian economy, they discovered low productivity in the industrial sector, which they defined as a generalized inefficiency given the potential for increased production without requiring additional inputs.

In conclusion, the work of Adamopoulos et al. (2017) presents a theoretical model that demonstrates the influence of agricultural sector productivity on total factor productivity (TFP), and consequently, on a country's development. In their work, the authors utilize farms

as the production unit and elucidate the manner in which misallocation at this level of aggregation affects the economy as a whole. The theoretical framework is based on the work of Lucas (1978), which provides a comprehensive understanding of how to model aggregate income differences based on differences in TFP at the disaggregated level. In light of the findings presented in the work of Adamopoulos et al. (2017), it became evident that municipal inefficiencies in production can give rise to disparities in regional income. This observation led to the formulation of a model that seeks to formalize this notion. This development is of great consequence, as it provides a mechanism by which regional disparities propagate and demonstrates how combating productive inefficiency can provide a solution to regional problems.

3 THE MODEL

This section develops a theoretical model of economic growth that incorporates regional inequalities as a function of productive inefficiency and local structural characteristics. In order to achieve this objective, two models are constructed. The first of these is a representative region without factor movement, with heterogeneity, and is presented in section 3.1. The second model is an aggregated region with factor mobility and productive homogeneity, and is presented in section 3.2

3.1 Representative region: model without factor mobility and with heterogeneities.

Let Region a consist of the sum of i municipalities, with i = 1,..., M, with M finite, where a representative firm can represent each city. Suppose that region a also has limited capital and labor resources, and there is no mobility of factors of production2. Furthermore, the aggregate product of this region, Y_a, can be defined as the sum of the products of each municipality that makes it up.

$$Y_a = \sum_{i=1}^{M} y_i \quad (1)$$

[2] The mobility of production factors only modifies the limit of available resources and does not affect the analytical results. Since the resources are assumed to be finite, this assumption is made for simplicity's sake and does not result in a loss of generality.

In this region, each municipality produces a homogeneous good and demands a specific amount of capital and labor to produce this final good. The municipalities in question exhibit considerable heterogeneity in their potential productivities. Furthermore, the technology of the representative firms demonstrates decreasing returns to scale in variable factors, a phenomenon that has been previously proposed by Lucas (1978) and Adamopoulos et al. (2017). Consequently, the production of each municipality (i) can be expressed as follows:

$$y_i = (A_a s_i)^{1-\theta} . (k_i^{\alpha} l_i^{1-\alpha})^{\theta} \quad (2)$$

Where, yi, li and ki, are the output of municipality i, the labor and capital used by i in production.

The term Aa is an everyday productivity and technology term associated with the municipalities in the region a, and $s_i \in (0,1]$ is the specific potential productivity term for each city and makes them heterogeneous among themselves, i.e., it is the particular productivity term for each municipality. Note that Aa makes the different regions heterogeneous since each area will have its own parameters. The parameters α and θ are, respectively, the relative importance of capital in the production of the final good and a span-of-control that governs the extent of returns to scale in all variable factors, with $\alpha \in [0,1]$ and $\theta \in (0,1)$.

In order to ascertain the income losses that a given region may incur as a consequence of suboptimal production, it is first necessary to identify the efficient or potential production capacity of each municipality and to compare it with the observed production levels. This enables the losses resulting from inefficiency to be inferred.

3.1.1 Efficient production

In order to ascertain the optimal levels of capital and labor that will maximize the output of each municipality i, and consequently maximize the aggregate production of the region a, one must solve the problem of the benevolent social planner who takes the specific potential productivities si as given.

By determining the optimal allocation of capital and labor within each municipality, it is possible to achieve efficient production, compare it with observed production, and infer the potential income gains that could be realized if the municipalities were operating at

optimal efficiency. In this sense, the benevolent social planner must allocate capital and labor among the municipalities of the same region in a manner that maximizes the output of each municipality, which consequently maximizes the aggregate production of the region. However, the social planner is constrained by the amount of resources available and is also required to assume that the technology and potential productivity of each municipality are fixed. In particular, the maximization problem faced by the benevolent social planner can be stated as follows:

$$\begin{aligned} &\max_{\{k_i,l_i\}_{i=1}^{M}} \; y_i \, i = 1, \ldots, M \\ s.a. \quad & y_i = (A_a s_i)^{1-\theta} . (k_i^{\alpha} l_i^{1-\alpha})^{\theta} \\ \text{and resource constraints: } & \textstyle\sum_{i=1}^{M} l_i = L \quad e \quad \sum_{i=1}^{M} k_i = K \end{aligned} \tag{3}$$

