Artículos

A Decade of Biodiesel Industry in Brazil: An Analysis of Concentration and Market Structure from 2010 to 2021

Una década de la Industria del Biodiésel en Brasil: Un Análisis de la Concentración y Estructura del Mercado desde 2010 hasta 2021

Uma década da Indústria do Biodiesel no Brasil: Uma Análise da Concentração e Estrutura de Mercado de 2010 a 2021

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Abstract: This article analyzes the Brazilian Biodiesel Industry from 2010 to 2021 using the CR4, CR8 indexes, and the Herfindahl-Hirschman Index (HHI). Utilizing biodiesel production data from the National Agency for Petroleum, Natural Gas, and Biofuels [ANP] database, we evaluate the concentration of producers in the CR2, CR4, and CR8 categories via frequency distribution. The findings reveal that the biodiesel industry maintains a moderately low level of concentration, exhibiting minor fluctuations in CR4 and CR8. The analysis characterizes the industry as an oligopoly plus oligopsony, or a bilateral oligopoly, where large producers dominate production, and small producers hold a negligible share.

Keywords: Biodiesel, Brazil, Industry Concentration, Industrial dynamic.

Resumen: Este artículo analiza la industria brasileña de biodiesel desde 2010 hasta 2021 utilizando los índices CR4, CR8 y el índice de Herfindahl-Hirschman (HHI). El estudio utiliza datos de producción de biodiesel de la base de datos de la Agencia Nacional de Petróleo, Gas Natural y Biocombustibles[ANP] y analiza la concentración de productores en las categorías CR2, CR4 y CR8 a través de la distribución de frecuencia. Los resultados muestran que la industria de biodiesel ha mantenido un nivel moderadamente bajo de concentración, con pequeñas variaciones en CR4 y CR8. El análisis identifica a la industria como un oligopolio más oligopsônio, o un oligopolio bilateral, donde los grandes productores dominan la producción y los pequeños productores tienen una participación insignificante.

Palabras clave: Biodiésel, Brasil, Concentración industrial, Dinámica industrial.

Resumo: Este artigo analisa a indústria brasileira de biodiesel de 2010 a 2021 utilizando os índices CR4, CR 8 e o índice de Herfindahl-Hirschman (HHI). O estudo utiliza os dados de produção de biodiesel advindos da base de dados da Agência Nacional do Petróleo, Gás Natural e Biocombustíveis [ANP],

e a analisa a concentração de produtores nas categorias CR2, CR4, CR8 através da distribuição de frequência. Os resultados mostram que a indústria de biodiesel tem mantido um nível moderadamente baixo de concentração com pequenas variações em CR4 e CR8. A análise identifica a indústria como um oligopólio mis um oligopsônio, ou oligopólio bilateral, com grandes produtores dominando a produção e com os pequenos produtores tendo uma participação insignificante.

Palavras-chave: Biodiesel, Brasil, Concentração, Dinâmica industrial.

Introduction

Biodiesel is a biofuel that has been gaining ground in the energy mix of many countries, stimulated by the replacement of fossil fuels. In Brazil, the biodiesel industry was stimulated by the implementation of the National Plan for the Production and Use of Biodiesel (PNPB) in 2003, specifically Law 11,097 (Brasil, 2022a), which establishes the regulatory framework for the introduction of biodiesel in the Brazilian energy matrix. The program aims to (i) promote the sustainable production and use of biodiesel while ensuring regional development and social inclusion, (ii) ensure competitive prices and quality, and (iii) supply biodiesel for blending with diesel across the country (Brasil, 2022b).

In 2016, the Brazilian Government launched a new regulatory framework for the biofuel sector, a program named RenovaBio 2030, which integrates biodiesel and bioethanol production. RenovaBio programrenewed th legal framework for biodiesel, focusing on the economic, environmental, and social sustainability of biodiesel and contributing to energy security, market predictability, and greenhouse gas emission reduction in the fuel sector.

