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Socioeconomic impacts of the biodiesel production chain on family agriculture in the Brazilian states of Rio Grande do Sul (RS) and Mato Grosso (MT)

Impactos socioeconômicos da cadeia produtiva do biodiesel na agricultura familiar dos estados brasileiros do Rio Grande do Sul (RS) e do Mato Grosso (MT)

Pedro Gilberto Cavalcante Filho [1,2]
Antônio Márcio Buainain [1]
Marcelo Pereira da Cunha [1]
Gabriela Solidario de Souza Benatti [1]

[1] Universidade Estadual de Campinas (Unicamp)
[2] Brazilian Agricultural Research Corporation (Embrapa) Territorial

Abstract

This paper evaluates the different socioeconomic impacts of the biodiesel sector on family farming and other sectors of the economy of the states of Rio Grande do Sul and Mato Grosso, which are the largest biodiesel producers in Brazil and have structural and regional differences. The Input-Output Theory was the methodology used to measure the direct and indirect effects on the jobs generated and on the Gross Domestic Product (GDP). The research shows that the production of biodiesel via family farming in Rio Grande do Sul is 66 times that of Mato Grosso, generating approximately 19,000 jobs, which is explained by the greater development of the agricultural sector in Rio Grande do Sul. Compared to fossil diesel, one million barrels of oil equivalent of family biodiesel in Rio Grande do Sul generates 7,700 jobs, while the fossil route generates 1,600 jobs.

Keywords

PNPB, production chain, biodiesel, family farming, socioeconomic impacts, input-output.

JEL Codes C67, Q1.

Resumo

Este trabalho tem o objetivo de avaliar os diferentes impactos socioeconômicos do setor do biodiesel na agricultura familiar e demais setores da economia dos estados do Rio Grande do Sul e do Mato Grosso, que são os maiores produtores de biodiesel no Brasil e possuem diferenças estruturais e regionais. Utilizou-se como base metodológica a Teoria de Insumo-Produto para mensurar os efeitos diretos e indiretos nas ocupações geradas e no Produto Interno Bruto (PIB). Os resultados indicam que a produção de biodiesel via agricultura familiar no Rio Grande do Sul é 66 vezes àquela no Mato Grosso, gerando aproximadamente 19 mil ocupações, que é explicado pelo maior desenvolvimento do setor agrícola gaúcho. Na comparação com o diesel fóssil, um milhão de barris equivalentes de petróleo (bep) de biodiesel familiar no Rio Grande do Sul gera 7,7 mil ocupações, enquanto na rota fóssil gera 1,6 mil ocupações.

Palavras-chave

PNPB, cadeia produtiva, biodiesel, agricultura familiar, impactos socioeconômicos, insumo-produto.

Códigos JEL *C67, Q1.*

1 **Introduction**

The production of biofuels in Brazil dates back to the 1930s, but only in the 1970s, with the launch of the National Alcohol Program (Proálcool), did Brazilian energy policy begin encouraging the production of ethanol fuel to reduce dependence on oil imports (Salles-Filho *et al*., 2016; Sampaio, 2017).

Starting with the 1990s, the incentive for biofuels was reinforced by environmental concerns and the commitment to reduce greenhouse gas (GHG) emissions, which Brazil made with the international community. However, the reduced dependence on imports and the impacts of oil price fluctuations remained as strategic reasons for the diversification of the country's energy sources. In fact, some studies have shown that different biofuel programs were more strongly influenced by economic uncertainties than by environmental and social aspects (Costa, 2017; Rico; Sauer, 2015). Despite this, there were positive socio-economic and environmental impacts from the biofuel programs. Brinkman *et al*. (2018) estimated a contribution of 2.6 billion USD to the Brazilian GDP and the generation of 53,000 jobs by 2030 in Brazil, and Machado *et al*. (2020) found that, although the impacts of bioeconomy are not high enough to significantly reduce GHG emissions, the effects are positive.

In the early 2000s, in addition to the objective of reducing dependence on imports of mineral diesel, the decision to support a biodiesel production program already brought arguments directly linked to environmental concerns, the opening of new opportunities for national agribusiness, the inclusion of family farming in the biodiesel chain, and poverty reduction in rural areas (Dufey, 2006; Flexor; Kato, 2015; Interlenghi *et al*., 2017; Pousa; Santos; Suarez, 2007; Ramos; Wilhelm, 2005). The Brazilian Biodiesel Program (PNPB), launched in 2004, was innovative in including among its institutional objectives the promotion of regional development in the peripheral regions of the country (North and Northeast) and the productive inclusion of family farming in the production chain of biodiesel (Flexor *et al*., 2011; Garcia, 2007; Pedroti, 2013). The PNPB was created in the context of environmental and socio-economic sustainability, in line with the United Nations Sustainable Development Goals (SDGs), which include poverty reduction, decent work and economic growth, and improving rural livelihoods (Lozano, 2008; Robert; Parris; Leiserowitz, 2005; United Nations, 2015).

The literature demonstrates that the production of raw materials for biofuels can directly and indirectly contribute to socioeconomic development in rural regions (Domac; Richards; Risovic, 2005; Gilio; Moraes, 2016; Machado *et al*., 2015; Moraes; Bacchi; Caldarelli, 2016; Moraes; Oliveira; Diaz-Chavez, 2015; Walter *et al*., 2011, 2014). These contributions to rural development occur through investments in capital goods and additional demand for labor in the countryside and in production plants. Furthermore, reduced dependence on fossil fuel imports, together with the potential for biofuel exports, can strengthen national and regional economies (Van Eijck *et al*., 2014; Wicke *et al*., 2009). Indirect contributions stem from increased production in the sectors of the economy that provide inputs for the biofuels sector. With the expansion of biofuels, positive effects are expected for the main socioeconomic indicators GDP, employment and trade (Walter *et al*., 2011).

