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The Impact of Sugarcane By-Product Exports on Income Inequality: How Sustainable Is This Relationship?

Thiago Vizine Da Cruz * and Ricardo Luiz Machado

Engineering Department, Pontifical Catholic University of Goiás, Av. Universitária 1440, Goiania 74175-120, Goiás, Brazil

* Correspondence: thiagovizine@yahoo.com.br

Abstract: The reduction in income inequality and its convergence between localities is one of the aims of the United Nations Sustainable Development Goals. This work aims to contribute to the theme, researching the relationship among international trade, the export of sugarcane by-products, and income inequality. A panel data regression was performed for a group of 98 cities from the state of Goiás-Brazil. Results indicate that international trade has a minimal, though positive effect, reducing income inequality. Nevertheless, the export of sugarcane by-product results indicates a harmful effect on workers' income in the poorest cities who work in the agricultural sector. The results indicate that international trade contributes to sustainable development by generating wealth, contributing to UN SDG number 1, and reducing income inequality, helping to achieve UN SDG number 10.

Keywords: income inequality; international trade; sugarcane; sustainable development goals

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1. Introduction

Despite having its main focus on the relationship between international trade and income inequality among the population of the same place, some researchers started to study the Heckscher–Ohlin and Stolper-Samuelson's theory on how international trade contributed to the promotion of the equalization of prices of production factors among countries. This analysis, also known as income convergence, seeks to verify if international trade has brought the income of countries to a common denominator.

Although the UN [1] definition of inequality shows that there will always be some disparity, Dabla-Norris et al. [2] argue that high rates of income inequality have a high social cost. Stiglitz [3] argue that high levels of income inequality harm economies' efficiency. Attending to these issues, the United Nations has set one of the Sustainable Development Goals (SDGs), the Reduction of Inequalities Within and Between Countries by 2030—Goal No. 10 UN [1].

Brazil is the largest producer of sugarcane in the world. According to FAOSTATS [4], in 2023/2022, the sugarcane-harvested area surpassed 9,870,590.00 (ha). Goiás is one of the 26 Brazilian states and the second largest sugarcane producer in Brazil, with a harvest area of 1,129,552.00 (ha) for the 2023/2022 harvest and a yield of 74.24 according to UNICA [5].

This research proposes to contribute to the theme of international trade and income convergence, analyzing sugarcane products' export impact over income inequality, based on an analysis with data disaggregated by municipalities. The main objective of this work was to verify whether international trade and, more specifically, the export of sugarcane by-products impacted more prominently the income of the richest or the poorest municipalities. The hypothesis of this work defends that the poorest, or developing, municipalities are the biggest beneficiaries of international trade, which would constitute an income convergence effect. If this hypothesis is confirmed, the importance of the promotion of this culture by governments and the stimulus to its export will be evident, since it will indicate that the cultivation of sugarcane not only generates income for the state of Goiás and their municipalities but also helps to reduce income inequality.

In order to perform the proposed analysis, data were collected from all municipalities in the state of Goiás that presented international trade activity between the years 2009 and 2018. The time horizon adopted was due to limitations in data availability.

After data collection, a panel data analysis was performed. This form of analysis provides the use of multiple observations of each individual overtime for HSIAO [6]. The use of regression with panel data presents some advantages for the data analysis, for example greater efficiency; a greater amount of information allows for a better study of the changes that occur over the period, as indicated by Gujarati and Porter [7].

The methodology used to analyze the data follows Rassekh [8]. The approach adopted by Rassekh [8] is based on the work developed by Frankel and Romer [9] and corrects endogeneity problems and measures the participation of localities in international trade. After Rassekh [8], other authors, such as Kim and Lin [10], Kim [11], and Zhang and Zhu [12], have also used this methodology, proving that this methodology is still effective, despite being almost 20 years old.

Finally, considering that the sugarcane sector outcomes has presented several variations, as Sulle and Dancer [13] states, this study contribute to the socio-economic research field by presenting the relationship and the impact of the sugarcane by-product exports on income inequality, which may help to develop new public policies and political economy actions aiming to improve worker wealth. The use of a panel data and the different regressions performed provide a better understanding of the impact of sugarcane by-product exports on the average income, including its impact on each sector of the economy, making it possible to develop different public policies, according to the sector needs.

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 found, and Section 5 presents the conclusions.

2. Theoretical Background

2.1. Income Inequality

According to the United Nations (UN), inequality means "[the] state of not being equal, especially in status, law and opportunity", UN [1]. Regarding economic inequality, the distinctions that occur are related to income, the financial situation, or living conditions, UN [1].

Concerning income inequality, Piketty [14] explains it is composed of two types of inequality, the one from income from work and from capital. Still according to Piketty [14], income from work, that is derived from labor income, accounts for a large part of the national income (between 2/3 and 3/4). However, although smaller in size, the income inequality of capital is greater than that of labor, since capital is more concentrated in the wealthier classes.

Although some degree of income inequality may be beneficial, as it encourages people to seek ways to progress, high rates of income inequality have a high social cost, according to Dabla-Norris et al. [2]. Moreover, it can undermine the efficiency, stability, and sustainability of economies and once may generate civil conflicts, high levels of crime, and social instability, which harm society [3].

