



Article An Empirical Approach Analyzing the Socioeconomic Sustainability of the International Sugarcane Trade

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Abstract: The rapport between international trade and income inequality came to light after the Heckscher–Ohlin/Stolper–Samuelson theorem (HOS). Nevertheless, researchers have not concluded whether the HOS theory truly reflects reality. Even though the main focus provided by the HOS theory is on internal inequality (existing inside the country among its population), another way of analyzing the HOS theory is through income inequality among countries. This last possibility is also called income convergence. This work contributes to the topic of researching the relationship between the export of sugarcane-derived products and income to verify the income convergence effect. The cultivation of sugarcane is a relevant activity for many developing countries, including Brazil. In addition, no developed country product, it would be possible to analyze the relationship among the variables in a broader sense. The results obtained in the research indicate that the impact of the export of sugarcane products on income is minimal. Although positive, it is only perceived over time. Due to the characteristics of this research, which involves performing an analysis involving green production, green energy, and income inequality, this study is related to the seventh, eighth, and tenth United Nations' SDG goals.

Keywords: international trade; income; income convergence; sugarcane

1. Introduction

Despite the Heckscher–Ohlin/Stolper–Samuelson theorem's effort to clarify the relationship between international trade, after more than 50 years, researchers still cannot confirm the so-called HOS theory.

Klein, Moser, and Urban [1]; Egger, Egger, and Kreickemeier [2]; and Borrs and Knauth [3] found evidence proving the HOS theory. However, some researchers claimed the contrary outcome was observed [4–7] or concluded that international trade did not exert an influence on income inequality [8]. Some claim that international trade leads to secondary outcomes, such as the import of new technologies, leading to a rise in the demand for skilled workers and increasing income inequality in developing countries, contradicting the HOS theory [9,10].

Another way to consider the HOS theory, besides the traditional way of focusing on income inequality inside the country, is to analyze how international trade impacts income inequality between countries. The premise behind this kind of analysis is that according to the HOS theory, international trade would promote the equalization of the price of factors, and as work is considered a production factor, its price should suffer the same equalization process. Jayanthakumaran and Verma [11] stated that following the income convergence theory, the greater the economic integration is among nations, the greater the benefits are flowing from richer countries to poorer ones.

Nevertheless, notwithstanding the researchers effort, the consensus of its proof is also far from being reached. While some authors claim to have proven the income convergence



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). theory, such as Ben-Davis [12], Ben-David and Kimhi [13], Cyrus [14], and Rassekh [15], others argue that no evidence was found or that other variables are involved in the process and deeper analyses should be conducted on the subject [16–18].

Concerning the subject of income inequality, it presents several difficulties toward sustainable development.

Aware of the importance of these issues, the United Nations has set, as one of the Sustainable Development Goals (SDGs), the Reduction of Inequalities Within and Between Countries by 2030—Goal No. 10 United Nations [19].

According to the United Nations [20], reducing inequality within and between countries is relevant because it will not achieve sustainable development while inequality persists.

Brazil is the largest producer of sugarcane in the world. The country produces over 654 million tons of sugarcane, according to IEA [21]. The state of Goiás, in turn, was responsible for producing 74.04 million tons of sugarcane in the last harvest. These data place the state of Goiás as the second biggest national producer [22].

The production of sugarcane in the state of Goiás has undergone a mechanization process during the last years. According to CONAB [23], more than 96% of the total planted sugarcane area in the Brazilian state uses mechanized production.

Mechanization may present positive outcomes, such as reducing greenhouse gases (considering the sugarcane burning in the harvest season in manual processes), soil protection against erosion, and increased fertility and organic matter content. However, it presents negative implications on the social side once those producers, who find themselves incapable of investing in mechanization because of the high investment cost it takes, are forced to leave their properties, causing the so-called agricultural exodus.

Regarding international trade, the state of Goiás also stands out for the export of products derived from sugarcane. According to UNICA [24], sugar and ethanol exports from Goiás have increased in the last three years. Considering the aggregate volume of the previous five years, the state of Goiás ranks as the fifth largest exporter of sugarcane products in Brazil.

This research aimed to contribute to the topic, studying the relationship between international trade and income. The question that guided this research was whether the export of sugarcane products contributed to the increase of income, helping to reduce the income gap between Brazil and the developed countries, therefore reducing income inequality among countries.

The main objective of this work was to verify if the export of sugarcane products increases the income of Goiás workers, leading to Income Convergence. Based on the results presented by Frankel and Romer [25], the hypothesis of this work defends the idea that the export of sugarcane products would increase the workers' income. This way, considering that sugarcane is mainly a developing country's product, it would be possible to assert that it helped produce the Income Convergence effect.

In case the hypothesis of this work proves to be positive, the importance of promoting this culture by governments will be evident, not only in Brazil but also in other developing countries that have the climate and environmental possibility to promote its planting.

The confirmation of the hypothesis of this work would also indicate that sugarcane production and export is a valuable tool to achieve goal number 10 of the United Nations' Sustainable Development Goals (SDG), once it helps reduce income inequality between countries.