Therefore, the first-order conditions of the Lagrangian of the benevolent social planner for municipality i are:

$$\theta\alpha(A_a s_i)^{1-\theta} . (k_i^{\alpha} l_i^{1-\alpha})^{\theta-1} k_i^{\alpha-1} l_i^{1-\alpha} - \mu_1 = 0 \tag{4}$$

$$\theta(1-\alpha)(A_a s_i)^{1-\theta} . (k_i^{\alpha} l_i^{1-\alpha})^{\theta-1} k_i^{\alpha} l_i^{-\alpha} - \mu_2 = 0 \tag{5}$$

$$\textstyle\sum_{i=1}^{M} l_i = L \tag{6}$$

$$\textstyle\sum_{i=1}^{M} k_i = K \tag{7}$$

The first-order conditions for a municipality j ≠ i are:

$$\theta\alpha(A_a s_j)^{1-\theta} . (k_j^{\alpha} l_j^{1-\alpha})^{\theta-1} k_j^{\alpha-1} l_j^{1-\alpha} - \mu_1 = 0 \tag{8}$$

$$\theta(1-\alpha)(A_a s_j)^{1-\theta} . (k_j^{\alpha} l_j^{1-\alpha})^{\theta-1} k_j^{\alpha} l_j^{-\alpha} - \mu_2 = 0 \tag{9}$$

$$\textstyle\sum_{i=1}^{M} l_j = L \tag{10}$$

$$\textstyle\sum_{i=1}^{M} k_j = K \tag{11}$$

It should be noted that equations (6) and (10) are analogous, as are equations (7) and (11). This implies that all municipalities within the same region are subject to the same resource constraints. By employing equations (4) and (8) or (5) and (9), it is possible to demonstrate the following relationships:

$$\frac{k_i}{l_i} = \frac{k_j}{l_j} \;\; or \;\; \frac{l_j}{l_i} = \frac{k_j}{k_i} \tag{12}$$

The aforementioned relationships Equation (12), in conjunction with Equations (6), (7), (10), and (11), facilitate the determination of the optimal proportions of capital and labor to be allocated to each municipality, with the objective of maximizing the output of their respective products and, consequently, the regional product. In light of the aforementioned considerations, the optimal levels of capital, labor, and product can be defined as follows:

$$l_i^e = s_i \gamma L \tag{13}$$

$$k_i^e = s_i \gamma K \tag{14}$$

$$y_i^e = (A_a s_i)^{1-\theta} . [(k_i^e)^{\alpha} (l_i^e)^{1-\alpha}]^{\theta} \tag{15}$$

The superscript e denotes efficiency, and $\gamma = \frac{1}{\sum_{j=1}^{M} s_j}$ is a positive constant, such that $\gamma \in (0,1)$.Thus, $\gamma = \frac{1}{M} \leftrightarrow s_j = 1, \ \forall j = 1, \dots, M$. In other words, the distribution of resources should only be equal if all municipalities have the same potential productivity and are efficient in achieving their maximum productivity. Thus, for a given municipality to have more resources available (attraction of resources), it must raise its productivity parameter.

Substituting equation (15) into equation (1) shows that the efficient aggregate product of region a is:

$$Y_a^e = A^e M^{1-\theta} [K^{\alpha} L^{1-\alpha}]^{\theta} \tag{16}$$

where A^e and notes the optimum level of productivity in the region, with $A^e = (A_a S)^{1-\theta}$ e $S = \frac{\sum_{i=1}^{M} s_i}{M}$ being the average potential productivity of the municipalities in the area.

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3.1.2 Deviations from potential productivity and observed inefficiency

It is now necessary to consider the possibility that a given municipality may have observed productivity that is lower than its potential productivity s_i, i.e., in the observed situation, municipality i faces productivity as follows:

$$s_i^o = e^{-\mu_i} . s_i \tag{17}$$

where, $e^{-\mu_i} \in (0,1)$ and represents a possible loss of productivity due to exogenous factors such as the quality of institutions, government intervention in the economy, and the stock of

human capital. Note that $s_i^o = s_i \leftrightarrow e^{-\mu_i} = 1$. The superscript o indicates an observed situation.