Garrett and Rausch [15] argue that one of the conditions to promote sustainable development is to create broadly distributed income. Aguilar-Rivera [16] states that the sugarcane industry has the possibility to help to achieve several United Nations Sustainable Development Goals (SDGs), such as SDG number 1 (No Poverty), UN [1], by generating biomass, and other sugarcane by-products that could be commercialized; SDG number 2 (Zero Hunger), UN [1], by using the sugarcane biomass by-products to restore degraded soils and produce food; and finally, the one that is related to this research, SDG number 10 (Reduced Inequality), UN [1], by generating wealth through the generation and commercialization, within the country and between countries, of sugarcane by-products.

2.2. International Trade and Inequality

The Heckscher–Ohlin/Stolper–Samuelson theorem (HOS) was the first theoretical attempt to explain the direct relationship between free trade and income distribution [17].

Considering a simple model with two variables (capital and labor), an environment of perfect competition, and with perfect mobility of capital and labor, the Heckscher–Ohlin theory predicts that countries should specialize in producing and exporting products that use the input (capital or labor) that is relatively abundant in that country [18,19].

Stolper and Samuelson [20] demonstrated that employing the existing resource in greater abundance and exporting the products resulting from it would raise the yield of factors employed. In the case of developing countries, the immediate consequence would be a reduction in inequality once they are unskilled-labor-abundant. Sachs and Shatz [21] draw attention to the emphasis given by the HOS theory between the prices of final products and the income of workers.

While some authors have claimed to have found evidence of the HOS theory for developed countries, such as Klein, Moser, and Urban [22], and Borrs and Knauth [23], Egger, Egger, and Kreickemeier [24], others have rejected it [25].

Some researchers, however, claim that the arguments supporting a positive relationship between international trade and income inequality are circumstantial evidence [21].

Regarding developing countries, Zhu and Trefler [26]; Lin and Fu [27]; Green, Dickerson, and Arbache [28]; and Castilho, Menendez, and Stulman [29] argue that effects contrary to those predicted by the HOS theory have been observed by researchers. Attanasio, Goldberg, and Pavcnik [18]; Robbins and Gindling [30]; Han, Liu, and Zhang [31]; Murakami [32]; Martorano and Sanfilippo [33]; Arbache, Green, and Dickerson [17]; and Pavcnik et al. [34] demonstrated that the HOS theory does not apply for Colombia, Costa Rica, China, Chile, East Asian countries and developing countries, and Brazil, respectively.

Lin and Fu [27] demonstrate that international trade increases income inequality in democratic countries but reduces it in autocratic countries, confirming the HOS theory only for the second group of countries.

Regarding the sugarcane–international trade relationship, research is scarce, a fact that comes as surprise, considering that the sugarcane crop ranked second in total production in the 2020/2021 period in the world, according to [35]. Batidzirai and Johnson [36] state that the sugarcane by-product international trade presents a great opportunity to the African countries, once South Africa can increase its sugarcane production and fulfill developed countries renewable energy needs. Nevertheless, the social impact of sugarcane international trade is uncertain. Machado and DA CRUZ [37] present a study indicating that sugarcane by-product export does not exert a positive effect on the average income of the Goiás state (Brazil). Quin [38], in turn, asserts that China's liberalization police and consequently access to international markets have positively impacted sugar prices but have a negative impact on farmer costs and profit in Guangxi Province.

2.3. Income Convergence

Another form of inequality measurements, also associated with the HOS theory, is the impact of international trade on income inequality between developed and developing countries, the so-called convergence of income.

According to Ben-David [39], the convergence of income was found in the HOS theory, which stated that international trade would lead commodity prices to equalize. Jayanthakumaran and Verma [40], Grossman and Helpman [41], and Cyrus [42] confirm the Ben-David [39] theory. In fact, Cyrus [42] argues that international trade would help achieve the convergence point described by Solow [43], i.e., it would produce income convergence.

Ben-David [39] analyzed several groups of countries and draws attention to the fact that the phenomenon of income convergence is not a worldwide achievement but is concentrated in those countries that transact strongly among themselves.

Following up on Ben-David's [39] work, other authors, such as Rassekh [8], Jayanthakumaran and Verma [40], Cyrus [42], and Ben-David and Kimhi [44], confirmed the income-convergence effect.

Despite the studies indicating a positive relationship between international trade and income convergence between countries, some claim to not have found results that confirm this relationship in their analyses or that more research should be done on the subject, like [45]. Harrison [46], Lee [47], and Lohani [48], who argue that the existence of a convergence-income effect depends on the existence of determinant factors.

3. Data and Methodology

3.1. Methodology

The methodology adopted by this work is based on Rassekh's [8] research, who based the methodology of his research on the work of Frankel and Romer [9]. According to the author, the adoption of the methodology proposed by Frankel and Romer [9] presents two main advantages, namely it allows the endogeneity problem existing in the relationship between international trade and income growth to be solved and uses the participation of international trade in the GDP of countries instead of trade openness variables, which permits a more accurate assessment of the impact of this sector of the economy on income inequality.