Since this paper focuses on a relationship that involves a plant that produces clean energy, this work is also related to SDG goal number seven: Ensure Access to Affordable, Reliable, Sustainable, and Modern Energy for All. More specifically, target 7.2 states: By 2030, Increase the Share of Renewable Energy in the Global Energy Mix (target 7.2) [19].

One of the products derived from sugarcane is ethanol, which is a cleaner fuel. Moreover, research involving other energy production resulting from sugarcane has proven to succeed well, including those related to electricity production [26,27]. A study that contributes to stimulating the production of sugarcane by investigating its social and economic aspects has a substantial contribution to the seventh SDG goal, helping to stimulate its production by understanding its impact on society.

Finally, once this work deals with local and regional production and analyzes its influence on the income to improve it at a local, regional, and personal level, this research also contributes to one last SDG goal: Promote Sustained, Inclusive, and Sustainable Economic Growth, Full and Productive Employment and Decent Work for All, SGD goal number eight. More specifically, target number 8.4, which states: Improve Progressively, through 2030, global resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation, following the 10-year framework of programs on sustainable consumption and production, with developed countries taking the lead [19].

The research was done with data disaggregated by municipalities. All the cities in Goiás that presented international trade activity from 2009 to 2018 had their data collected. The time horizon adopted was due to limitations in data availability.

After data collection, a panel data regression analysis was performed. The research methodology follows that presented by Frankel and Romer [25]. According to Rassekh [15], the approach adopted by Frankel and Romer [25] provides a better option to analyze the relationship between international trade and labor income once it corrects endogeneity problems and measures the participation of localities in international trade through the share of international trade on GDP. Rassekh [15] asserts that by following the model proposed by Frankel and Romer [25], the problem of possible endogeneity between international trade and income is solved. The author also states that using the share of international trade in countries' GDP, as Frankel and Romer [25] proposed, instead of another way of measuring trade openness (some authors use tariffs or another way of measuring it) ensures that the data analyzed are free from interference caused by political decisions, which usually occur in several countries, and often simultaneously. Moreover, despite being almost 20 years old and despite Rassekh [15], the Frankel and Romer [25] model has been used several times in studies, such as Kim and Lin [28], Kim [29], and Zhang and Zhu [30], which proves that besides being old, it is still an appropriate model to investigate the relationship between international trade and income. Furthermore, none of the above-mentioned research developed an investigation with municipality data, such as ours.

Despite the limitation of analyzing a small number of municipalities (less than half of the municipalities of Goiás present international trade activity), this research presents an original contribution to the field because of the disaggregated results it provides, as formerly stated. In addition, the research presents results regarding one specific economic activity, making it possible to verify how exports of a specific product impact the workers' income. Furthermore, this work deals with a theoretical gap by analyzing the income convergence theory in a specific economic sector. For as long as we have been investigating, this approach has not been adopted so far.

This article is organized as follows: Section 2 presents the literature review, while Section 3 presents the methodology and the data used. Section 4 presents the results, and Section 5 presents the conclusions.

2. Theoretical Background

2.1. Sugarcane, the Brazilian Economy and the State of Goiás

Brazil is the largest producer of sugarcane in the world, being responsible for the production of more than 654 million tons of sugarcane, according to data from IEA [21]. From 2000 to 2018, the planted area increased from 4,879,841 to 10,063,739 hectares, according to UNICA [31]. In addition, as stated by UNICA [24], Brazilian sugarcane product exports have risen in the last years. The sugar exports increased from 4.11 million tons in 2017 (the first year of the record) to 30.6 million tons in 2020. Ethanol exports have also grown from 200 thousand cubic meters in 2017 (the first year of the record) to 2.7 million cubic meters in 2020 [24].

According to CONAB [22], in the 2020/2021 harvest period, 654.53 million tons of sugarcane were produced in Brazil in a harvested area of 8.62 million hectares, generating an average productivity of 75.93 million tons of sugarcane per hectare. In this period, Brazil produced 41.25 million tons of sugar and 32.77 billion liters of ethanol (considering the total production obtained from sugar cane and corn). According to the RFA [32], Brazil is responsible for 30% of the volume of ethanol produced in the world, second only to the United States, with 53% of global production.

Goiás is in the Midwest region of Brazil and stands out for sugarcane production. An illustrative picture with the position of the state of Goiás in relation to the rest of the country can be found in Appendix A, Figure A1. As happened to Brazil, the planted area in Goiás has increased in the past years. In 2000, the total sugarcane planted area was 139,186 hectares, while in 2018, it reached 948,091 hectares [31]. From the last harvest recorded in the state of Goiás, in the period 2020/2021, 74.04 million tons of sugarcane were produced on 971.6 thousand hectares of harvested area, with an average productivity of 76.20 tons of sugarcane per hectare and a production of 2.32 million tons of sugar and 5.26 billion liters of ethanol (considering sugar cane and corn). Those data place Goiás second in national production, behind only the state of São Paulo [22].