However, the expansion of biofuel production and related impacts are not evenly distributed across the country (Martinelli *et al*., 2011). The dynamics and specific characteristics of the production region determine the direction and size of impacts on local economies (Hall *et al*., 2009; Sawyer, 2008). Consequently, it is important to understand not only the impacts of expanding biofuel production across the economy, but also the distribution of these impacts. This information helps to identify weaknesses and socioeconomic opportunities in the expansion of biofuels to different regions and income classes. This is essential for Brazil, where there are still large inequalities between regions (Da Costa; Burnquist; Guilhoto, 2006; World Bank, 2015).

The PNPB's actions to promote the inclusion of family farming present different results among Brazilian regions and states. The concentration of biodiesel production is itself evidence of the differences (Cavalcante Filho; Buainain; Cunha, 2020). The states of Rio Grande do Sul and Mato Grosso have established themselves as the main biodiesel producers in the country. In both states the main source of raw material used is soy. However, agriculture in Rio Grande do Sul and Mato Grosso, in particular soybean production, has very different structural characteristics. While the agrarian structure of Rio Grande do Sul is marked by the strong presence of family farmers, organized into cooperatives and associations and inserted in other dynamic agricultural chains, Mato Grosso is marked by large-scale agricultural economic dynamics with a low presence of family farmers compared to other Brazilian regions. Hence, the comparison of the socioeconomic impacts of the soy-based biodiesel production chain in the two states can elucidate its impact on family farming and on local economies.

As such, this article identifies and measures the impacts of the biodiesel chain on the economy of the states of Rio Grande do Sul and Mato Grosso, given its direct and indirect effects on family farming and other sectors of the regional economy. We seek to answer the question: what are the differences in socioeconomic impacts of the soy-based biodiesel production chain on family farming in the states of Rio Grande do Sul and Mato Grosso? The method used was the interregional Input-Output model, followed by a survey in secondary and complementary databases to understand the structure of the biodiesel sector and family farming. This methodology is used to capture the direct and indirect effects involved throughout the production chain to meet the input supply needs of the sectors of the economy.

Aside from the introduction, the article is divided into four additional sections. The second section is a brief literature review about the constitution and results of PNPB evaluations, as well as a summary of Brazilian agriculture. The third section presents in greater detail the input-output method applied in the present study to obtain the results. The fourth section presents the main results and analysis of the application of the input-output model. Lastly, the fifth section is reserved for final considerations.

2 **PNPB: some evaluations based on the literature**

The PNPB sought to link together strategic sectors to achieve its strategic objectives – ensuring the supply of biodiesel, promoting the inclusion of family farming and local development, and consolidating the biodiesel chain (Stattman; Hospes; Mol, 2013). However, little is known about the impacts of the biodiesel production chain on Brazilian family farming, the determinants for the inclusion of the family farming sector and the effects generated by the construction of new supply chains to produce second generation biodiesel, obtained from alternative sources of biomass.

In terms of assessing the impacts of the PNPB on family farming, it is of utmost importance that the heterogeneity of family farming is acknowledged, both in terms of agricultural structure and systems, to understand the capacity and engagement of these farmers in the production and supply of raw materials for the biodiesel production chain (Leite *et al.*, 2013).

It is also necessary to consider the structural heterogeneity of Brazilian agriculture (Vieira Filho; Santos; Fornazier, 2013) and, in particular, that Brazilian agriculture itself is characterized by marked differences in terms of agrarian and organizational structure (Buainain *et al.*, 2007; Guanziroli; Buainain; Sabbato, 2012; Souza *et al.*, 2018). Thus, any assessment of the impacts of the biodiesel chain on family farming and on local and regional economies needs to take these differences into account.

Most studies that qualitatively and descriptively evaluated the relationship between PNPB and/or SBS and family farming (Abramovay; Magalhães, 2007; César; Batalha, 2010, 2011, 2013; Garcia, 2007; Gonçalves; Favareto; Abramovay, 2014; Isolani; Tonin, 2013; Leite *et al.*, 2013; Monteiro, 2007; Ribeiro *et al.*, 2018; Silva *et al.*, 2014), found that the inclusion of family farmers was hampered by problems that include the low scale of production, lack of resources for investment, logistical deficit, access to markets, etc. Family farmers from the Northeast and North regions were practically left out of the chain.

The few studies that carried out a quantitative analysis (Prado, 2015; Ribeiro, 2014; Ribeiro *et al.*, 2015; Rodrigues; Zavala, 2017) concluded that the program's regional performance was affected by differences in the organization of raw material production and by low income generation, which led to the ineffectiveness of the social inclusion objective. Some studies carried out a quantitative assessment of the socioeconomic impacts of the biodiesel chain through the approach of the Input-Output Theory, the same used in the present study (Cunha, 2011; Evangelista Junior, 2009).

Yuuki, Conejero and Neves (2007) accomplished one of the first evaluations of the Biodiesel Program using the Input-Output Matrix approach. The authors estimated the employment multipliers of the biodiesel industries and found that they were one of the highest compared to other sectors. Thus, the estimate was that the direct and indirect generation of jobs would increase, if biodiesel production were to consolidate in Brazil. Based on the results obtained from the direct and indirect impacts of biodiesel production on employment in the soybean and castor bean sectors, it was concluded that biodiesel production would cause a strong impact on the level of employment, mainly in castor bean crops in the Northeast.

Evangelista Junior (2009) evaluated the impacts of the small-scale biodiesel production chain based on sunflower in the semiarid region of Rio Grande do Norte and showed that investment in agricultural activities resulted in a significant increase in income for family farmers. The study had also found the viability of sunflower cultivation by family farmers, potential addition of value to family farming production, but those farmers would encounter production difficulties related to the low level of mechanization, the scarcity of certified seeds and specialized technical assistance, as well as cultural traits that would need to be adjusted with the introduction of sunflower. It is possible that these obstacles were responsible for the discontinuity of the project in this location.