From equations (2) to (11) and (17), we can define the new quantities of capital, labor, and product as a function of s_i^o:

$$l_i^o = \gamma e^{-\mu_i} s_i L = s_i^o \gamma L \tag{18}$$

$$k_i^o = \gamma e^{-\mu_i} s_i K = s_i^o \gamma K \tag{19}$$

$$y_i^o = (A_a s_i^o)^{1-\theta} . [(k_i^o)^{\alpha} (l_i^o)^{1-\alpha}]^{\theta} \tag{20}$$

From (18), (19) and (20) we arrive at the following equations:

$$y_i^o = (A_a s_i^o)^{1-\theta} . [(s_i^o \gamma K)^{\alpha} (s_i^o \gamma L)^{1-\alpha}]^{\theta} \tag{21}$$

$$y_i^o = (A_a s_i^o)^{1-\theta} . [(\gamma e^{-\mu_i} s_i L)^{\alpha} (\gamma e^{-\mu_i} s_i K)^{1-\alpha}]^{\theta} \tag{22}$$

$$y_i^o = (A_a s_i e^{-\mu_i})^{1-\theta} . [(k_i^e e^{-\mu_i})^{\alpha} (l_i^e e^{-\mu_i})^{1-\alpha}]^{\theta} \tag{23}$$

$$y_i^o = (A_a s_i)^{1-\theta} e^{-\mu_i 1-\theta} . [(k_i^e)^{\alpha} (l_i^e)^{1-\alpha}]^{\theta} . e^{-\mu_i \theta} \tag{24}$$

$$y_i^o = e^{-\mu_i} . (A_a s_i)^{1-\theta} . [(k_i^e)^{\alpha} (l_i^e)^{1-\alpha}]^{\theta} \tag{25}$$

$$y_i^o = e^{-\mu_i} . y_i^e \tag{26}$$

Note that municipality i only reaches its potential product, $y_i^o = y_i^e$, when $e^{-\mu_i} = 1$, which implies that there are no productivity deviations in the municipality i about to its potential productivity, that is $s_i^o = s_i$. Also note that $\forall e^{-\mu_i} < 1 \rightarrow s_i^o < s_i \rightarrow y_i^o < y_i^e$.

The following equation provides the formula for calculating the inefficient regional aggregate product:

$$Y_a^o = E . A^e . M^{1-\theta} . [K^{\alpha} L^{1-\alpha}]^{\theta} \tag{27}$$

where $A^e = (A_a S)^{1-\theta}$ and $S = \frac{\sum_{i=1}^{M} s_i}{M}$ is the average productivity, and $E \in (0,1)$ is a term that captures the aggregate inefficiency.

3.2 Aggregation of regions: model with mobility and productive homogeneity

In evaluating the inefficiency of municipalities in disparate regions, it is essential to assume that the areas in question possess analogous production technologies, thereby ensuring productive homogeneity. Furthermore, it is feasible to consider the free mobility of production factors and integrate these assumptions into the income optimization problem faced by the benevolent social planner. Once this has been completed, the situation becomes analogous to that previously discussed in the context of a representative region (productive heterogeneity).

Let regions a and b with i and j municipalities respectively, i=1, ..., M; j=1, ..., P; e i+ j = 1, ..., N. A representative firm represents each municipality, and the aggregate products of the regions are given respectively by Ya e Yb. Also, assume that each region a and b has limited capital and labor resources but that there is free mobility of production factors between the regions. Let the aggregate products of these regions be defined as the sum of the products of each municipality that compose it, as seen in (28).

$$Y_a = \sum_{i=1}^{M} y_i \qquad Y_b = \sum_{j=1}^{P} y_j \tag{28}$$

with,

$$y_i = (A_a s_i)^{1-\theta}.(k_i^{\alpha} l_i^{1-\alpha})^{\theta} \qquad y_j = (A_a s_j)^{1-\theta}.(k_j^{\alpha} l_j^{1-\alpha})^{\theta} \tag{29}$$

equations (28) and (29) can be summarized as follows:

$$Y_a + Y_b = Y_{ab} = \sum_{j=1}^{P} y_j + \sum_{i=1}^{M} y_i = \sum_{i=1}^{N} y_i \tag{30}$$

$$y_i = (A_a s_i)^{1-\theta}.(k_i^{\alpha} l_i^{1-\alpha})^{\theta},\ com \quad i = 1, \dots, NeN = M + P \tag{31}$$

It is important to note that equations (30) and (31) above are strikingly similar to those presented in the representative region model. Nevertheless, this outcome is contingent upon the stipulation that municipalities across disparate regions exhibit analogous forms of production functions and identical productivity and technology parameters, specifically A_a.