The new strategic policy aims to discuss biofuel sustainability - environmentally, economically, and socially - establish trading rules, and encourage investments in this industry until 2030, in accordance with the Brazilian commitments at COP21 (UN Climate Conference) of increasing the share of sustainable biofuels to around 18% of the overall national energy mix by 2030 (Brasil, 2022b). RenovaBio has three strategic axles: Decarbonization Targets, Biofuel Production Certification, and Decarbonization Credit (CBIO).

Since the implementation of PNPB, going through RenovaBio, the biodiesel industry has consolidated its market. The production had a significant increase from 736 m^3 in 2005 to 2,171,614 in 2010 and bounced to 6,765,850 in 2022 (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis [ANP], 2022a). The motivation for this growth was the increase in the percentage of biodiesel blended with mineral diesel, which is set by the government, and which led to the incorporation of many plants within the industry. In 2005, the optional blend percentage was 2% (B2). In 2007, the use of biodiesel became mandatory, and the blend percentage was set at 3% (B3) in the first half of 2008. By mid-2009, the blend percentage of biodiesel had risen to 4% (B4). From 2010 until July 2014, the blend percentage was stable at 5% (B5). From July to October 2014, the blend percentage was 6%, rising to 7% between November 2014 and February 2017, and to B8 from March 2017 to February 2018 (ANP, 2022a).

In 2018, CNPE Resolution n°16 predicted a yearly 1% increase in the blend percentage up to 15% in 2023. However, the industry had an increase in the blend percentage until October 2020, returning to the level of 10% in October 2020 which remains at the present date, August 2022. Apart from regulating the blend percentage, the Brazilian government also directs and manages the trading of biodiesel. It is important to note that the progressive increase in the blend rates has been parallel to the structural changes on biodiesel sales undergone in 2012.

The National Energy Policy Council (CNPE) established the biodiesel purchase and sale model, mandating that producers and importers of mineral diesel buy biodiesel through auctions conducted by the ANP. Until 2012, the volume of auctions was defined based on the proportion of biodiesel to their national market share of diesel, as per Resolution No. 3 of September 23, 2005. The ANP set the maximum price to be paid for the biodiesel at auction before the auction took place. During the auctions, approximately 80% of the traded volume was reserved for bids from producers who held the Social Fuel Seal, certifying that the biodiesel produced by the plant meets the minimum percentages of raw materials obtained from Family Farmers, as required by Instruction No. 1 of July 5, 2005 (ANP, 2022b). The remaining 20% of the volume received bids from plants without Social Fuel Seal. After purchasing biodiesel in those auctions, Petrobras and REFAP sold the volumes through auction to private distributors such as Shell, Esso, Ipiranga, Texaco, BR Distribuidora, among others, responsible for blending biodiesel with the mineral diesel based on the percentages determined at the time.

The change in the biodiesel auction format in 2012 played a crucial role in increasing competition. Distributors were allowed, for the first time, to choose the plants that best suited their needs in terms of logistics, price, and quality. In the new model, each supplier could submit up to three volume and price proposals, and the price proposals had to be lowered at least once before being offered to Petrobras. The key difference is that the state-owned company, Petrobras, could buy the fuel considering the demands of the distributors for volume and quality. This improved the quality of the final product and the provision of services by the producers, enabling distributors to buy lots from those who had better delivery conditions and product quality (Brasil, 2022b).

The evolution of demand, driven by legislation, has influenced the growth of the biodiesel industry in Brazil. The government has played an important role in regulating the industry, creating an interesting economic and political context for the sector. The government's ability to alter the course of the biodiesel industry in Brazil is in line with the argument presented by Bhattcharya & Bloch (2000), which suggests that trade policy may have more influence over industry concentration than competition policy, supporting the findings of Henley (1994), as we see in the biodiesel industry in Brazil.