Using this perspective, Cunha (2011) evaluated the socioeconomic and environmental impacts of the biodiesel production chain in Brazil while considering the different biofuel production routes. With the sunflower-based route, the author identified that the number of jobs generated would be 15 times greater than the production of soy-based biodiesel, but that the labor factor would earn less than 87% of the country's average. For the other evaluated routes, no significant differences were identified. However, in the soy routes evaluated, given the scenarios for its use and its oil directed to exporting, the conversion of soy into biodiesel was shown to be more advantageous than the conversion to soy oil in terms of impact to GDP and job generation.

This paper conducts a quantitative evaluation, considering the performance of the Program in two Brazilian states with very different productive structures: Rio Grande do Sul is marked by the strong presence of family farming and Mato Grosso is characterized by the production of grains in large scale. The comparison of socioeconomic impacts of the biodiesel chain is valid to address the fundamental question that concerns the evaluation of the contributions of the biodiesel program to the strengthening of family farming and local economies.

3 **Methodology**

The socioeconomic impacts of soy-based biodiesel production were calculated based on the inter-regional Input-Output model. This model was adapted for this study based on the official tables of the Brazilian Institute of Geography and Statistics (IBGE)[1] and contains three regions (Section 2.1). The sectors of interest for analysis were obtained via breakdown procedure following specific criteria based on the consultation of secondary sources to identify the technological configuration of such sectors (Section 2.2). Four shocks[2] were applied to compare the differences in regional impacts of the biodiesel sectors and another five shocks considering the energy content to compare with mineral diesel oil (Section 2.4). With the inclusion of the shocks, it was possible to capture the direct effects[3] (suppliers of inputs to the biodiesel sector), the indirect effects (sectors that deliver inputs to the sectors that supply the biodiesel sector) and the spillover effects (generated in other regions) (MILLER; BLAIR, 2009). The effects were captured for the socioeconomic indicators GDP, employed persons and Value Added at Cost of Factors (VACF).

3.1 **Input-output model**

This study used the interregional Input-Output Matrix for the year 2011[4], made available by the Regional and Urban Economics Lab of the University of São Paulo (Nereus, 2021), which is estimated using the Interregional Use and Production Tables method (TUPI). In this model, the economies of the states of Rio Grande do Sul and Mato Grosso were broken down from the official national Input-Output tables published by the IBGE (IBGE, 2021a, 2021b). The method and different data sources used to obtain an inter-regional state-level Input-Output table were described by Guilhoto *et al*. (2017). The two selected states were broken down by estimating the monetary flows in the inter- and intra-regional matrices of the states. The estimation of these flows was mainly based on 1) statistical data at the state level provided by IBGE (IBGE, 2019a, 2019b, 2021c): Municipal Agricultural Production (PAM), Municipal Livestock Production (PPM) and Production of Vegetal Extraction and Forestry (PEVS) for the

1 Institution responsible for data collection and dissemination of official statistics in Brazil.

2 Technically, matrix shocks consist of adding a resource to the final demand of a sector to verify its direct and indirect effects on other sectors of the economy.

3 The effects generated throughout the economy's production chain are also called "impact."

4 This is the year with the most inter-regional data. The analyses are not compromised by assuming the hypothesis that there were no significant changes in the structure of the Brazilian economy.

agricultural sector; Annual Industrial Survey (PIA) for the industrial sectors (IBGE, 2018a) and Annual Services Survey (PAS) for the service sectors (IBGE, 2018b); and 2) by using cross-sector location quotients that are combined with the Annual Social Information Report (RAIS, 2022).

The regional breakdown used in this study distinguishes three regions: two states presented above (Rio Grande do Sul and Mato Grosso) and the Rest of Brazil. The equations of the basic Input-Output model are described in the appendices and can be found in more detail in well-established literature such as Miller and Blair (Miller; Blair, 2009) and Guilhoto (Guilhoto, 2011). The original matrix is structured in 59 sectors and 67 products, totaling 177 sectors and 201 products for the selected regions.

3.2 Brief description of the structure of the biodiesel production chain in Brazil

At the end of 2018, 51 ANP-authorized biodiesel production plants were in operation in Brazil, distributed in all regions: 5.9% in the North region, 7.8% in the Northeast region, 15.7% in the Southeast region, 21.6% in the South region and 49% in the Center-West region. The biodiesel production chain is mainly supplied with raw materials and inputs produced in the country. The main raw materials used in the production process to obtain biodiesel are soy and beef tallow. Industrial plants that have a crusher for oil extraction purchase soybeans directly from the agricultural sector, produced by family and non-family farming. Plants that do not have crushing capacity obtain oil of animal or vegetable origin from the vegetable and animal oil and fat manufacturing sector.

The commercialization[5] of biodiesel, in turn, is regulated by public auctions promoted by the ANP and mediated by Petrobras, where the fuel distributors acquire the biodiesel production batches offered by the plants to carry out the addition to mineral diesel oil, in accordance with the percentage established by the Ministry of Mining and Energy (MME).

5 In January 2022, the marketing model was be replaced by direct acquisition between fuel distributors and biodiesel plants. It is still unclear what the new governance model will look like.

3.3 **Breakdown of sectors and products**[6]

To achieve the proposed objective of evaluating the different impacts of the biodiesel sector on family farming in the states of Rio Grande do Sul and Mato Grosso, it was necessary to break down the sector and the biodiesel product into the following segments: non-family biodiesel and family biodiesel. Table 1 summarizes the characteristics and definitions of the disaggregated sectors and products.