From equations (30) and (31) and the assumption of free mobility of factors of production between regions a e b we arrive at the new income optimization problem of the benevolent social planner:

$$\max_{\{k_i, l_i\}_{i=1}^{N}} y_i$$

$$s.a.\ y_i = (A_a s_i)^{1-\theta}.(k_i^{\alpha} l_i^{1-\alpha})^{\theta} \tag{32}$$

and resource constraints: $\begin{cases} \sum_{i=1}^{P} l_i + \sum_{i=1}^{M} l_i = \sum_{i=1}^{N} l_i = L \\ \sum_{i=1}^{P} k_i + \sum_{i=1}^{M} k_i = \sum_{i=1}^{N} k_i = K \end{cases}$

As demonstrated in the equations presented in (32), we employ a similar methodology to that utilized in the model with a representative region (heterogeneous regions), thereby deriving the quantities of efficient and observed resources and products within this economic system as a function of potential and observed productivities.

$$l_i^e = s_i \gamma L \tag{33}$$

$$k_i^e = s_i \gamma K \tag{34}$$

$$y_i^e = (A_a s_i)^{1-\theta} . [(k_i^e)^{\alpha} (l_i^e)^{1-\alpha}]^{\theta} \tag{35}$$

$$l_i^o = \gamma e^{-\mu_i} s_i L = s_i^o \gamma L \tag{36}$$

$$k_i^o = \gamma e^{-\mu_i} s_i K = s_i^o \gamma K \tag{37}$$

$$y_i^o = (A_a s_i^o)^{1-\theta} . [(k_i^o)^{\alpha} (l_i^o)^{1-\alpha}]^{\theta} \tag{38}$$

with, $s_i^o = e^{-\mu_i} . s_i$ e $y_i^o = e^{-\mu_i} . y_i^e$.

The aggregate products are similar to equations (16) and (27). Thus, the efficient aggregate product is given by:

$$Y^e = A^e N^{1-\theta} [K^{\alpha} L^{1-\alpha}]^{\theta} \tag{39}$$

where A^e denotes the optimal productivity level of the region, where $A^e = (A_a S)^{1-\theta}$. $S = \frac{\sum_{i=1}^{N} s_i}{N}$ is the average productivity of the municipalities in the region (supposedly optimal).

In addition, the observed aggregate product is calculated using the following equation:

$$Y^O = E . A^e . N^{1-\theta} . [K^{\alpha} L^{1-\alpha}]^{\theta} \tag{40}$$

where $A^e = (A_a S)^{1-\theta}$ and $S = \frac{\sum_{i=1}^{N} s_i}{N}$ s the average productivity and $E \in (0,1)$ is a term that captures the aggregate inefficiency.

4 Mechanisms and causes of inefficiency

4.1 Distortions in Marginal Productivities

As already discussed in the literature review, there is consensus that the lack of equalization of marginal product revenues across producing units is an indicator of resource misallocation in the economy. These models postulate that this lack of equalization reduces aggregate TFP, resulting in a deviation from the optimal allocation and, consequently, in an observed output lower than the efficient output (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Resttucia and Rogerson, 2012; Schelkle, 2017; Adamopoulos et al., 2017).

To ascertain the impact of misallocation on observed inefficiency, Hsieh and Klenow (2009) and Adamopoulos et al. (2017) propose utilising discrepancies in average products. The results of their studies indicate that the average product is proportional to the marginal product, thereby providing an effective means of measuring differences in marginal products.

Following this theoretical framework, our goal is to demonstrate how policy distortions lead to aggregate productivity losses, highlighting the causes and mechanisms behind this efficiency loss. Thus, this section explains how idiosyncratic fiscal policies can distort the marginal products of representative firms and lead to inequalities in efficiency, productivity, and income between two regions. Therefore, income inequality becomes endogenous to the current fiscal policy, since we demonstrate that inefficiencies are a function of fiscal distortions.