The study of industrial organization, through the traditional structure-conduct-performance approach, has determined that concentration is influenced by the basic supply and demand conditions facing an industry. In the biodiesel industry, studies have shown that the industry is concentrated based on biodiesel production volume or sales volume (Tanaca & Souza, 2010; Leonardi, Scarton, Padula & Coronel, 2011; Santos & Padula, 2012; Cavalheiro, 2014; Moreno-Pérez, Marcossi & Ortiz-Miranda, 2017). Santos and Padula (2012) demonstrated that the biodiesel industry's dynamics shifted from highly concentrated in 2005 to moderately concentrated in 2010, and even with the entrance of small biodiesel production plants, biodiesel production remained concentrated in large plants. Moreno-Pérez et al. (2017), based on biodiesel delivery, showed a trend towards lower concentration during the first years of the market's development, and an apparent stability. For the authors, this indicates an apparent stability, resulting from a certain level of maturity.

The question that arises from these results is: what has happened with the biodiesel industry's dynamics since then? To answer this question, the aim of this study is to analyze the dynamics of the Brazilian biodiesel industry from 2010 to 2021."

Industrial Organization and Concentration

Within the economic theory of Industrial Organization, one of the ways to understand the term "market structure" is to use the Structure-Conduct-Performance model, originally proposed by E. S. Mason and disseminated from contributions made by Joe S. Bain. For Bain (1959), a market exerts strategic influence on the nature of competition and pricing in the market. In this industrial organization approach, the notion

that concentration is determined by the market structure, which is seen as the organizing feature of the basic supply and demand condition facing an industry, is complemented by the notion that there is a simultaneous determination of concentration and pricing behavior in equilibrium (Cowling & Waterson, 1976) and that an inverse relation is expected between a lower bound for concentration and market size, only if set-up costs for the industry are exogenously determined (Sutton, 1991).

The structural characteristics of an industry influence the behavior of the firms, as well as the costs, prices, profits, and innovative activities within it. These structural characteristics form the market structures, which have features such as market concentration, substitutability of products, and entry barriers (Possas, 1990). Market concentration, especially the concentration of production or sales, plays an important role in determining the behavior and performance of the firm and may be seen as a determinant of competition (Bain, 1959; George, Joll & Lynk 1992).

In the structure-conduct-performance paradigm, industry concentration is a crucial aspect in market structure design, as it defines the allocative performance of the markets. Therefore, concentration is frequently used as a measure to summarize the structural characteristics of the industry. However, it is noteworthy that concentration is just one of many features that represent the structure of a given market (Curry & George, 1983; Scherer & Ross, 1990).

On the other hand, the concentration level can be seen as a result of stochastic elements. Thus, it can be understood as a product of a growth process rather than as its determinant (Caves, 1998). Therefore, industrial concentration should be seen not only as a variable that summarizes the structural characteristics of a market, but it also consolidates information about forces operating in a market, including strategic (in the case of the structure-conduct-performance paradigm) and stochastic variables (as in the case of the Law of Proportionate Effect and its consequences).

The evolution of concentration within an industry expresses the characteristics of the flow of firms into it and the ability of leading firms to protect and expand their market shares. According to Donsimoni, et al. (1984), concentration rates may provide an important indicator of the industrial structure, especially if performance measures are not clearly observed. Thus, an examination of the evolution of concentration levels is still relevant in the analysis of the dynamics of industrial sectors where there is insufficient data or information available to use more robust models or indexes. This is the case for new industries or those in which there is not sufficient data.

For Bain (1959), concentration refers to the control or ownership of an aggregate of economic resources and activities, in a large proportion, by a limited number of production units. On the other hand, an industry is a group of companies that produce substitute products or the same product (Bain, 1951;1959). Thus, the concentration of an industry is seen as "the proportion of the combined production volume of such a group of close substitute outputs supplied by one, four, eight, or twenty firms" (Bain, 1951, p. 298).

Regarding this vision of concentration, the main questions raised are: (i) whether the number of sellers in this industry is small or large; (ii) whether the market share controlled by some or all of the sellers is large enough to permit the existence of an oligopolistic pricing strategy or conduct; (iii) if the oligopolistic interdependence exists, how strong it is (Bain 1959)? This oligopolistic interdependence exists when a small number of sellers in an industry have a market share so large that an increase in their share of sales occurs with the loss of a portion of the share of other companies in the same industry.