Table 1 **Definition of breakdown of products and sectors**

Product	Definition	Sector	Definition
Family farming soybean	Soy production supplied by family farming to biodiesel production plants	**Family farm that supplies soy for biodiesel**	Family agricultural sector that supplies soy to produce biodiesel
Soy beans	Rest of soy production from soy cultivation supplied to biodiesel producing plants	**Soy cultivation**	Non-family farming sector that supplies soy for biodiesel
Biodiesel – family farming or from SBS	Biodiesel produced with soy from family farming under the SBS	**Family farming biodiesel manufacturing**	Portion of the biodiesel manufacturing sector that produces soy from family farming
Biodiesel – not family farming	Biodiesel produced with non-family farming raw material	**Non-family farming biodiesel manufacturing**	Portion of the biodiesel manufacturing sector that produces with non-family farming raw materials

Source: Prepared by the authors.

Breakdowns were performed for the regions of the model: the states of Rio Grande do Sul and Mato Grosso. Thus, 61 sectors and 69 products were established in these states and the initial 59 sectors and 67 products were maintained in the Rest of Brazil, which resulted in the total definition of 181 sectors and 205 products in the matrix used to capture the effects of the sector of biodiesel on family farming and the local economy in these states.

3.4 **Study objective**

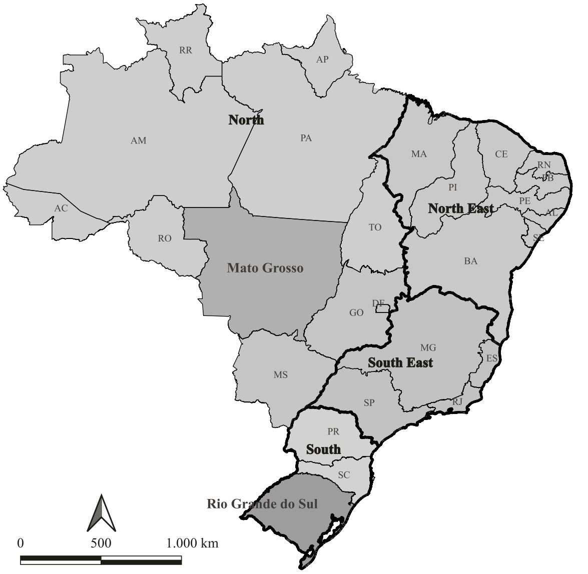
To assess and compare the socioeconomic impacts of biodiesel produc-

6 For more details on the criteria for breaking down sectors and producers, see section 3.3 in Cavalcante Filho (2020).

tion on family farming and on the local economy, the inter-regional model was picked, focusing on the states of Rio Grande do Sul, Mato Grosso and the rest of Brazil. The choice of these states is justified because they are the main biodiesel producers in Brazil (Figure 1), responsible for approximately 50% of its production, and because they have different structural characteristics, especially in terms of family farming.

While in Rio Grande do Sul family farming units correspond to 80% of all units, occupying 25.3% of the area and being responsible for 37.4% of the VBP, in Mato Grosso family producers represent 68% of the total, occupy 9.3% of the area and account for 6.6% of the VBP. Furthermore, in Rio Grande do Sul, family farmers are integrated into dynamic agribusiness chains, are well organized in cooperatives (47% of family members are associated with cooperatives), whereas in MT they are poorly integrated into production chains and have a lower level of organization (8.1% of family members are associated with cooperatives), according to data from the 2017 Agricultural Census (Table 2). Furthermore, as they are states in different regions, they have different parameters for acquiring raw materials within the scope of the SBS (40% for the South region and 15% for the Central-West region.

Figure 1 **Location of the states of Rio Grande do Sul and Mato Grosso in Brazil and biodiesel production characteristics in 2018**



Region	Productive capacity (m³/year)	Production (m³/year)	Factory (Un.)
Rio Grande do Sul	2,351,999	1,479,467	9
Mato Grosso	1,768,126	1,133,560	16
Rest of Brazil	4,419,083	2,737,009	26
Brazil	8,539,207	5,350,036	51

Source: Prepared by the authors based on (ANP, 2019; IBGE, 2021a).

Table 2 **Agrarian and agricultural structural characteristics of the states of Rio Grande do Sul and Mato Grosso and Brazil in 2017**

Characteristic		Family farming			Non-family farming		
		RS	MT	Brazil	RS	MT	Brazil
Units (Per thousand)		294	82	3,897	71	37	1,176
Area (Thousand ha)		5,476	5,131	80,891	16,208	49,792	270,399
Employed personnel (Per thousand)		770	230	11,644	305	224	5,906
Soybean	Units (Per thousand)	76,027	2,308	164,710	19,455	4,789	71,535
	Volume (Thousand tons)	3,917	631	9,559	13,395	29,147	93,598
	Production Value (Million USD)	2,388	335	5,765	8,413	16,618	56,357

Source: Prepared by the authors based on (IBGE, 2017).

3.5 Shock used in the model

In the present work, nine different shocks were performed to evaluate the impacts, considering the production volume of the year 2018 at prices of the year 2011[7]. The production volume and the base price practiced in the period were consulted in the database provided by ANP (2019). The production value of each product was considered as the shock value at the respective product's final demand to compare the socioeconomic impacts of the biodiesel chain in the evaluated states. The fossil diesel shock was

7 The shocks and model results were converted to values in US dollars (USD), taking into account the average exchange rate for the year 2011 (IPEA) (2021). The exchange rate adopted for converting the real (R$) into the dollar (US$) was 1.675.

carried out only in Rio Grande do Sul, since there are no oil refineries installed in Mato Grosso. Table 3 summarizes the objective, the application vector and the applied shock value.