Following Rassekh [8], the set of municipalities in the state of Goiás that presented international trade activity during the studied period was divided into two groups, according to their respective GDP per capita, constituting a group of wealthier municipalities, which was classified as "Developed" and a second group, containing poorer municipalities, which were classified as "Developing".

The parameter used to classify the municipalities in these two groups was the GDP per capita of the state of Goiás in 2009, the year the analysis of this work began. The GDP per capita of Goiás in 2009 was US$ 6578.55 [45]. The cities whose GDP per capita in 2009 was higher than the average of all municipalities was classified as "Developed", while those whose GDP per capita was lower than the 2009 average were grouped in the "Developing" category. The list with the sugarcane exporting municipalities' names in the analyzed period, classified according to their respective GDP per capita, is in Appendix A.

The period analyzed in this research comprises 2009–2018. The choice of this time window was due to data availability limitations. The choice of variables to be analyzed and used as explanatory or control variables was based on Rassekh's [8] research, with the difference that the variable referring to products derived from the sugarcane export share was added, which also acts as an explanatory variable, alongside trade openness.

Another relevant difference about Rassekh's [8] work is that the author performed a cross-section analysis, while this developed a panel data analysis. According to Gujarati and Porter [7], among the advantages presented using this method, one can cite the fact that it presents a lower degree of collinearity among the variables, allowing for a better study of the changes presented in the period and a reduction of bias in the analysis.

Finally, this work carried out only one type of analysis, using the Ordinary Least Squares (OLS) method, unlike Rassekh [8], who, like Frankel and Romer [9], carried out two analyses in his research, one using the method (OLS) and the other using an instrumental variable constructed from country data. Considering that this study analyzed the municipalities of Goiás and not the countries, the construction of the instrumental variable becomes unfeasible since some information, such as the existence of borders between municipalities, becomes irrelevant, making it impossible to construct the instrumental variable. Furthermore, Frankel and Romer [9] claim to have found no evidence that the MQO method overestimates the results of research involving international trade, which proves the effectiveness of this methodology.

3.2. Data

The GDP per capita of each municipality was used to measure income inequality. Rassekh [8], based on the work of Frankel and Romer [9], used this variable in his studies. In addition, other authors have discussed the effectiveness of this variable on other occasions, such as [27,49]. GDP per capita data were collected in [50].

This work will have two explanatory variables: the export of sugarcane products and the trade openness of each municipality. Brazil's foreign trade data are made available by [51].

According to the Comex Stat [51], four products derived from sugarcane were exported in the period analyzed in 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 product total exports of each municipality in Goiás were added and divided by the GDP of the respective municipality. This procedure was adopted for all the years throughout the period studied.

Trade Openness represents the degree of trade openness of each municipality. The indicator is calculated by adding export and import values and dividing the sum by the GDP of each municipality.

Following what was exposed in Section 2, international trade and the export of sugarcane products are expected to be negatively correlated with income inequality among the municipalities. Appendix B presents a scatter plot with sugarcane exports and GDP per capita. It is possible to see that the wealthiest cities do not export sugarcane by-products.

Following Rassekh [8], the Economically Active Population (EAP) and municipality area were used as control variables. The EAP is made up of people aged 16 and older, who can work. This definition follows that provided by the IBGE [52]. The amount of economically active people impacts the country's production and the amount of trade, as per Frankel and Romer [9]. Thus, a positive relationship between this variable and the dependent one is expected.

Finally, Frankel and Romer [9] argue that the municipality area indicates a possible increase in natural resources held by the country (in the case of this work, the municipality). Thus, a positive relationship is expected between the area and the GDP per capita of the municipality.

3.2.1. Descriptive Statistics

Table 1 below presents the descriptive statistics. The information is divided into two groups: developed and developing municipalities.

Table 1 shows significant variations between the two groups of municipalities. Regarding GDP per capita, we note that municipalities classified as "Developed" are at least two times richer than those classified as "Developing" since the average value of the GDP per capita for the former group is more than twice as high as that for the latter.

Regarding the explanatory variables, while the Developed group of municipalities presents an average value for Trade Openness of 14.58% of the municipal GDP, the second group has an average value of only 3.94%. Therefore, it is to be expected that the impact of the Trade Openness variable is lower in municipalities classified as "Developing".

The same analysis can be extended to the Sugarcane Export variable. The group of "Developed" municipalities presents an average of sugarcane exportation 10.94 times higher than that presented in the group of "Developing" municipalities. Nevertheless, it is essential to note that the values are low even when the "Developed" municipalities group is evaluated. From what is observed in Table 1, the export of sugarcane products is expected to present a low impact on both municipalities' groups.

Table 1. Descriptive statistics by municipality group.