The topography in Goiás contributes to the mechanization of sugarcane farming in the state. The mechanized harvesting system has increased significantly in the state of Goiás. In its region, the mechanization of sugarcane harvesting has exceeded 96% of the total planting area [23]. The mechanization presents benefits for the soil, once it allows the straw to protect it against erosion and favors increased fertility and organic matter content, instead of being burned. [23].

2.2. International Trade and Income

Although research referencing international trade and income records dates back to before Adam Smith and David Ricardo, it is with the Heckscher–Ohlin model and the Stolper–Samuelson theorem (HOS) that the first theoretical attempts were made to explain the direct relationship between international trade and income distribution [5].

The Heckscher–Ohlin theory predicts that countries should specialize in producing and exporting products using the inputs (capital or labor) considered relatively abundant in that country. On the other hand, they should import those products that require inputs that are not abundant in their own country [33].

It was up to Stolper and Samuelson [34] to demonstrate that employing the existing resources in greater abundance and exporting the products resulting from this production would cause the yield of factors employed for this production to rise. Thus, the more developed countries, which have more skilled labor, would increase the income of this factor, while the developing countries, which have abundant unskilled labor, would see an increase in income for this input. The immediate consequence for developing countries would be a reduction in inequality.

Some researchers, such as Klein, Moser, and Urban [1]; Egger, Egger, and Kreickmeier [2]; and Borrs and Knauth [3], for example, were able to confirm the HOS theory for developed countries.

This notwithstanding, some research contradicted the HOS theory and asserted that no evidence was found for developed countries [7,35].

Regarding developing countries, several researchers claim to have failed to prove the HOS theory. Some of them tried to analyze the HOS theory in specific countries, such as Robbins and Gindling [4], who studied the data of Costa Rica. Attanasio, Goldberg, and Pavcnik [33] analyzed Colombian data. Han, Liu, and Zhang [6] investigated the HOS theory in Chinese regions, and Murakami [10] considered the data from Chile.

Studies involving Brazil were also performed, such as Pavcnik et al. [8], Green, Dickerson, and Arbache [36]; and Castilho, Menendez, and Sztulman [37], but the re-

sults they reached were also inconclusive. Pavcnik et al. [8] claimed that there was no proof of an increase in inequality due to the fact that international trade was identified. Green, Dickerson, and Arbache [36] recognized an increase in the income of the more skilled workers after trade opening but stated that this did not mean that income inequality had risen. Castilho, Menendez, and Sztulman [37] instead detected small increases (decreases) in income inequality for urban areas (rural areas).

Oppositely, some tried to observe the HOS theory from a broader perspective, investigating it in a group of countries [5,9,38,39]. However, despite their effort, none of them was able to prove the HOS theory.

During the past decades, another way of measuring the relationship between income inequality and international trade was disclosure, analyzing the impact of international trade on income inequality between developed and developing countries, the so-called income convergence.

Departing from the steady-state paradigm, extracted from Solow's [40] theory, this model seeks to investigate if international economic interaction among countries leads their incomes to converge. Solow's [40] theory states that the growth of countries' economies would lead to a situation he described as the steady state, in which the level of depreciation would equal the level of investment. It also predicts that the farther a country is from this endpoint, the faster the speed of its convergence would be to it. Finally, as countries approached the steady state, their income would grow and, consequently, the income of their population. In the final phase of the growth stage, all countries would present a similar level of income.

Ben-David [12] stated that income convergence is present in the HOS theory, once it predicts that international trade would lead commodities to equalize, balancing factor prices. Jayanthakumaran and Verma [11] stated that the greater economic integration among nations, the greater the benefits flowing from more prosperous to poorer countries.

Even though some authors have found empirical evidence of the income convergence theory, such as [11,12,14,15], other researchers claim not have found any proof of it [16–18,41].

Regarding Rassekh [15], the methodology adopted by the author is quite different from the other researchers. Rassekh [15] based his work on the Frankel and Romer [25] paper, which analyzed the impact of international trade on the income of a group of countries. The researchers proved that international trade impacts positively, though weakly, on the country's income.

As can be seen, despite the efforts of researchers, the relationship between international trade and income inequality is still inconclusive.

This paper aims to contribute to the discussion on the HOS theory by investigating the impact of international trade and the export of sugarcane products on income.

As exposed at the beginning of this chapter, sugarcane has a major impact on Brazil's and Goiás' economies. Therefore, analyzing the relationship between international trade and income for the export of a specific product, i.e., sugarcane is critical to understand the economy of this particular sector. Moreover, isolating the effect of the export of sugarcane on income will make it possible to analyze if the HOS theory is being held, once it becomes possible to verify the impact of a product that is mainly produced in developing countries on income. According to FAOSTATS [42], in 2019, the leading sugarcane producers were: 1 Brazil, 2 India, 3 Thailand, 4 China, 5 Mainland China, 6 Pakistan, 7 Mexico, 8 Colombia, 9 Australia, and 10 Indonesia, of which Brazil alone accounted for more than a third of the world's sugarcane production; Brazil and India represented more than half of the world's production, and the top eight producers accounted for more than 80% of the world's production.