Table 3 **Shocks carried out for the assessment of impacts in Rio Grande do Sul and Mato Grosso**

Objective	Application vector	Shock Value (Million USD)
Comparing the effects of biodiesel production on family farming	Final demand for family biodiesel product from RS	590.51
	Final demand for family biodiesel product from MT	9.41
Comparing the effects of biodiesel production on the rest of agriculture	Final demand of the biodiesel product – non-family farming from RS	1,408.09
	Final demand for biodiesel product – non-family farming from MT	1,521,92
Comparing the effects of biodiesel and diesel production on one million BOE[8]	Final demand for biodiesel products (family and non-family farming) in the states of RS and MT	242.28
	Final demand for mineral diesel oil product from RS[9]	142.65

Source: Prepared by the author.

The energy measure of 1 million barrels of oil equivalent (BOE) was adopted in the present paper because it is conventionally used in the world to compare the energy content of different energy sources. To this end, in Brazil, according to ANP data (2020), 2.58 million barrels of oil were produced per day in 2018. Therefore, the energy unit of 1 million BOE is equivalent to 38% of oil production in 2018.

4 **The input-output analysis**

Impacts of biodiesel chains on the Brazilian economy

The biodiesel production chains in Rio Grande do Sul and Mato Grosso were responsible for generating 107,860 jobs, contributing 3,193.15 mil-

8 The energy measurement unit barrel of oil equivalent (BOE) is used to convert a volume of any fuel or biofuel into a volume of oil equivalent, based on the energy equivalence between the oil and the converted fuel, which is measured by the ratio between the calorific value of the fluids. Thus, this unit expresses the amount of energy released by burning a barrel of oil.

9 The state of Mato Grosso has no oil refineries. Therefore, the shock was applied only to the oil refining sector in the state of Rio Grande do Sul.

lion USD to the GDP and 8,313.7 million USD to the production of the Brazilian economy, considering its direct and indirect effects (Table 4). The family farming biodiesel production routes of the states accounted for at least 17% of the total effects on job generation and GDP.

The results obtained make it possible to infer that the production of family farming biodiesel is more important for the local economy, since more than 70% of the impacts are concentrated in the internal chains, as those demand more raw materials and inputs from the local sectors. The production of non-family farming biodiesel in both states, in turn, has impacts distributed among the sectors of the local economies and the Rest of Brazil, which in the case of the external regions occurs especially indirectly (Table 5).

Table 4 **Total effect of job generation, in units, and of GDP and production, in million USD, and the spillover effect, in percentage, in Brazil and the Rest of Brazil and in the states of Rio Grande do Sul and Mato Grosso, resulting from the shocks in family and non-family farming biodiesel in 2018**

Region	Charac-teristic	Family farming biodiesel		Biodiesel – non-family farming	
		RS	MT	RS	MT
Brazil (Total)	Jobs	18,877	348	43,525	45,100
	GDP	546.44	8.71	1,256.16	1,381.84
	Production	1,108.15	18.41	3,472.45	3,714.68
Rio Grande do Sul (RS)	Jobs	75.2%	1.3%	54.0%	2.4%
	GDP	76.9%	1.3%	59.5%	1.9%
	Production	74.4%	1.8%	67.7%	1.9%
Mato Grosso (MT)	Jobs	0.8%	77.2%	1.8%	48.4%
	GDP	0.4%	72.1%	1.7%	56.3%
	Production	0.7%	70.1%	1.5%	63.9%
Rest of Brazil (RBr)	Jobs	24.1%	21.5%	44.2%	49.2%
	GDP	22.6%	26.6%	38.8%	41.8%
	Production	25.0%	28.2%	30.7%	34.3%

Source: Research results.

Table 5 **Participation of indirect effects, in percentage, in Brazil and the Rest of Brazil and in the states of Rio Grande do Sul and Mato Grosso, resulting from the shocks in family and non-family farming biodiesel in 2018**

Region	Charac-teristic	Family farming biodiesel		Biodiesel – non-family farming	
		RS	MT	RS	MT
Brazil (Total)	Jobs	23.0%	21.2%	40.1%	41.6%
	GDP	20.4%	23.0%	37.4%	37.0%
	Production	21.5%	23.6%	28.2%	29.3%
Rio Grande do Sul (RS)	Jobs	7.8%	67.0%	22.2%	66.5%
	GDP	7.0%	66.9%	18.7%	69.6%
	Production	8.1%	62.7%	12.5%	68.1%
Mato Grosso (MT)	Jobs	82.9%	7.9%	59.1%	21.5%
	GDP	72.6%	6.5%	54.9%	14.2%
	Production	52.6%	6.2%	45.8%	9.1%
Rest of Brazil (RBr)	Jobs	68.5%	66.2%	61.1%	60.1%
	GDP	64.8%	65.4%	65.4%	66.2%
	Production	60.6%	64.6%	61.8%	64.7%

Source: Research results.

There is a strong distinction in the socioeconomic impacts of soy-based biodiesel production on family farming in the states of Rio Grande do Sul and Mato Grosso and in other sectors of the Brazilian economy (Table 6). The impact on family farming job generation in the state of Rio Grande do Sul was 51 times greater compared to the family farming sector in Mato Grosso. In terms of GDP, this difference was even greater among family farming sectors, corresponding to 79 times more. On the other hand, in terms of average monthly income by generated jobs, the differences were not so expressive, but still higher among family farmers from Rio Grande do Sul, who earned 323.39 USD from the sale of soybeans for the production of biodiesel, while in Mato Grosso it corresponded to 205.37 USD. Compared to the minimum wage in 2011 (325.37 USD), the commercialization of soybeans for biodiesel in Rio Grande do Sul paid family farmers the equivalent of one monthly minimum wage and in Mato Grosso the remuneration was 36% lower than in the state of Rio Grande do Sul.