4.1.1 The efficiency of marginal products

Based on the assumption of authors such as Restuccia and Rogerson (2008, 2012), Hsieh and Klenow (2009), Schelkle (2017), Adamopoulos et al. (2017) that distortions influence TFP in marginal productivity, it is possible to derive here equivalent conditions for this model that show how $TFP_i = (A_a s_i)^{1-\theta} = \frac{y_i}{(k_i^{\alpha} l_i^{1-\alpha})^{\theta}}$ is impacted by policy distortions on marginal productivities. In this sense, it should be expected that the observed productivity, $TFP_i^o = e^{-\mu_i}.(A_a s_i)^{1-\theta} = e^{-\mu_i}.TFP_i^e$, is a function of the marginal products of capital and labor.

As seen below, it is possible to show that inefficiency is a function of policy distortions on the marginal products of capital and labor. This condition leads to the hypothesis that differences between observed and potential productivities, $s_i^o \neq s_i$, occur when distortions exist in at least one of the marginal products. Thus, it is possible to infer that differences between observed and efficient income, $y_i^o \neq y_i^e$, would be related to deviations in marginal productivities.

In this sense, to advance in identifying the relationship between inefficiency and distortions in marginal products, define pmg_k e pmg_l of the firm representing municipality i as follows:

$$pmg_{k_i} = \frac{\partial y_i}{\partial k_i} \quad and \quad pmg_{l_i} = \frac{\partial y_i}{\partial l_i} \tag{41}$$

Now, as an example, suppose that idiosyncratic tax regimes can distort the profit maximization problem of the representative firm3, distorting the marginal product of capital and labor, as follows:

$$\begin{gathered} Max \;\; \pi_i = y_i - rk_i - wl_i \\ \text{or} \\ Max \;\; \pi_i = y_i - \left(1 - \tau_i^k\right) rk_i - \left(1 - \tau_i^l\right) wl_i \end{gathered} \tag{42}$$

where, y_i is the product of municipality i, τ_i^k represents a subsidy on capital income, τ_i^l represents a subsidy on labor income, r is the remuneration of capital, and w is labor remuneration. For illustrative purposes, policy distortions originating from tax regimes are used to introduce subsidies to solve the optimization problem of the representative firms. However, distortions can come from several sources, as already discussed in the literature review.

Note that tax regimes distort marginal productivity:

$$pmg_{k_i}^o = pmg_{k_i}^e . \left(1 - \tau_i^k\right) \quad and \quad pmg_{l_i}^o = pmg_{l_i}^e . (1 - \tau_i^l) \tag{43}$$

with $\tau_i^k \in [0,1)$ e $\tau_i^l \in [0,1)$.

[3] Such is the case with the Brazilian tax system, which taxes capital and labor differently through tax exemptions for some sectors of the economy.

Assuming $\tau_i^k \neq 0$ and $\tau_i^l \neq 0$ and using (43) it is possible to arrive at the following equations:

$$\frac{1}{(1-\tau_i^k)} \cdot pmg_{k_i}^o = pmg_{k_i}^e \quad and \quad \frac{1}{(1-\tau_i^l)} \cdot pmg_{l_i}^o = pmg_{l_i}^e \tag{44}$$

$$d_{o,e}^{k_i} \cdot pmg_{k_i}^o = pmg_{k_i}^e \quad and \quad d_{o,e}^{l_i} \cdot pmg_{l_i}^o = pmg_{l_i}^e \tag{45}$$

where $d_{o,e}^{k_i}$ e $d_{o,e}^{l_i}$ represent, respectively, distortions (or deviations) in the observed marginal productivities of capital and labor relative to the efficient one. Thus, since $d_{o,e}^{k_i}$ e $d_{o,e}^{l_i}$ are necessarily more significant than 1, the observed marginal product is less than the efficient marginal product.

In this context, in order to demonstrate the relationship between policy distortions and inefficiency, the revenue productivity TFPR will be defined below as in Hsieh and Klenow (2009) and Adamopoulos et al. (2017), showing how these distortions result in differences between the observed TFP and the efficient TFP.