3. Data and Methodology

3.1. Methodology

The methodology adopted by this research is based on the work performed by Frankel and Romer [25]. In their work, the authors analyzed how international trade impacted on

the GDP per capita of a group of countries. As stated in the former section, Frankel and Romer [25] concluded that international trade exerts a positive, though weak, impact on the GDP per capita.

Besides the two variables stated above, Frankel and Romer [25] used two control variables in their study: country area and economically active population. Therefore, in order to perform this research, the four information variables were collected. Hence, following Frankel and Romer [25] but aiming to analyze the role of the export of sugarcane products on income, this work presents two explanatory variables, international trade, and sugarcane product export. Therefore, the model will contain the dependent variable, the income, and two explanatory variables and two control variables, economically active population and municipality area. In order to perform this research, the five information variables were collected for all the municipalities that presented international trade activity in the studied period.

Considering the high mechanization level of the agriculture of the state of Goiás, as reported in Section 1, one could claim that it would be appropriate to include a variable concerning the income of capital. However, two points must be considered: (1) These data are not available at a municipal level; hence, this paper would be forced to abandon its objective of a disaggregated analysis. (2) Neither Frankel and Romer [25] nor Rassekh [15] utilized such a variable in their studies, which proves that such a procedure is not necessary. Moreover, Acemoglu [43] demonstrated that technical change and its adoption by the companies has been on course since the 19th century. Therefore, if that were the case, all the economic analyses involving income and labor should have implemented such a variable in their models, and that has not been the case.

Finally, concerning the control variables, i.e., the geographical information of the localities, even though some researchers, such as Rodriguez and Rodrik [44], questioned the suitability of these variables as control ones, the experiments of Frankel and Rose [45], Rassekh [15], and Kim [29] proved the appropriateness of utilizing geographical characteristics as control variables when analyzing the impact of trade on income.

Due to the data availability restriction, the period analyzed was from 2009 to 2018. During this period, 98 out of the 246 municipalities in the state of Goiás presented international trade activity. The list with the municipalities analyzed in this work can be found in Appendix B, Table A1.

A critical difference related to the Frankel and Romer [25] work is that they performed a cross-section analysis, while this research developed a panel data analysis. A panel data analysis offers more precise results about the studied subject. Moreover, according to Gujarati and Porter [46], among the advantages presented by this method, one can cite the fact that it presents a lower degree of collinearity among the variables, allowing a better study of the changes presented in the period and a reduction of bias in the analysis.

Another difference is that although Frankel and Romer [25] used logarithm variable transformation in their analyses, this research adopted the first difference model in order to fix multicollinearity and unit root problems that were found in the control tests. The unit root test was performed using the augmented Dickey–Fuller test, controlling for drift and trend where it was necessary. Guarati and Porter [46] asserted that there was no reason to believe that the problem of multicollinearity can persist once the model is transformed to first difference. Moreover, this transformation of the model to the first differences presents the advantage of correcting unit root problems, which was also detected in the control tests of this work, as already exposed.

Finally, in the autocorrelation test, the Wooldridge test was used, with the model already transformed for the first differences. The test did not refute the HOS hypothesis.

The model of first differences, as well as the fixed effects model, considers that variables that cannot be measured or that do not vary over time are correlated with other explanatory variables [47]. The adoption of this model also helped ensure that the regression was not biased, according to Liker, Augustyniak, and Duncan [48], in addition to correcting unit root problems, according to Wooldridge [47].

Besides, the first difference approach presents the advantage of avoiding excluding any variable or combining time-series and cross-sectional data, which despite solving the problems, could also interfere with the outcomes of the research [46].

Finally, this work performed only one type of analysis using the Ordinary Least Squares (OLS) method, unlike Frankel and Romer [25], who carried out two analyses in their research, one using the OLS method and the other using an instrumental variable constructed from country data.

Once this study analyzed the impact of international trade and the export of sugarcane products on the income of the municipalities of Goiás (and not the countries), the construction of the instrumental variable became impracticable, considering the way Frankel and Romer [25] constructed theirs. Moreover, Frankel and Romer [25] stated that no evidence was found that the OLS method overestimated the results of research involving international trade.

3.2. Data on Trade Description

Unlike Frankel and Romer [25], who used the GDP per capita in their research, this work utilized the workers' average income as the dependent variable. Even though some authors, such as Figini and Görg [49] and Alili and Adnett [50], asserted the feasibility of the GDP per capita to measure income, as Todaro and Smith [51] explained, this index is susceptible to variation due to noneconomic factors, such as the increase or decrease of the population, for example.

Average income adoption allows for a more disaggregated analysis once it concentrates on the workers' yield. Furthermore, the adoption of the average income offers one more advantage. Contrary to the GDP per capita, which cannot control the informal sector, the average income refers only to the formal sector income.

The Mauro Borges Institute [52] provided the average income data for each municipality in Goiás. The data provided by the Mauro Borges Institute [52] concerned the mean regular income of workers. Therefore, the data utilized do not present any interference with other kind of income, such as capital, for example. Regarding the explanatory variables, data were collected by the Ministry of Economics [53].