DEVELOPED MUNICIPALITIES						
Variable	**Unit**	**Observations**	**Mean**	**Standard Deviation**	**Min**	**Max**
GDP per capita	US$	460	20,533.48	14,516.16	6297.20	100,667.24
International Trade	Decimal	459	0.1458011	0.4328853	0	4.53525
EAP	Number	414	51,185	162,991	2829	1,175,556.00
Municipality Area	Km^2	460	2393.661	2307.859	204.22	9843.25
Sugarcane Export	Decimal	460	0.012922	0.0495834	0	0.4458368
DEVELOPING MUNICIPALITIES						
Variable	Unit	Observations	Mean	Standard Deviation	Min	Max
GDP per capita	US$	520	8806.56	5535.16	609.76	49,826.77
International Trade	Decimal	520	0.0394716	0.1561163	0	1.947047
EAP	Number	468	31,376	57,579	2111	414,504
Municipality Area	Km^2	520	1318.473	1250.231	60.95	5813.64
Sugarcane Export	Decimal	520	0.0011807	0.0090288	0	0.1080639

3.2.2. Econometric Specification

Following the work of Rassekh [8], the model used by this research was as follows:

$$Y = \beta 0 + \beta 1\ \mathrm{IT} + \beta 2 \ln \mathrm{EAP} + \beta 3 \ln \mathrm{Area} + \beta 4\ \mathrm{SE} + \beta 5\ \mathrm{year} + \mu \quad (1)$$

Most of the variables presented in Equation (1) have already been presented before: Y is the logarithmical GDP per capita, IT refers to Trade Openness, EAP is the Economically Active Population, Area refers to the Municipality's Area, and SE indicates Sugarcane Exports. $\beta 5$ refers to the year's control in the model so that the passage of time does not cause interference in the results, and μ is the error term of the equation.

Following Rassekh [8] and Frankel and Romer [9], GDP per capita, Economically Active Population, and Area of Municipalities were transformed to logarithms.

Before performing the regression of the specified model, the control tests for Unit Root, Heteroscedasticity, Multicollinearity, and Autocorrelation were performed. The Wooldridge Autocorrelation test indicated the presence of Autocorrelation in all panels analyzed, while the Heteroscedasticity test rejected the hypothesis of homoscedasticity in some panels. Standard deviation variance and covariance matrix were used in order to correct both problems. The outliers were removed, avoiding interference in the results. Finally, the Hausman test indicated that Fixed Effects should be used for all panels under analysis.

4. Results

The results of the regressions performed are presented below. Column 1 of Table 2 presents the results for the municipalities classified as "Developed", while column 2 contains the values for the municipalities identified as "Developing".

Table 2 indicates that, in the case of Developed municipalities, only the variable Trade Openness presented a significant result, while the second group, the Developing municipalities, did not present a significant result for any of the variables in the model.

The primary explanatory variable of this model (Sugarcane Exports) did not present a significant result for any of the analyzed groups.

Concerning the Trade Openness variable, the result presented for "Developed" municipalities indicates that international trade reduces people's wealth since the value presented in Table 2 is negative and significant at 5%. Even though this result may express a reduction in income inequality among the municipalities, the way this reduction happens is worrisome, once the result indicates a worsening in the income level of the population.

Table 2. Sugarcane export effect on GDP per capita.

Variable	(1) Developed GDP per Capita	(2) Developing GDP per Capita
International Trade	−0.145 **	0.369
	(0.0645)	(0.342)
Sugarcane Exports	0.0778	0.993
	(0.536)	(0.673)
EAP	−1.264	−0.183
	(1.200)	(0.449)
Area	18.01	2.546
	(11.13)	(1.586)
Constant	−110.7	−6.087
	(81.76)	(11.36)
Observation	413	468
R^2	0.563	0.760
Number of Municipalities	46	52

Robust standard errors in parentheses. ** $p < 0.05$.

Attanasio, Goldberg, and Pavcnik [18] reported that trade openness promoted a reduction in the income of less-skilled workers in Colombia. According to data from the 2010 Census, the last one conducted in Brazil, the resident population aged 25 years or older in Goiás with college degrees represents 10.279% of the population. This situation may explain the result presented in Table 2. As Castilho, Menendez, and Sztulman [29] show, Brazil's degree of trade interaction with the rest of the world increased significantly from 1998 onwards. This increase may have generated a framework of adjustment in workers' wages similar to that presented by the Colombian economy.

The Developing municipalities did not present any significant result in the analysis performed. This result is similar to the work of Green, Dickerson, and Arbache [28] and Pavcnik et al. [34], who found no evidence of an impact of international trade on income inequality for Brazil. Martorano and Sanfilippo [33] also reported non-significant results for this international trade variable in their analysis.

The lack of significant results for the Trade Openness variable of the "Developing" municipalities group is credited to the low interaction of this group with the rest of the world. As it is possible to observe in Table 1, the average presented for this variable for the Developing group was less than 4%, which indicates that even though the maximum value presented for this variable is close to 200%, most of the computed values are close to the minimum registered, 0%.

The above analysis can be extended to the primary explanatory variable of this research, Sugarcane Exports.

Regarding the income convergence analysis, the results presented in Table 2 do not confirm the works of Rassekh [8], Ben-David [39], Jayanthakumaran and Verma [40], Cyrus [42], and Ben-David and Kimhi [44], which state that international trade leads to income convergence. Moreover, it is not possible to assert that international trade benefits the poorest municipalities more convincingly.