Market concentration is not static, as it is influenced by various factors such as firms' pursuit of maximum efficiency, technological advancements, market growth rates, advertising, mergers, and government policies (Bain, 1959;George, Joll & Lynk, 1992). Despite its dynamic nature, market concentration can be measured by assessing the proportion of sales or production generated by companies within a specific industry and time frame.

In addition to the concentration of supply, Bain (1959) emphasizes the importance of considering the degree of concentration of demand when analyzing market structure. This refers to the number and

distribution of buyers in an industry. When buyers are highly concentrated (oligopsony or a monopsony), their large purchasing power gives them greater bargaining power. This contrasts with oligopoly (or monopoly), where producers have more power to set prices.

There are four categories which are distinguished based on the concentration of sellers and buyers, which: (i) Fully atomistic markets - many small buyers and sellers, (ii) Ordinary Oligopoly - many small buyers, but with a significant degree of concentration of sellers, (iii) Ordinary Oligopsony, or oligopsony plus atomistic selling – a significant degree of concentration of buyers with many small sellers, and (iv) Oligopoly plus Oligopsony or Bilateral Oligopoly - a significant degree of concentration of sellers and buyers. Thus, the analysis of the concentration within an industry may consider the issues related to both its supply and demand sides (Bain, 1959).

Hall and Tideman (1967) and Hannah and Kay (1977) have identified several features that must be considered when measuring industrial concentration. These authors propose that any concentration measure should be based on market shares and should take into account concentration as a function of the inequality of market shares and the number of companies.

Bain's (1951) concentration index, which considers the control of business by a limited number of firms, and the Herfindahl-Hirschman Index (HHI) both meet the requirements set forth by Hall and Tideman and Hannah & Kay. However, both indices have limitations. They only deal with one point on the curve of cumulative concentration (Curry & George, 1983), and the HHI is influenced by variations in the number of companies, which can affect the dispersion of the average size of enterprises in the sector. An increase in the number of companies, while the variance is held constant, can lead to an increase in inequality. Additionally, it can be difficult to determine the relative size of new firm entries.

Despite these limitations, concentration indices are still useful when other performance measures cannot be used (Donsimoni, Geroski, & Jacquemin, 1984), or when a more comprehensive view of industrial dynamics is desired.

Method and Procedures

To achieve the aim of this research, two measures were used to determine the concentration degree within the Biodiesel Industry: The Concentration Ratio (CR) proposed by Bain in 1951, which measures the market share of the top "n" largest companies, and the Herfindahl-Hirschman Index (HHI), which calculates the sum of squared market shares of all companies in the market. The CR can be calculated using the following formula:"

$$CR(k) = \sum_{i=1}^{k} Si \quad (1)$$

CR(k) represents the concentration ratio of the top k industries and Si denotes the market share (expressed in parts per unit) of the I industries. When using the Concentration Ratio (CR), there is a degree of arbitrariness in selecting the value of "n" for the concentration ratio. To address this issue, we have used the ranking system proposed by Bain (1959) as a reference point (see Table 1). Table 1 displays the concentration levels for CR4 and CR8, starting from the highest level of concentration and descending to lower levels of concentration.

TABLE 1
Industry concentration patterns

Percentage of the market held by the 4 largest companies	Percentage of the market held by the 8 largest companies	Degree of concentration
75% or higher	90% or higher	Very High
65 to 75%	85 to 90%	High
50 to 65%	70 to 85%	Moderately High
35 to 50%	45 to 70%	Moderately Low
35% or lower	45 or lower	Low

Note. Based on Bain (1959).