Considering the export of sugarcane products, according to the Ministry of Economics [53], four products derived from sugarcane were exported in the period analyzed by this work: sugar from sugarcane, molasses resulting from the extraction or refining of sugar, undenatured ethyl alcohol with an alcohol content equal to or higher than 80%, and undenatured ethyl alcohol with an alcohol content below 80%.

The sugarcane export indicator was calculated by adding together all the sugarcane product exports of each municipality and dividing them by the respective municipality GDP, for each year.

International trade represents the degree of trade openness of each municipality. The indicator is calculated by adding the value of exports and imports and dividing the sum by each municipality's GDP.

As exposed in Section 2, according to the HOS theory, the export performed by developed countries which contain many skilled people should report an increase in the income of this type of input. Conversely, developing countries, rich in unskilled people, should export products that need this kind of unskilled work to increase their income.

Nevertheless, as also stated in Section 2, the sugarcane industry in Goiás has been incorporating new technologies in its production, which has led to an increase in the demand for skilled workers, who command a higher income. Therefore, following the HOS theory, international trade is expected to impact the average income positively.

Regarding the control variables, the economically active population (EAP) constitutes people aged 16 and older. This definition is provided by the IBGE [54], and the data of this variable were collected by the Mauro Borges Institute [55]. A positive relationship between this variable and the dependent variable is expected once the amount of economically active people impacts the country's production and the amount of trade.

According to Frankel and Romer [25], the municipality's area allows one to understand the country's internal trade. The authors state that an increase in the region's area indicates a possible increase in natural resources held by the region. Thus, a positive relationship is expected between the area and the average income.

3.2.1. Descriptive Analyses

Table 1 presents the descriptive statistics of the variables used in the regression. For the monetary index Exchange Rate of 30 December 2009, provided by IPEA was used to convert the values from BRL to USD.

Variable	Unit	Observations	Mean	Standard Deviation	Min	Max
Average Income	USD	980	886.31	319.90	375.50	3149.30
International Trade	Decimal	979	0.0893237	0.3217254	0	4.53525
EAP	Number	882	40,673	119,620	2110	1,175,556
Municipality's Area	Km ²	980	1823.153	1901.06	60.95	9843.25
Sugarcane Export	Decimal	980	0.006692	0.0350749	0	0.4458368

Table 1. Descriptive Statistics.

Table 1 shows that the average income of the Goiás municipalities is meager. Even though the maximum value can reach USD 3149.30, the average is below USD 900.00, indicating that Goiás workers are expected to earn salaries closer to the minimum value.

Regarding the control variables, the size of the cities can vary by a large amount. On the one hand, there are cities with an economically active population (EAP) of more than 1,000,000, and, on the other hand, there are cities that barely surpass an EAP of 2000.

The same analyses can be extended to the municipality's area data, which indicate that some cities may reach almost twice the size of the smallest ones.

Concerning the explanatory variables, when it comes to international trade, the municipalities of Goiás do not possess a great deal of foreign interaction. Although the most significant value presented is above four points, indicating that international trade may represent more than 400% of the total GDP, the mean value is only 0.08 points, i.e., 8% of the GDP.

When it comes to the number of sugarcane products exported, the situation is even worst once the mean value is 0.006, representing a total amount of less than 1% of the GDP of the municipality.

3.2.2. Econometric Specification

Considering what was formerly exposed, and following the work of Frankel and Romer [25], this research will use the following model:

$$d.AI = \beta 0 + \beta 1 d.IT + \beta 2 d. EAP + \beta 3 d.Area + \beta 4 d.SE + Y ano + \mu$$
(1)

Most of the variables presented in equation 1 have already been presented before: AI is average income; IT refers to international trade; EAP is the economically active population; area refers to the municipality's area, and SE indicates sugarcane exports. As explained before, due to the unit root and multicollinearity problems, all variables were transformed to their first difference form. Y refer to the year's control in the model so that the passage of time does not cause interference with the results, and μ is the error term of the equation.

As the first differences model was adopted, the Hausman test was not performed. The first differences model, such as the fixed effects, considers that variables that cannot be measured or that do not vary over time are correlated with the other explanatory variables [47].

4. Results and Discussion

The results of the regressions performed are presented in Table 2.

Variable	Average Income	
International Trade	0.624 ***	
	(0.199)	
Sugarcane Exports	-40.30	
	(518.9)	
EAP	0.00506 ***	
	(0.00170)	
Area	0.850	
	(1.001)	
Observation	784	
R ²	0.247	

Table 2. Effects of Sugarcane Exports on Average Income.

Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1.