Concerning the sugarcane–international trade relationship, Table 2 results confirm Machado and DA CRUZ's [37] results and, consequently, are not in line with Quin's [38] findings. Nevertheless, following Machado and DA CRUZ [37], this may be credited to the low export values of the region. This would explain the similarities of the presented results with Machado and DA CRUZ [37] and the different results from Quin [38], who analyzed the first impact of liberalization in the Guangxi region, which may have represented a cumulative impact on the people' income. However, it would be necessary to repeat Quin's [38] study with newer data to confirm this hypothesis.

4.1. Robustness Check

In his work, Rassekh [8] performs robustness tests applying the model of Rodriguez and Rodrik [53]. However, considering that the analysis proposed in this research studies a group of municipalities located in the same macro-region, the adoption suggested by Rodriguez and Rodrik [53] would not be possible.

Nevertheless, to verify the impact of sugarcane exports on income inequality in the municipalities, the analysis initially proposed was repeated, adopting the average income of workers in each municipality as a dependent variable. These data are made available in [50]. As it was performed in the first analysis, the municipalities were divided into "Developed" and "Developing" groups. The metric used to divide the group of municipalities in two was the average Workers' Income of the municipalities for 2009.

The control tests were repeated in this second stage of the research and the Hausman test, which indicated the use of Fixed Effects. The result of this regression is shown in Table 3.

Table 3. Sugarcane export effects of income inequality—average income.

Variable	(1) Developed Average Income	(2) Developing Average Income
International Trade	−0.0196 (0.0302)	0.217 (0.173)
Sugarcane Exports	0.156 (0.246)	
EAP	−0.457 (0.375)	−0.00106 (0.199)
Area	−0.00117 (1.147)	2.909 (3.599)
Constant	11.65 (7.730)	−13.20 (24.21)
Observation	484	397
R^2	0.893	0.886
Number of Municipalities	54	44

Robust standard errors in parentheses.

The numbers presented in Table 3 do not confirm the values of Table 2 regarding the Developed municipalities. Based on Table 3 results, it is possible to assert that the negative effect of international trade on the GDP per capita displayed in Table 2 do not reflect the aggregate income of workers in these cities. The other variables confirm the values presented in Table 2 indicating that neither the explanatory or the control variables impact the workers' average income.

Regarding the group of "Developing" municipalities, the result of Table 3 confirms the values of Table 2. The low interaction of this set of municipalities with the rest of the world limits the impact on income inequality. The case of the omitted results of the explanatory variable Sugarcane Exports for this group indicates that the software cannot perform the analysis of these values and reinforces how low the values related to the export of this product are.

4.2. Robustness Check 2

A third regression was carried out, with the Disaggregated Average Income by economic sector as the dependent variable. Data were collected for the following branches of the economy: Industrial, Commerce, Services, and Agriculture in [50].

The analyzed municipalities were divided into two groups, according to their 2009 average incomes. Control and Hausman tests were performed, indicating the use of Fixed Effects. The regression results are displayed in Table 4.

Table 4. Sugarcane export effects of income inequality—Disaggregated Average Income.

Variable	(1) Developed Industry	(2) Developing Industry	(3) Developed Commerce	(4) Developing Commerce	(5) Developed Services	(6) Developing Services	(7) Developed Agriculture	(8) Developing Agriculture
International Trade	0.198 ***	0.386 **	0.195	−0.0169	−0.0361	−0.0111	−0.0139	0.0591 **
	(0.0477)	(0.163)	(0.173)	(0.0332)	(0.0313)	(0.0928)	(0.0213)	(0.0228)
Sugarcane Exports	0.539		0.0845	0.158	0.315	−1.290	0.144	−14.81 ***
	(0.497)		(0.411)	(0.174)	(0.260)	(0.777)	(0.218)	(3.130)
EAP	1.212 **	0.0872	0.137	−0.0940	0.517	−0.411 **	−0.245	−0.274 **
	(0.515)	(0.225)	(0.430)	(0.146)	(0.433)	(0.201)	(0.308)	(0.105)
Area	0.628	2.144	−0.887	3.261 **	−12.01 **	−0.0395	−10.79	2.019 ***
	(0.772)	(3.036)	(1.835)	(1.551)	(4.799)	(1.469)	(10.06)	(0.598)
Constant	−9.405	−8.765	11.82	−14.84	87.27 **	11.05	91.52	−4.110
	(6.809)	(20.71)	(15.01)	(10.26)	(32.45)	(10.04)	(75.95)	(4.035)
Observation	396	447	359	522	349	532	341	540
R^2	0.576	0.749	0.861	0.916	0.624	0.833	0.890	0.919
Number of Municipalities	46	50	40	58	38	60	38	60

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

The Average Income of Industry results, columns 1 and 2, indicates that the Trade Openness favors the Developing municipalities more than the Developed ones, contributing to the reduction in income inequality. Both values are significant at 1% in Developed municipalities and at 5% for Developing municipalities. This result confirms that found by [8,39,40,42,44].