When calculating the HHI, a company's market share can be expressed as a percentage or in decimal form (e.g. 9% or 0.09). When expressed in decimals, the result falls within the range of zero to one. A value close to zero indicates a higher number of firms serving the market, which corresponds to a less concentrated market. Conversely, an HHI value close to one indicates a small number of firms serving the market, making it more concentrated, with a value of 1 representing a monopoly. HHI range bellow 0.15 indicates an unconcentrated industry, between 0.15 and 0.25 a moderately concentrated market and above 0.25 a concentrated one[1]. The HHI index is defined as follows:

$$HHI = \sum_{i=1}^{N} S_i^2 \tag{2}$$

George, Joll, and Lynk (1992) emphasize the importance of clearly defining the industry to be analyzed to avoid problems related to representativeness in concentration calculations. Therefore, we have chosen to focus on the biodiesel industry at the national level, where there are no regional markets and strong product differentiation is absent. Biodiesel plants currently compete with each other nationally.

In this study, we used the volume of biodiesel produced in Brazil between 2010 and 2021, as reported in the National Agency of Petroleum (ANP) databases, to calculate the CR and HHI. This approach enabled us to identify changes in the structure of the biodiesel industry during the period of analysis. The indexes were calculated annually (bids held in the same year were aggregated), based on the amount of biodiesel produced (rather than delivered). The unit of analysis was the firm, regardless of whether it produced in one or more plants located in different regions, considered as an economic group.

ANP data also allowed for an analysis of the industry structure based on plant size. We utilized frequency distribution to determine the predominant size of biodiesel plants produced between 2010 and 2021. Table 2, below, displays the classification of plant sizes used for calculating the frequency distribution.

TABLE 2
Classification by size of the biodiesel plants

Classification	Nominal Capacity (m3/year)
Small	<120,000 m3/year
Medium	120,000 - 200,000 m3/year
Large plant	>200,000 m3/year

Note. Based on Moreno-Pérez et al. (2017).

To explore and describe the organization and history of the Brazilian biodiesel industry, we utilized data and information from various sources, including the Ministry of Mining and Energy (MME), the regulations and guidelines of the National Program for Production and Use of Biodiesel (PNPB), and RENOVABIO.

Expansion and concentration of biodiesel industry in Brazil

Between 2005 and 2021, biodiesel production showed a significant increase, a growth of 184%. The biodiesel production structure shows a significant presence in the Midwest and South regions, accounting for 86.6% of the national production (Figure 1). This configuration can be attributed to the principal row material used in biodiesel production, which is soybean (ANP, 2022c). Additionally, biodiesel supply chain structure in those regions is characterized by the presence of well-established consolidated players in grain activity, specifically in soy market, which has oil as a co-product and had higher utilization and value with the emergence of the biodiesel market (Santos, 2013).

The soybean represents 72.2% of all raw material in 2021, in Midwest was used by 79.5% of biodiesel production and 75.5% in South% (ANP, 2022c). Soy production chain is well structured and highly dynamic chain with up-to-date and precise technologies, allied to this fact, the soy is not produced primarily for the biofuels market, but as raw material to the production of meat, eggs and milk (Oliveira & Coelho, 2017).

Those regions also received investments in machinery and equipment for agro-industrial implementation and agricultural investments directed towards the soybean activity, undergone a major process of agricultural development, which consolidated themselves as major grain producers with the installation of dynamic agro-industrial hubs (Cavalcante Filho, Buainain & Souza Benatti et al, 2019).