The results also reveal the difference in the configuration of the biodiesel sector itself. While the family production route demands raw material directly from the agricultural sector, non-family farming production is linked to the demand for vegetable and animal oils, resulting in significant impacts on job generation and on the GDP of the vegetable and animal oils and fats manufacturing sector. Furthermore, the spillover effect (Tables 7 and 8) demonstrates that the non-family farming biodiesel sector in Rio Grande do Sul needs to import larger volumes of vegetable and animal oils from the Rest of Brazil, compared to the non-family farming biodiesel chain in Mato Grosso.

Table 6 **Total effect of job generation, in units, and of GDP, in million USD, by sectors in the state of Rio Grande do Sul and Mato Grosso, resulting from the shock in family and non-family farming biodiesel in the respective states in 2018**

Sector	Jobs (Units)		GDP (Million USD)	
	RS	MT	RS	MT
Family farming biodiesel				
Family farming	9,046	175	36.5	0.5
Family farming biodiesel manufacturing	1,942	39	298.1	4.6
Commercialization	930	12	15.7	0.2
Livestock farming	125	9	0.9	0.1
Land transportation	635	8	11.6	0.2
Services	522	11	14.5	0.2
Other sectors	988	14	43.3	0.6
Biodiesel – non-family farming				
Commercialization	5,626	4,419	94.8	80.8
Manufacture of vegetable and animal oils and fats	3,676	3,691	140.1	107.7
Rest of farming	3,227	608	34.4	15.2
Non-family farming biodiesel manufacturing	2,853	4,768	152.3	302.4
Land transportation	1,824	1,537	33.2	34.7
Soybean	500	933	102.1	85.5
Livestock farming	1,068	1,392	7.6	10.7
Other sectors	4,739	4,482	183.3	141

Source: Research results.

Table 7 **Overflow effect resulting from biodiesel production in Rio Grande do Sul by sectors in the state of Mato Grosso and the Rest of Brazil in 2018**

Sector	Jobs (Units)		GDP (Million USD)	
	RS	MT	RS	MT
Family farming biodiesel				
Livestock farming	82	988	0.63	4.21
Commercialization	17	1,090	0.31	17.84
Land transportation	6	270	0.12	5.46
Slaughter and food of animal origin	18	130	0.53	4.03
Services	5	755	0.16	29.18
Soybean	2	6	0.15	0.48
Oil and gas extraction	0	12	0.00	7.45
Other sectors	15	1,292	0.51	54.89
Biodiesel – non-family farming				
Commercialization	179	5,384	3.28	88.15
Livestock farming	158	2,066	1.21	8.81
Rest of farming and soybean	171	3,191	8.10	32.51
Manufacture of vegetable and animal oils and fats	98	699	2.87	25.37
Land transportation	31	1,261	0.71	25.50
Services	18	1,120	0.56	51.14
Oil and gas extraction	0	36	0.00	33.39
Other sectors	120	5,480	4.04	222.67

Source: Research results.

Faced with energy alternatives for replacing fossil fuels, an additional assessment was carried out to identify the potential socioeconomic impacts of biodiesel chains compared to diesel, considering the conventional measure of energy content of BOE. The impact on job creation due to the energy shock of 1 million BOE shows that the different biodiesel routes of the states, for family and non-family farming, generated an average of 6,200 jobs throughout Brazil, which corresponds to 3.6 times more than was generated by mineral diesel oil produced in Rio Grande do Sul. Biodiesel production via family farming in Rio Grande do Sul and Mato Grosso had the greatest impact for job generation in the country, accounting for 7,745 and 5,273 jobs, respectively (Table 9).

Table 8 **Overflow effect resulting from the production of biodiesel in Mato Grosso by sectors in the state of Rio Grande do Sul and the Rest of Brazil in 2018**

Sector	Jobs (Units)		GDP (Million USD)	
	RS	RBr	RS	RBr
Family farming biodiesel				
Commercialization	1	20	0.02	0.34
Rest of farming	1	3	0.01	0.02
Livestock farming	0	9	0.00	0.04
Land transportation	0	5	0.01	0.09
Manufacture of organic and inorganic chemicals	0	1	0.01	0.10
Oil and gas extraction	0	0	0.00	0.20
Services	1	19	0.02	0.70
Other sectors	1	19	0.05	0.83
Biodiesel – non-family farming				
Commercialization	208	5,978	3.5	97.9
Rest of farming	275	4,264	4.6	36.9
Livestock farming	96	1,777	0.7	7.6
Land transportation	72	1,332	1.3	26.9
Manufacture of organic and inorganic chemicals	16	149	2.1	19.2
Oil and gas extraction	0	42	0.0	38.4
Services	82	2,120	2.4	83.6
Other sectors	328	6,532	11.1	267.6

Source: Research results.

The expressive difference in the impact on occupations in an energy measure of 1 million BOE is a result, especially, of the technological difference that exists between the biodiesel and petroleum refining sectors, responsible for the production of diesel oil. Compared to the refining sector, which is characterized by intensive use of technology and capital, this result demonstrates that the biodiesel sector requires more labor to meet some variation in final demand, especially due to the direct link with the agricultural sector through the demand for raw materials.

Biodiesel chains contribute to the generation of wealth equivalent to an average of 175.52 million USD for the GDP. The production of mineral diesel oil from Rio Grande do Sul had an impact of 102.09 million USD. The greater impact of biodiesel on GDP is explained, in part, by its price, which is traditionally equivalent to almost double that of mineral diesel oil, and by the greater amount contained in a BOE. Thus, in terms of energy, diesel is more efficient, since fewer liters are needed compared to biodiesel to meet the energy demand of 1 million BOE. However, the price of biodiesel, higher than that of diesel oil, will make commercialized diesel more expensive and may result in a reduction in the consumption of biofuel.