Regarding the values of the Sugarcane Export variable, the problem pointed out in the previous items is repeated. The statistical software could not analyze its impact on the Developing group due to a lack of data. Therefore, it cannot be said that there is an increase or reduction in income inequality. However, aiming to provide a better visualization of the relationship between sugarcane by-product exports and income, two graphics are provided in Appendix C.

The Trade Openness variable also proved to be significant for Average Agrobusiness Income, but only for the Developing group. Although low, the value is positive and significant, showing that international trade reduces income inequality among the state's municipalities, with a 95% confidence level.

It is important to note that the reduction in income inequality presented in Table 4 is different from that presented in Table 2. Nevertheless, it is important to stress that this result seems to confirm and extend to the one pointed out by Harrison [46], who reported that the convergence relationship was fragile. The results presented in Table 4 indicate that the impact of international trade on the income-convergence effect depends on the sector being evaluated.

The results presented for columns seven and eight are in line with what was reported by Castilho, Menendez, and Sztulman [29]. The opening of the trade to rural areas, where the agricultural jobs are located, reduces income inequality.

Column 8 of Table 4 also indicates that the export of sugarcane products reduces workers' income in the agricultural sector in the Developing municipalities. The result presented is significant at the 1% level. A possible explanation for this result is the fact that the sugar-alcohol sector has been going through a process of modernization, which has been harming the workers average income.

Borrs and Knauth [23] reported that the exposure of German companies to international trade led to the closing of jobs for less-qualified workers. Therefore, the evolution

of jobs in the agricultural sector of the "Developing" municipalities was verified to check whether the result presented by the Sugarcane Export variable in column 8 would be associated with jobs loss. However, this hypothesis was rejected once in the period analyzed by this work, and the jobs in this sector of the economy were stable for the group of Developing municipalities, with a slight increase in jobs in some municipalities.

4.3. Time Lag Analyses

Aiming to verify whether the export of sugarcane-derived products presented a significant impact on income inequality over time, the tests performed in the previous sections were repeated, using the variables Trade Openness and Sugarcane Export with a time lag of 1 year. Thus, we sought to analyze whether the municipality's trade interaction, mainly the export of sugarcane products, was impacted in the long run. This type of analysis was also performed by [34].

The results confirm and extend those initially found. The regression presented a negative and significant result at 1% for the Trade Openness variable for the Developed group, showing that the deleterious effect presented in Table 2 is maintained over time. No other variable presented a significant result, confirming what was presented at the beginning of Section 4. The results of this regression are shown in Appendix D.

The regression with the average income of workers in the state of Goiás did not present any significant variable when the time lag analysis was performed, confirming and extending the result of Table 3.

Finally, the analysis with the Disaggregated Average Income by economy sector presented similar results to those shown in Table 4. The test performed in this last step indicated that the Trade Openness variable continues to positively affect workers' income in the industrial sector of the wealthiest municipalities over time. However, the positive effect identified for the group of Developing municipalities was not identified when the time lag analysis was executed. It is possible to say that as time goes by, the commercial interaction of the Goiás municipalities increases income inequality for the set of workers in this segment of the economy.

The other variables that had shown significant results in Table 4 did not maintain their significance when the tests with the time lag were performed, indicating that the effects presented in Section 4.2 are not maintained over time.

Finally, the exports of sugarcane by-products presented a positive impact on the average income of the Commerce Sector of the Developing municipalities and a negative relationship with the Average income of the Service Sector of the Develop municipalities.

The table showing the results of this regression is shown in Appendix E.

5. Conclusions

The research sought to verify whether the sugarcane product export and the international trade of the municipalities of the state of Goiás has reduced the income inequality within the state of Goiás.

The results presented based on the econometric analysis demonstrate that even though International Trade contributes to the Income Convergence effect between the municipalities of Goiás, it cannot be said that this is a healthy contribution, once the reduction in income inequality occurs through a deleterious effect on the GDP per capita of the richer cities. This effect was observed using current data and with the time lag analysis. Therefore, it can be deducted that the harmful effect persists over time.

However, the results presented in the analysis involving Average Income presented an opposite effect. The presented results indicate that International Trade increases the Average Income of the Industrial Sector of both groups of municipalities, having a stronger effect in the poorest group. A positive effect was also noticed in the Agrobusiness sector of the Developing cities group. Those results indicate that international trade contributes to the Sustainable Development of those two groups, once it generates wealth, contributing to UN SDG number 1, and helps to reduce income inequality, helping to achieve UN SDG

number 10. Nevertheless, in the long run, the only positive effect registered refers to the industrial sector of the richer cities, which may indicate that the positive effects displayed earlier are not persistent overtime.

Regarding the export of sugarcane products, results presented in this research indicate that it does not help to produce Sustainable Development once it presented a negative relationship with the Average Income of the Agrobusiness sector of the poorest cities. Moreover, when the long run impact is analyzed, although it has presented a positive impact on the Average Income of the Commerce sector of the Developing group, it has also presented a negative influence on the Average Income of the Service sector of the wealthier cities. All the results found for the export of sugarcane products indicate that altogether, this activity presents a deleterious effect on the employees' income.