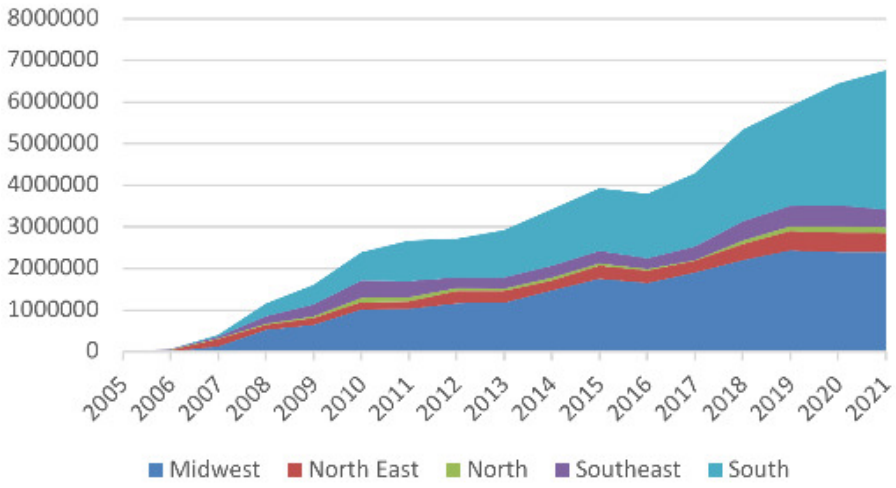

FIGURE 1

Evolution of biodiesel production (m3) by Brazilian region

Note. Made from ANP (2022a) biodiesel production data.

As of 2021, Brazil possessed 55 biodiesel plants (Figure 2), boasting a collective production capacity of 33,931 m3/day. The largest capacity was held by Potencial Biodiesel Ltda., being able to produce 2,500 m3/day. Following closely is Olfar S/A unit Porangatu Goias with a capacity of 1,800 m3/day, and Granol unit Anapolis Goais with a capacity of 1,550 m3/day. However, when considering the economic groups, Olfar stands out with a production capacity of 3,450 m3/day, spread across three units. Granol is the second one with three units and a total 3,283 m3/day. BsBios and Oleoplan both operate two plants each, with an authorized capacity of 2,600 m3/day. Despit e having plants distributed throughout all national regions, there is a concentration and production representation in the Midwest and South.

FIGURE 2
Brazilian producer locations
Note: Developed by the authors from ANP (2022c).

The highest incidence of biodiesel producing units in those regions can be attributed to the greatest raw material supply for biodiesel production. In fact, soybeans serve as primary raw material feeding the Brazilian biodiesel supply chain (Santos & Padula, 2012; Santos, 2013;ANP, 2022c), due to it intrinsic advantages. The soybean production not only fulfills the domestic demand for biodiesel, but also offers the most competitive prices, compared to other raw materials, (Padula, Santos, Ferreita & Borenstein, 2012; da Silva César, Conejero, Ribeiro & Batalha, 2019), and give a better support to the social aspect of the federal program (da Silva César, Conejero, Ribeiro & Batalha, 2019). Additionally, biodiesel from soybean demonstrates a higher profitability (Alves, Belarmino & Padula, 2017). Alves et al. (2017) emphasize that alternative oilseed production systems for biodiesel production are still rudimentary, experimental and surrounded by uncertainty in the various Brazilian regions, reinforcing the statement that soybean continue to be the best option to biodiesel production in Brazil.

Upon analyzing the origin and destination of biodiesel in 2021, the data reveals that despite being a major producer of biodiesel, Midwest ranks fourth in terms of consumption. On the other hand, the Southeast region takes the lead as primary destination for biodiesel, while it ranks fourth in terms of production (ANP, 2022c). This phenomenon was also observed by Cremonez et. al (2015) who describe a similar movement in 2015. They asserted that the biodiesel produced in decentralized areas (South and Midwest) are primarily sent to southeastern region, the most populous and industrialized region in the country.

Several studies (Tanaca & de Souza, 2010; Leonardi, Scarton, Padula & Coronel, 2011; Santos & Padula, 2012; Cavalheiro, 2014) have examined the concentration of businesses in biodiesel industry

during its initial expansion stage (between 2005 and 2010). These studies have pointed out the high level of concentration in this industry during that period, with only a few companies as biodiesel supplier. However, despite the industry's concentration during this period, there was a reduction in the concentration percentage. In fact, according to Santos and Padula (2012), the concentration rate CR2 was 90.57% in 2005 and 24% in 2010.This could be attributed to a more homogeneous production distribution among the major producers, which have consolidated their position in the industry over the years.