In equations (42), it is possible to arrive at the revenues of the marginal products (Rpmg), which, given the normalization of the price of the homogeneous product to the numeraire, are also marginal products, as follows:

$$\frac{Rpmg_{i_k}^e}{\alpha\theta} = \frac{y_i}{k_i} = \frac{r}{\alpha\theta} \quad \text{and} \quad \frac{Rpmg_{i_k}^o}{\alpha\theta} = \frac{y_i}{k_i} = \frac{r(1-\tau_i^k)}{\alpha\theta} \tag{46}$$

$$\frac{Rpmg_{i_l}^e}{(1-\alpha)\theta} = \frac{y_i}{l_i} = \frac{w}{(1-\alpha)\theta} \quad \text{and} \quad \frac{Rpmg_{i_l}^o}{(1-\alpha)\theta} = \frac{y_i}{l_i} = \frac{w(1-\tau_i^l)}{(1-\alpha)\theta} \tag{47}$$

where, $Rpmg_{i_k}^e$ is the marginal revenue product of efficient capital of municipality i, $Rpmg_{i_k}^o$ is the marginal revenue product of distorted capital of municipality i, $Rpmg_{i_l}^e$is the marginal revenue product of efficient labor of municipality i and $Rpmg_{i_l}^o$ is the marginal revenue product of efficient labor of municipality i.

Equations (46) and (47) provide the observed (distorted) and efficient revenue productivities and the relationship between them:

$$TFPR_i^{\,e} = \frac{y_i}{k_i^{\alpha} l_i^{1-\alpha}} = \left(\frac{r}{\alpha\theta}\right)^{\alpha} . \left(\frac{w}{(1-\alpha)\theta}\right)^{1-\alpha} \tag{48}$$

$$TFPR_i^{\,o} = \frac{y_i}{k_i^{\alpha} l_i^{1-\alpha}} = \left(\frac{r}{\alpha\theta}\right)^{\alpha} . \left(\frac{w}{(1-\alpha)\theta}\right)^{1-\alpha} . (1-\tau_i^k)^{\alpha} . (1-\tau_i^l)^{1-\alpha} \tag{49}$$

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$$TFPR_i{}^o = TFPR_i{}^e . (1 - \tau_i^k)^\alpha . (1 - \tau_i^l)^{1-\alpha} \quad (50)$$

where, $TFPR_i{}^o$ is the observed (distorted) productivity revenue and $TFPR_i{}^e$ is efficient.

Equations (48) and (49) correspond to the TFPR found in Hsieh and Klenow (2009) and Adamopoulos et al. (2017). The following equations (51) and (52) can be derived, which show an alternative way to calculate this model's TFP and determine the relationship between TFP and TFPR.

$$TFPR = \frac{(A_a s_i)^{1-\theta}}{(k_i^\alpha l_i^{1-\alpha})^{1-\theta}} = \frac{TFP}{(k_i^\alpha l_i^{1-\alpha})^{1-\theta}} \quad (51)$$

therefore,

$$TFP^e = TFPR^e . (k_i^\alpha l_i^{1-\alpha})^{1-\theta} \quad \text{and} \quad TFP^o = TFPR^o . (k_i^\alpha l_i^{1-\alpha})^{1-\theta} \quad (52)$$

From the equations in (48) to (52) it is possible to show the following relations:

$$TFP^o = TFPR^e . (k_i^\alpha l_i^{1-\alpha})^{1-\theta} . (1 - \tau_i^k)^\alpha . (1 - \tau_i^l)^{1-\alpha} \quad (53)$$

$$TFP^o = TFP^e . (1 - \tau_i^k)^\alpha . (1 - \tau_i^l)^{1-\alpha} \quad (54)$$

$$\frac{TFP^o}{TFP^e} = \frac{TFPR^o . (k_i^\alpha l_i^{1-\alpha})^{1-\theta}}{TFPR^e . (k_i^\alpha l_i^{1-\alpha})^{1-\theta}} = \frac{TFPR^o}{TFPR^e} = (1 - \tau_i^k)^\alpha . (1 - \tau_i^l)^{1-\alpha} \quad (55)$$

On the other hand, it is also possible to show the following relation:

$$\frac{TFP_i^o}{TFP_i^e} = e^{-\mu_i} \quad (56)$$

therefore,

$$e^{-\mu_i} = (1 - \tau_i^k)^\alpha . (1 - \tau_i^l)^{1-\alpha} \quad (57)$$

It can thus be defined that the observed inefficiency is a function of the distortions on the marginal products, that is to say, $e^{-\mu_i} = F(\tau_i^k, \tau_i^l)$. In other words, inefficiency is present when there are distortions in the marginal products. Consequently, the total factor

productivity (TFP) is deemed efficient when the total factor productivity ratio (TFPR) is efficient; conversely, the TFP is deemed inefficient when the TFPR exhibits distortions. Accordingly, the distortions in the marginal products are, by definition, the cause of the differentials in municipal products, and thus a source of regional inequalities.