Table 9 **Impacts on job generation, in units, and on GDP and VACF, in million USD, and the spillover effect, in percentage, in Brazil and the Rest of Brazil and in the states of Rio Grande do Sul and Mato Grosso, resulting from the energy shock of one million BOE in biodiesel, family farming biodiesel and mineral diesel products in 2018**

Region	Charac-teristic	Mato Grosso		Rio Grande do Sul		
		Biodiesel – family farming	Biodiesel – non-family farming	Biodiesel – family farming	Biodiesel – non-family farming	Mineral diesel oil
Brazil (Total)	Jobs	5,273	4,227	7,745	7,489	1,697
	GDP	132.14	129.52	224.20	216.14	102.19
	VACF	89.61	114.80	201.01	180.39	77.32
Rio Grande do Sul (RS)	Jobs	1.3%	2.4%	75.2%	54.0%	41.5%
	GDP	1.3%	1.9%	76.9%	59.5%	24.0%
	VACF	1.6%	1.8%	77.7%	57.6%	9.0%
Mato Grosso (MT)	Jobs	77.2%	48.4%	0.8%	1.8%	0.7%
	GDP	72.1%	56.3%	0.4%	1.7%	0.4%
	VACF	64.5%	57.1%	0.4%	1.8%	0.5%
Rest of Brazil (RBr)	Jobs	21.5%	49.2%	24.1%	44.2%	57.8%
	GDP	26.6%	41.8%	22.6%	38.8%	75.6%
	VACF	33.9%	41.1%	21.9%	40.6%	90.5%

Source: Research results.

In terms of impact on income generation, despite the total effects on the value added to factor costs (VACF) presenting large differences between the chains, the average monthly income per job generated in Brazil from the different biodiesel routes resulted in levels close to 1.91 thousand USD. The production of mineral diesel oil in Rio Grande do Sul, in turn, showed an income level almost twice as high as the effect of biodiesel production, which corresponded to an average income of 3,760 USD per month.

5 **Conclusion**

The research found that there are significant differences between the family biodiesel routes in the states of Rio Grande do Sul and Mato Grosso and in relation to non-family farming biodiesel routes. The impacts of job generation were shown to occur more intensely in family farming, which is a reflection of the characteristics of the Brazilian rural environment. The results showed that family farmers in Rio Grande do Sul were able to establish themselves in the biodiesel production chain. This is a region characterized by a family farming sector with better organizational, structural and productive conditions than the rest of the country.

In Mato Grosso, which is characterized by agricultural and agrarian development based on large-scale production, the impacts of biodiesel production resulted in effects far below what was observed in Rio Grande do Sul due to the low supply of raw material from family farmers. In turn, the low supply of family farmers from Mato Grosso is a result of the structural conditions of the state and the incompatibility of soybean production with the family farming structure, as this oilseed is based on an economy of scale that requires greater areas. Thus, the biodiesel production chain in Mato Grosso has selected only farmers who have this profile.

As such, the impacts resulting from the PNPB on family farming occur especially due to the structural conditions of the local economies, which can be observed in Rio Grande do Sul, which has a greater participation of family farmers, because it does effectively have family farming, including in other dynamic production chains.

The evidence gathered validates the importance of the Social Biofuel Seal insofar as it shows the relationship between the biodiesel chain and family farmers, which results in impacts on the local economy and family farming. However, it was not possible to confirm whether the Seal is responsible for the relationship between these sectors and requires additional analyses to validate the idea of the SBS, such as the application of General or even Partial Balance models to assess whether changes in the Seal tax rates displace the demand for raw material from family farming to states with more developed family farming sectors.

The participation of family farmers from Rio Grande do Sul in the biodiesel production chain shows that these farmers had significant gains with their participation in the Program, which was not observed in Mato

Grosso, where structural restrictions and local conditions limited the access of family farming in the biodiesel chain.

In short, the Program has not been able to promote the cultivation of alternative crops that are more viable for small producers, so it has selected only the most capitalized farmers who are able to produce soybeans on their property in a profitable manner, which explains the inexpressive production of family biodiesel in the state of Mato Grosso and in most of the other state.

The promotion of alternative cultures requires investments, scientific-technological development and regulation, to mention a few factors. As it involves many risks, the promotion of new cultures also needs incentives, which one would expect to be provided by the government. However, the State lacks the capacity to lead a national project capable of carrying out these investments and promoting the necessary incentives.

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About the authors

Pedro Gilberto Cavalcante Filho – pedro.gilberto@hotmail.com
Center for Applied, Agricultural and Environmental Economics (CEA+) of the Institute of Economics of the State University of Campinas (IE/UNICAMP), Campinas, SP, Brazil and Brazilian Agricultural Research Corporation (Embrapa) Territorial, Campinas, SP, Brazil.
ORCID: https://orcid.org/0000-0003-1776-0295.

Antônio Márcio Buainain – buainain@unicamp.br
Center for Applied, Agricultural and Environmental Economics (CEA+) of the Institute of Economics of the State University of Campinas (IE/UNICAMP), Campinas, SP, Brazil.
ORCID: https://orcid.org/0000-0002-1779-5589.

Marcelo Pereira da Cunha – mpcunha@unicamp.br
Center for Applied, Agricultural and Environmental Economics (CEA+) of the Institute of Economics of the State University of Campinas (IE/UNICAMP), Campinas, SP, Brazil.
ORCID: https://orcid.org/0000-0002-1027-1694.

Gabriela Solidario de Souza Benatti – gssbenatti@gmail.com
Center for Applied, Agricultural and Environmental Economics (CEA+) of the Institute of Economics of the State University of Campinas (IE/UNICAMP), Campinas, SP, Brazil.
ORCID: https://orcid.org/0000-0002-1594-9919.