Table 2 indicates that international trade presented a significant result, together with EAP, both at a 99% confidence level (The data used for this research were analyzed with Stata v17 software. When reporting the results of the analysis, this software indicated the significance level based on the *p*-value. The *p*-value is also known as the probability value or even the exact significance level. According to [46], the *p*-value indicates the lowest level of significance at which a null hypothesis can be rejected. The authors asserted that although commonly accepted values for the *p*-value are 1%, 5%, and 10%, it should be left to the reader to decide whether or not to reject the null hypothesis. Stata uses the null hypothesis so that there is no relationship between the variables and presents three possibilities for the *p*-value, 1%, 5%, and 10%, as can be seen in the legend of Table 2. This work presented its conclusions on the parameters established by the software used.).

Concerning the international trade variable, the result presented in Table 2 confirms the work of Frankel and Romer [25].

The primary explanatory variable of this model (Sugarcane Exports) did not present a significant result for the analyzed group. Therefore, it is impossible to assert that the results presented in Table 2 lead to the income convergence effect, once the variable that refers to a product produced mainly by developing countries was not significant on workers' income. Consequently, the results presented so far are not in line with the outcomes presented by Jayanthakumaran and Verma [11], Ben-David [12], Ben-David and Kimhi [13], Cyrus [14], and Rassekh [15], who claimed that international trade leads to income convergence.

The sugarcane variable results make it impossible to confirm the main hypothesis (exported sugarcane products increase workers' income and help produce the income convergence effect). Therefore, it cannot be said that the export of sugarcane products contributes to achieving the SDGs numbers 8 and 10 or stimulating SDG number 7.

We hypothesized that the lack of significant results for the sugarcane exports variable was due to the low values presented by the municipalities of Goiás when it comes to the export of sugarcane products. The average presented for this variable in Table 1 was lower than 1%, indicating that even though the maximum value is close to 44%, most of the computed values are near the minimum registered of 0%.

Concerning the two control variables suggested by Frankel and Romer [25], as it was stated above, only the EAP variable presented a significant result, indicating that the higher the amount of people available to work, the higher the average income of the municipalities, even if the impact is relatively low.

4.1. Robustness Check

In order to confirm and verify the results presented in the former section in a more detailed way, the analysis was repeated using the average income disaggregated by sector as the dependent variable. Data were collected for the following sectors of the economy: industrial, commerce, services, and agriculture. Those data are available from the Mauro Borges Institute [52], which obtained them from the Annual Social Information Report

(RAIS), according to their website. RAIS is an administrative record published annually by the Labor Ministry of Brazil.

The control tests were repeated in this second stage of the research, and as in the first regression model, it utilized the first differences model, in order to correct for multi-collinearity and unit root problems. The result of this regression is shown in Table 3.

	(1)	(2)	(3)	(4)
Variable	Industrial Income	Commerce Income	Service Income	Agrobusiness Income
International Trade	1.925 ***	0.0724	-0.819	0.0265
	(0.396)	(0.110)	(0.617)	(0.313)
Sugarcane Exports	265.5	3.370	150.7	-95.81
о́ ,	(860.8)	(161.5)	(760.9)	(328.4)
EAP	0.00366 *	0.00222 ***	0.00400 **	-0.000845
	(0.00221)	(0.000803)	(0.00192)	(0.00482)
Area	2.522	2.283 *	1.845	-0.576
	(1.896)	(1.382)	(2.088)	(1.152)
Observation	745	784	784	784
R ²	0.097	0.391	0.168	0.408

Table 3. Effects of Sugarcane Exports on Disaggregated Average Income.

Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * and p < 0.1.

When disaggregating the values of income by the different sectors of the economy, only the industrial sector presented significant results for the explanatory variables. The results presented in Table 3 confirm the results shown in Table 2 and indicate which sector of the economy is beneficiated by international trade.

The results exposed in column 1 of Table 3 confirm the one presented in Table 2, the one indicated by Frankel and Romer [25], and indicate in what economic sector the impact of international trade occurs.

Concerning the studies conducted in Brazil, if we consider that the industrial area is mainly situated in urban regions, this result is not in line with Castilho Menendez and Sztulman [37], who reported that trade opening increases poverty in the urban area.

Regarding the sugarcane export variable, the results exhibited in Table 2 were confirmed by Table 3 once no significant results were encountered, reassuring that the main hypothesis of this work is not confirmed, nor its positive impact on the SDGs targets.

As in the previous section, it is believed that the lack of significance is caused by the small quantity of sugarcane product export. Therefore, when it comes to the income convergence effect over this section of the economy, as stated in the previous section, it cannot be argued that the outcomes presented so far confirm the work conducted by Jayanthakumaran and Verma [11], Ben-David [12], Ben-David and Kimhi [13], Cyrus [14], and Rassekh [15], who reported that international trade promoted income convergence.

Finally, taking into consideration that Castilho, Menendez, and Sztulman [37] stated that export activity reduced poverty in Brazil, the results presented by the export variable (Sugarcane Export) do not fit with what was reported by the authors once this variable did not present significant values in Tables 2 and 3. It is hypothesized that this difference in the results may be because the effect captured by Castilho, Menendez, and Sztulman [37] referred to the export of other products, alongside the export of sugarcane products, which would confer an aggregated impact on the dependent variable.