As a conclusion, it is suggested that future analyses on the subject should be performed, seeking to incorporate a larger dataset, aiming to confirm the results presented by this work.

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Appendix A. List of the Analyzed Municipalities of Goiás, Classified According to the Level of GDP per Capita

Table A1. Cities of Goiás according to the development classification.

Municipality	Classification According to the Gdp Per Capita	Municipality	Classification According to the Gdp Per Capita
Acreuna	High	Abadia De Goias	Low
Água Fria De Goias	High	Abadiania	Low
Alexania	High	Águas Lindas De Goias	Low
Alto Horizonte	High	Alto Paraiso De Goias	Low
Anapolis	High	Americano Do Brasil	Low
Anicuns	High	Aparecida De Goiania	Low
Bela Vista De Goias	High	Aruanã	Low
Bom Jesus De Goias	High	Barro Alto	Low
Cachoeira Alta	High	Bonfinopolis	Low
Caçu	High	Brazabrantes	Low
Caldas Novas	High	Britania	Low
Campo Alegre De Goias	High	Campos Verdes	Low
Carmo Do Rio Verde	High	Cidade Ocidental	Low
Castelândia	High	Faina	Low

Table A1. *Cont.*

Municipality	Classification According to the Gdp Per Capita	Municipality	Classification According to the Gdp Per Capita
Catalão	High	Formosa	Low
Cezarina	High	Goianésia	Low
Chapadão Do Ceu	High	Goianira	Low
Corumbaíba	High	Goiás	Low
Cristalina	High	Guarani De Goias	Low
Crixás	High	Inhumas	Low
Edéia	High	Iporá	Low
Goiania	High	Itaguaru	Low
Goiatuba	High	Itapirapuã	Low
Gouvelandia	High	Itapuranga	Low
Hidrolandia	High	Jaraguá	Low
Ipameri	High	Luziânia	Low
Itaberaí	High	Mara Rosa	Low
Itarumã	High	Montividiu Do Norte	Low
Jataí	High	Nazário	Low
Minaçu	High	Nova Roma	Low
Mineiros	High	Pilar De Goiás	Low
Montividiu	High	Pirenópolis	Low
Morrinhos	High	Pires Do Rio	Low
Mozarlândia	High	Planaltina	Low
Nerópolis	High	Pontalina	Low
Niquelândia	High	Porangatu	Low
Orizona	High	Posse	Low
Ouvidor	High	Rubiataba	Low
Palmeiras De Goiás	High	Sanclerlândia	Low
Quirinópolis	High	Santa Bárbara De Goiás	Low
Rio Verde	High	Santa Helena De Goiás	Low
São Luís De Montes Belos	High	Santa Rita Do Novo Destino	Low
São Simão	High	Santa Terezinha De Goiás	Low
Silvânia	High	Santo Antonio De Goiás	Low
Vicentinópolis	High	São Domingos	Low
Vila Boa	High	São Luiz Do Norte	Low
		Senador Canedo	Low
		Taquaral De Goiás	Low
		Terezópolis De Goiás	Low
		Trindade	Low
		Uruaçu	Low
		Valparaíso De Goiás	Low

Appendix B. Scatter Plot of Sugarcane by-Product Export and GDP per Capita

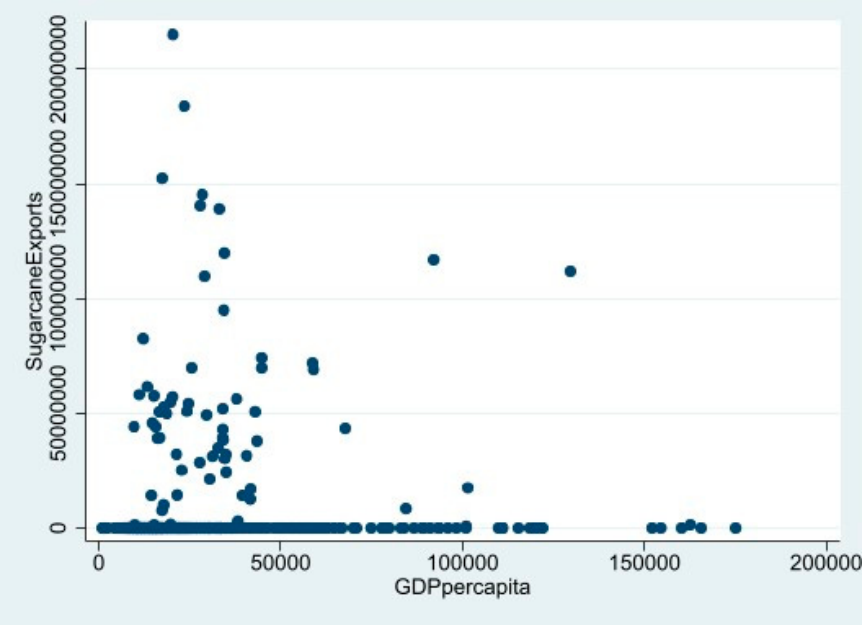

Figure A1. Scatter plot between sugarcane by-product export and GDP per capita.