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Contribution of the authors

Pedro Gilberto Cavalcante Filho: data collection, data analysis and text writing.
Antônio Márcio Buainain: Work supervision, text review, text writing.
Marcelo Pereira da Cunha: data collection, text review.
Gabriela Solidario de Souza Benatti: text review, text writing.

About the article

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APPENDIX

A1 **Input-Out Matrix**

The inter-regional input-output matrix (Z Matrix) is obtained through the inter- and intra-regional matrice ($Z^{n,n}$), considering the three regions defined in this work:

$$Z = \begin{bmatrix} Z^{1,1} & \cdots & Z^{1,3} \\ \vdots & \ddots & \vdots \\ Z^{3,1} & \cdots & Z^{3,3} \end{bmatrix} \tag{A1}$$

Matrix $Z^{1,1}$ represents the internal flow of goods and services in region 1. Trade flows between regions are computed by off-diagonal matrix elements. For example, the elements in $Z^{1,3}$ describe the flow of goods and services from region 1 to region 3 (MILLER; BLAIR, 2009).

The division of the monetary flows in each sector of each region ($z_{i,j}$) by the total product (x_j) of that sector results in the technology matrix (A). The elements ($a_{i,j}$) represent the technical coefficients. Estimates of cash flows are unique to each sector within each region in the model and result in an estimate of region-specific intra- and inter-regional technology matrices, reflecting regional differences in economic structures.

The elements of the technical coefficient matrix A are calculated as follows:

$$\text{Intra-regional: } a_{i,j}^{1,1} = \frac{z_{i,j}^{1,1}}{x_j^1} \text{ where } A^{1,1} = \begin{bmatrix} a_{1,1}^{1,1} & a_{1,2}^{1,1} & \cdots & a_{1,n}^{1,1} \\ a_{2,1}^{1,1} & a_{2,2}^{1,1} & \cdots & a_{2,n}^{1,1} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1}^{1,1} & a_{n,2}^{1,1} & \cdots & a_{n,n}^{1,1} \end{bmatrix} \tag{A2}$$

$$\text{Inter-regional: } a_{i,j}^{1,3} = \frac{z_{i,j}^{1,3}}{x_j^3} \text{ where } A^{1,3} = \begin{bmatrix} a_{1,3}^{1,3} & a_{1,2}^{1,3} & \cdots & a_{1,n}^{1,3} \\ a_{2,1}^{1,3} & a_{2,2}^{1,3} & \cdots & a_{2,n}^{1,3} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1}^{1,3} & a_{n,2}^{1,3} & \cdots & a_{n,n}^{1,3} \end{bmatrix} \tag{A3}$$

The interregional model has the same structure as the basic equation of the input-output analysis $(IA)^{-1}. X = Y$, where I is the identity matrix, A is the matrix of technical coefficients, X is the product and Y the final demand. The Leontief system for the inter-regional model is described as follows (MILLER; BLAIR, 2009):

$$\left\{\begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} \begin{bmatrix} A^{1,3} & \cdots & A^{1,3} \\ \vdots & \ddots & \vdots \\ A^{3,1} & \cdots & A^{3,3} \end{bmatrix}\right\} \begin{bmatrix} x^1 \\ \cdots \\ x^3 \end{bmatrix} = \begin{bmatrix} Y^1 \\ \cdots \\ Y^3 \end{bmatrix} \tag{A4}$$

The direct and indirect effects on GDP, employed persons and VACF were obtained by multiplying the region's total sector product X by their respective coefficients. These coefficients were obtained by dividing the variables analyzed (total sectoral GDP, employed persons and VACF) by their respective production values (MILLER; BLAIR, 2009). The sectoral GDP corresponds to the sum of total net indirect taxes on domestic and imported intermediate consumption, labor remuneration, capital remuneration and direct taxes on this sector.

A2 **Procedure for disaggregating products and sectors**

In order to disaggregate the family biodiesel manufacturing sectors and the cultivation of soy from family farming, and the family biodiesel and soy products from family farming for the production of biodiesel, the proportion of biodiesel produced with raw material from the family farming in relation to the total amount of biodiesel produced in their respective state. This measurement was possible through data from the SCS, which records the amount of raw material sold by family farmers, and from the ANP, which has the quantity of biodiesel production at the state level.

Thus, for the case of Rio Grande do Sul, it was identified that 27% of biodiesel production in that state originates from raw material in family farming. Therefore, in the model, these sectors and products that were disaggregated in the state of Rio Grande do Sul account for 27% of the original sectors and products.

The disaggregation criterion for such sectors and products in the state of Mato Grosso was 5%, since it was identified that the biodiesel produced in that state comes from raw material in family farming corresponding to this percentage. Thus, based on this criterion, it was possible to obtain the production value of these products and sectors in their respective states.

After obtaining the production value, it was possible to calculate the proportion to estimate intermediate consumption, taxes, wages, imports and the gross mixed income of the sectors in the regions. The number of jobs in the family biodiesel manufacturing sector was estimated from this proportion. However, the number of jobs in the soy sector of family farming for the production of biodiesel was estimated considering the average proportion of labor used by family farming in the states of Rio Grande do Sul and Mato Grosso, based on the Agricultural Censuses of 2006 and 2017. Thus, it was established that Personnel Employed by family farming (PO_{Af}) is generated by the following equation:

$$PO_{Af} = VP_{Af} \,.\, Propmédia_{PO_{Af}} \quad \text{(A5)}$$

where, VP_{Af} is the production value of family agriculture that supplies soybeans for biodiesel and $Propmédia_{PO_{Af}}$ is the average proportion of the years 2006 and 2017 of people employed by family farming by value of the total production of the establishments. We chose to use the average of the years 2006 and 2017, as the estimated matrix is for the year 2011.