4.2. Time Lag Analyses

In order to verify whether the export of sugarcane products presented a significant impact on income over time, the tests performed in the previous sections were repeated, using, however, the variables international trade and sugarcane export with a one-year time lag. Thus, we sought to analyze if the municipality's trade interaction, mainly the export of sugarcane products, impacted on income in the long run.

(1)(2)(3)(4)(5) Variable Average Income **Industrial Income Commerce** Income Service Income Agrobusiness Income -1.563 ** International TradeL1 -0.316 0.159 -0.846-0.0995 (0.336)(0.614)(0.277)(0.574)(0.255)Sugarcane ExportsL1 772.1 ** 600.3 232.6 -318.144.87 (357.9) (761.1)(144.7)(467.4)(224.9)0.00499 *** EAP 0.00363 0.00220 *** 0.00403 ** -0.000855(0.00170)(0.00222)(0.000803)(0.00191)(0.00482)0.8462.515 2.282 * 1.844-0.575Area (0.995)(1.902)(1.376)(2.093)(1.152)Observation 784 745 784 784 784 R² 0.250 0.097 0.392 0.168 0.408

one-year lag analysis are exposed below in Table 4.

 Table 4. Effects of Sugarcane Exports on Average Income—One-Year Time Lag Analyses.

The time lag analysis was also performed by Pavcnik et al. [8]. The results for the

Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1.

Table 4 presents the regression results with the average income as a dependent variable in column 1 and the other disaggregated incomes, just as was done in Table 3 in the other columns.

Column 1 of Table 4 shows a significant result: the sugarcane export variable's positive and significant impact on the average income. Despite having presented no significant results in Table 2, based on what is displayed in Table 4, the export of sugarcane products improves the workers' income in the long run, confirming the paper's hypothesis and indicating that the export of sugarcane products may be used to fulfill SDGs numbers 7, 8, and 10 if the long term is considered in the analysis.

Nevertheless, one crucial aspect must be analyzed. Table 4 presents a substantial value (772.1), indicating that the increase of one point on the sugarcane export would boost the average income by more than 700 points. Considering the small R squared value and the fact that this variable did not present any other significant value in the other columns, it is conceivable to admit that the export of sugarcane products does not possess this amount of influence on the average income. Nonetheless, considering that the result was presented with 95% confidence, it is likely that this variable impacts average income over the long term, but not with this intensity. As extensively exposed in the previous pages, the municipalities of Goiás do not possess great sugarcane export activity, which may have influenced the results presented in Table 4 and the previous ones.

Nonetheless, based on the results presented in the first column, the result for the international trade variable was not significant, indicating that the positive impact presented in Table 2 does not continue over time.

Another significant value is exposed in column 2. Table 4 results indicate that international trade negatively impacts industrial income over the long term with 5% significance. This outcome indicates that the positive effect presented in Table 3 is almost lost in the long run.

5. Conclusions

The impact of international trade has been the subject of economic analysis for a long time. Before Adam Smith, its influence on economic growth and income was already studied, and after Hecksher–Ohlin/Stolper–Samuelson, the relationship between international trade and wage inequality became part of the research field.

The research developed in this paper aimed to contribute to the subject, researching how the export of sugarcane impacted the average income of a group of municipalities of Goiás and verify if it contributes to the reduction of income inequality between developed and developing countries. The presumption that guided this research was that sugarcane is a developing country product, and, consequently, the export of its products can promote the increase of their workers' average income, leading to the income convergence effect between developing and developed countries.

The results indicate that although international trade improved the average income of the state of Goiás workers, it cannot be said that there is an income convergence effect promoted by the export of sugarcane products. The robustness check with disaggregated average income as a dependent variable showed that this improvement on income promoted by international trade is concentrated on the industrial sector only.

In order to verify how the impact of the explanatory variables behaved over time, a time lag regression with one-year lag was performed.

The one-year time lag regression demonstrated that after the positive effect registered initially, international trade diminished the industrial income in the long run. Nonetheless, based on the one-year time lag regression, it was possible to observe that the export of sugarcane products improved the average income of the municipalities of the state of Goiás, leading to the income convergence effect. However, the size of this impact must become the subject of further investigations to reach a better comprehension of this relationship.

Two points deserve attention. The first one refers to the almost inexistent impact of the export of sugarcane products on average income (aggregated or disaggregated) of the municipalities of Goiás. Despite the increase in the amount of export of these products over the years, the total financial value is still low. According to the Ministry of Economics [56], in 2020, the export of sugarcane products ranked eighth place on products exported by the state of Goiás, with USD 339 million. The main products exported by the state of Goiás in that year were: 1 soy, 2 meat of bovine animals, 3 iron ores, 4 copper ores, 5 corn, 6 bran (soy, meat, etc.) for animal food, 7 poultry meat, 8 sugarcane sugar. 9 gold, and 10 other industrial products. That year, the total export value performed by the state of Goiás reached almost USD 8 billion.