Finally, in this section, by characterizing the deviation between observed and potential output through shocks to marginal productivity—introducing tax regimes into the core of the analysis—we incorporate the public policy framework into the discussion of income inequality. By demonstrating that inefficiencies, initially postulated as exogenous, derive from idiosyncratic tax regimes, we show that tax policy decisions function as endogenous determinants of the marginal rates of return on capital and labor in representative firms.

Thus, the same set of institutional and administrative choices that establish tax incentives in each region ends up perpetuating distortions in factor allocation and widening productivity disparities. From this perspective, three lines of action naturally emerge: standardizing tax bases and rates, reducing sectoral subsidies and arbitrage opportunities; strengthening revenue collection and control capacity, ensuring greater alignment between declared and effective tax rates; and the implementation of horizontal equalization mechanisms, which mitigate differences in the tax base and level the playing field for interregional competitiveness.

5 FINAL CONSIDERATIONS

This article aimed to develop a theoretical model to examine the nexus between productivity, efficiency, and regional inequality. The model assumes that poor resource allocation is a determining factor in the inefficiency that leads to income disparities between regions. The study demonstrated that productive efficiency is a crucial factor in elucidating productivity disparities between regions. More efficient areas, capable of utilizing their capital and labor resources more effectively, tend to attract greater resources, increasing their productivity. This, in turn, contributes to the worsening of regional inequalities.

The representative region model suggests that each region has its own particularities and that when comparing the products of two different municipalities within the same region, they will depend on: i) productivity and technology associated with the municipalities in the region; ii) the amount of capital and labor available in that region (a factor that can be made more flexible assuming some degree of productive resource capacity); iii) the relative

importance of capital and labor in the production of the municipalities; and iv) the specific productivity of each municipality (potential and productive effort). Another important implication of the model is that a region's output depends significantly on the technology associated with its municipalities. Therefore, heterogeneous regions should be studied separately to avoid the error of considering differences in each region's productive characteristics as inefficiencies.

On the other hand, the aggregated regions model suggests that aggregating regions under an assumption of productive homogeneity is possible. Thus, it is possible to compare the productivity of two different municipalities in distinct regions, but with due caution in understanding the limitations of this comparison, given the assumption of productive homogeneity. In this sense, production differences would be attributed solely to each municipality's specific productivity (potential and productive effort), thus increasing the importance of efficiency in the results of these federal entities.

Both models show that it is possible to increase the aggregate output of regions by increasing productivity, primarily through the productive efficiency of the municipalities that comprise them. However, the weight of efficiency in aggregate results can be artificially increased when the assumption of productive homogeneity is imposed across municipalities. In both the representative regions model and the aggregation of regions model, efficiency is a fundamental explanatory factor of municipal and regional productivity.

In other words, when resources are limited, municipalities that are more productive receive a greater proportion of resources allocated to production. Thus, municipalities must increase their productivity to increase their output. In particular, if $\forall i, s_i = 1$, resources should be distributed equally in the amount of capital $\frac{K}{N}$ and labor $\frac{L}{N}$ to each municipality, thus leading to the maximum possible production in the economy and equity between regions.

One of the principal implications of the proposed models is their potential to augment the aggregate production of regions. By enhancing productivity, particularly through the productive efficiency of the municipalities that constitute the region, these models illustrate the potential for increased regional production. It is important to note, however, that the weight of efficiency in aggregate results can be artificially inflated when the assumption of productive homogeneity in the municipalities is enforced.

Finally, another important implication of this research is the demonstration of how idiosyncratic tax regimes generate significant distortions in the allocation of capital and labor, resulting in losses in efficiency, productivity, and income. Different exemptions and subsidies

by region and sector compromise productive efficiency and exacerbate income disparities. Therefore, it is clear that a tax-neutral fiscal policy can increase efficiency and consequently reduce regional disparities. Therefore, tax legislation that adopts unified tax bases and rates, eliminates sectoral subsidies, and closes arbitrage loopholes will promote the interregional competitiveness necessary for income equity.

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