Appendix C.

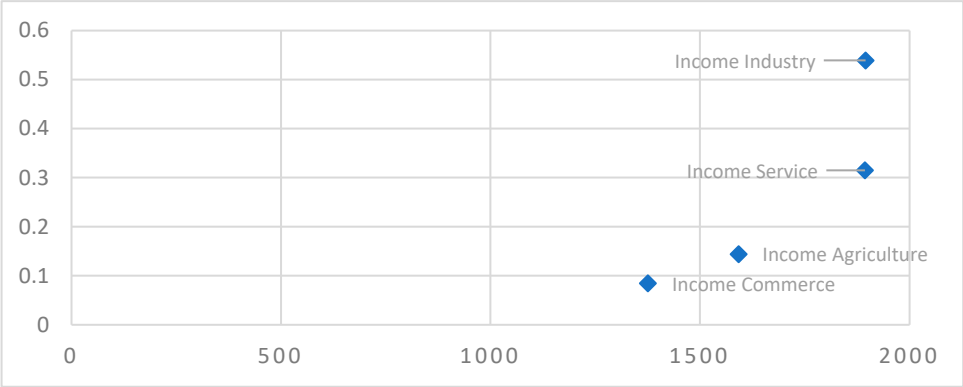

Figure A2. Sugarcane by-product export and income for Developed cities.

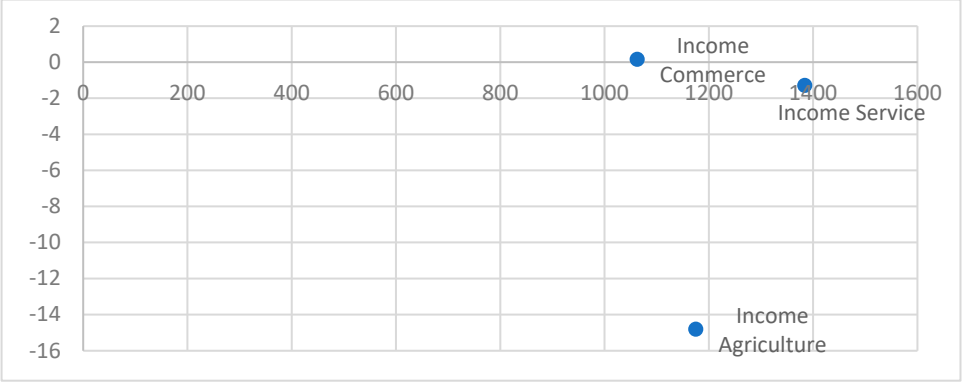

Figure A3. Sugarcane by-products export and income for Developing cities.

Appendix D. Time Lag Regression—GDP per Capita

Table A2. Time lag regression—GDP per capita.

Variable	Developed GDP per Capita	Developing GDP per Capita
International Trade L1	−0.138 ***	0.232
	(0.0486)	(0.262)
Sugarcane Exports L1	0.405	0.662
	(0.571)	(0.582)
EAP	−1.229	−0.188
	(1.177)	(0.462)
Area	17.76	2.644
	(11.11)	(1.623)
Constant	−109.2	−6.687
	(81.76)	(11.68)
Observations	413	468
R^2	0.560	0.752
Number of Municipalities	46	52

Robust standard errors in parentheses. *** $p < 0.01$.

Appendix E. Time Lag Regression—Disaggregated Average Income

Table A3. Time lag regression—Disaggregated Average Income.

Variable	Developed (1) Industry	Developing (2) Industry	Developed (3) Commerce	Developing (4) Commerce	Developed (5) Service	Developing (6) Service	Developed (7) Agriculture	Developing (8) Agriculture
International Trade L1	0.201 ***	−0.0750	0.0984	−0.0283	0.0848	−0.0845	−0.000982	0.0556
	(0.0530)	(0.202)	(0.170)	(0.0251)	(0.0627)	(0.103)	(0.0221)	(0.0361)
Sugarcane Exports L1	0.264		−0.0914	0.265 *	−0.665 **	−0.220	−0.151	−1.512
	(0.217)		(0.306)	(0.135)	(0.297)	(0.293)	(0.220)	(3.776)
EAP	1.211 **	0.0488	0.133	−0.0930	0.427	−0.429 *	−0.261	−0.276 **
	(0.510)	(0.228)	(0.436)	(0.150)	(0.352)	(0.223)	(0.300)	(0.108)
Area	0.626	2.810	−0.950	3.266 **	−12.02 **	−0.0258	−10.85	2.022 ***
	(0.880)	(2.992)	(1.774)	(1.544)	(4.796)	(1.483)	(9.836)	(0.594)
Constant	−9.376	−12.90	12.33	−14.88	88.18 **	11.14	92.13	−4.110
	(7.481)	(20.34)	(14.56)	(10.23)	(32.79)	(10.12)	(74.22)	(4.008)
Observations	396	447	359	522	349	532	341	540
R^2	0.571	0.744	0.860	0.916	0.631	0.833	0.890	0.919
Number of Municipalities	46	50	40	58	39	60	38	60

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

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