Moreover, this result should not come as completely unexpected. If it is considered that international trade itself has a low impact on income [15,25,57], it is reasonable to expect that the impact analysis of one product on income presented a smaller impact. Nevertheless, as stated in the above paragraph, the still low amount of export of this product by the state of Goiás must have contributed to the result. Therefore, more analyses are suggested, either in the future, or with other localities, such as the state of São Paulo, which possesses a higher amount of export of this product.

The second point is related to the one just analyzed: the international trade activity. Even though the total financial volume of imported products is less than half of the total export amount, its composition is made of products destined to the industry. According to the Ministry of Economics [56], in 2020, the total of imports performed by the state of Goiás reached USD 3.3 billion, while the total of export totaled USD 7.9 billion. Therefore, it is possible that the results displayed in this paper capture two distinct movements. First, the export performed by the municipalities increases the income of its workers in the current year. However, in the following years, the import of products decreases the average income. If this hypothesis is confirmed, it would mean that the import of products realized by the municipalities is substituting workers in the industrial, commercial, and agribusiness sectors.

Another possibility is that considering the products exported by the municipalities (mainly agricultural or originated from extractive activity), their value is low and temporary. Thus, their impact over time is barely existent or negative. This result would indicate that the government should rethink the characteristics of the products directed to foreign markets in order to obtain social–economic benefits from them.

As formerly discussed, the number of municipalities engaging in international trade is below the mean of the total number of cities in Goiás. In addition, the total value of international trade, mainly when it comes to exporting sugarcane products, is still low. These two factors may have influenced the results obtained in this investigation. As a suggestion for further research, it would be relevant to analyze a larger group of municipalities or a more extended period to confirm the outcomes presented in this study. Author Contributions: Conceptualization, R.L.M. and T.V.d.C.; methodology, R.L.M. and T.V.d.C.; software, T.V.d.C.; validation, R.L.M. and T.V.d.C.; formal analysis, R.L.M. and T.V.d.C.; investigation, R.L.M. and T.V.d.C.; resources, R.L.M.; data curation, T.V.d.C.; writing—original draft preparation, R.L.M. and T.V.d.C.; writing—review and editing, R.L.M. and T.V.d.C.; supervision, R.L.M.; project administration, R.L.M.; funding acquisition, R.L.M. All authors have read and agreed to the published version of the manuscript.

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Appendix A

microeconomic level.



Figure A1. Map of Brazil with Goiás. Source: 123RF.

Appendix **B**

Table A1. Municipalities of Goiás analyzed.

ABADIA DE GOIAS	CASTELÂNDIA	ITAPURANGA	POSSE
ABADIANIA	CATALÃO	ITARUMÃ	QUIRINÓPOLIS
ACREUNA	CEZARINA	JARAGUÁ	RIO VERDE
ÁGUA FRIA DE GOIAS	CHAPADÃO DO CEU	JATAÍ	RUBIATABA
ÁGUAS LINDAS DE GOIAS	CIDADE OCIDENTAL	LUZIÂNIA	SANCLERLÂNDIA
ALEXANIA	CORUMBAÍBA	MARA ROSA	SANTA BÁRBARA DE GOIÁS
ALTO HORIZONTE	CRISTALINA	MINAÇU	SANTA HELENA DE GOIÁS
ALTO PARAISO DE GOIAS	CRIXÁS	MINEIROS	SANTA RITA DO NOVO DESTINO
AMERICANO DO BRASIL	EDÉIA	MONTIVIDIU	SANTA TEREZINHA DE GOIÁS
ANAPOLIS	FAINA	MONTIVIDIU DO NORTE	SANTO ANTONIO DE GOIÁS
ANICUNS	FORMOSA	MORRINHOS	SÃO DOMINGOS
APARECIDA DE GOIANIA	GOIANÉSIA	MOZARLÂNDIA	SÃO LUÍS DE MONTES BELOS
ARUANÃ	GOIANIA	NAZÁRIO	SÃO LUIZ DO NORTE
BARRO ALTO	GOIANIRA	NERÓPOLIS	SÃO SIMÃO
BELA VISTA DE GOIAS	GOIÁS	NIQUELÂNDIA	SENADOR CANEDO
BOM JESUS DE GOIAS	GOIATUBA	NOVA ROMA	SILVÂNIA
BONFINOPOLIS	GOUVELANDIA	ORIZONA	TAQUARAL DE GOIÁS
BRAZABRANTES	GUARANI DE GOIAS	OUVIDOR	TEREZÓPOLIS DE GOIÁS
BRITANIA	HIDROLANDIA	PALMEIRAS DE GOIÁS	TRINDADE
CACHOEIRA ALTA	INHUMAS	PILAR DE GOIÁS	URUAÇU
CAÇU	IPAMERI	PIRENÓPOLIS	VALPARAÍSO DE GOIÁS
CALDAS NOVAS	IPORÁ	PIRES DO RIO	VICENTINÓPOLIS
CAMPO ALEGRE DE GOIAS	ITABERAÍ	PLANALTINA	VILA BOA
CAMPOS VERDES	ITAGUARU	PONTALINA	
CARMO DO RIO VERDE	ITAPIRAPUÃ	PORANGATU	

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