The data revels that in 2010, there was a 33% variation in production compared to previous year. The concentration rate CR2 was 24%, CR4 stood 41.12%, and CR8 reached 66.93% (Table 3a and 3b), indicating a moderately low degree of concentration. Granol maintained its first-place position with a 14.05% share of annual production. The HHI achieve 0.0703, denoting a trend towards less concentration within the industry. The next year had the top four producers accounted for 40.6% of biodiesel production, while the CR8 reached 66.1%. Granol continued to lead the industry with the highest production volume, while Caramuru moved up two positions and maintained the second position with a 9% share of total production. The concentration of the industry followed the trend of 2010 and remained moderately low.

TABLE 3A
Biodiesel industry concentration ratio in 2010

2010						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	335,342.56	14.1%	14.1%	14.1%	14.1%	0.020
ADM	237,534.95	10.0%	10.0%	10.0%	10.0%	0.010
PETROBRAS	202,223.26	8.5%		8.5%	8.5%	0.007
CARAMURU	198,792.81	8.3%		8.3%	8.3%	0.007
OLEOPLAN	196,144.52	8.2%			8.2%	0.007
BSBIOS	174,661.55	7.3%			7.3%	0.005
BRASIL ECODIESEL	173,125.50	7.3%			7.3%	0.005
JBS	119,974.44	5.0%			5.0%	0.003
Subtotal	1,637,799.59		24.0%	40.8%	68.6%	
Others	748,598.93		76.0%	59.2%	31.4%	
Total	2,386,398.52		100.0%	100.0%	100.0%	0.064

Note. Author calculations based on data from ANP (2022a).

TABLE 3B
Biodiesel industry concentration ratio in 2011

ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	381,196.45	14.3%	14.3%	14.3%	14.3%	0.020
CARAMURU	239,993.90	9.0%	9.0%	9.0%	9.0%	0.008
OLEOPLAN	237,755.55	8.9%		8.9%	8.9%	0.008
PETROBRAS	225,946.86	8.5%		8.5%	8.5%	0.007
BSBIOS	217,179.63	8.1%			8.1%	0.007
BRASIL ECODIESEL	174,155.35	6.5%			6.5%	0.004
ADM	150,032.12	5.6%			5.6%	0.003
FIAGRIL	140,238.00	5.2%			5.2%	0.003
Subtotal	1,766,497.85		23.2%	40.6%	66.1%	
Others	906,262.06		76.8%	59.4%	33.9%	
Total	2,672,759.92		100.0%	100.0%	100.0%	0.060

Note. Author calculations based on data from ANP (2022a)

In the year 2012, there were 42 economic groups producing biodiesel, and there was a slight increase in the concentration level, CR4 went up almost 5 points, reaching 44.7%, while the CR8 stood 70.1% (Table 4). Despite this increment in concentration, it level remained moderately low, due to the non-existence of a significant change in concentration levels among producers participating in the CR8, even with the entrance of a new producer, Camara, as part of the top eight biodiesel producers. It is worth noting that in 2012, the auction rules changed, prioritizing producers with the best quality and guaranteed delivery, However, even this alteration in the regulation, did not change the configuration of industry concentration.

TABLE 4
Biodiesel industry concentration ratio in 2012

ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	352,439.56	13.0%	13.0%	13.0%	13.0%	0.017
OLEOPLAN	301,079.08	11.1%	11.1%	11.1%	11.1%	0.012
PETROBRAS	296,302.39	10.9%		10.9%	10.9%	0.012
CARAMURU	265,138.02	9.8%		9.8%	9.8%	0.010
BSBIOS	244,511.20	9.0%			9.0%	0.008
CAMERA	168,553.62	6.2%			6.2%	0.004
ADM	149,547.09	5.5%			5.5%	0.003
FIAGRIL	126,533.39	4.7%			4.7%	0.002
Subtotal	1,904,104.34		24.0%	44.7%	70.1%	
Others	813,379.15		76.0%	55.3%	29.9%	
Total	2,717,483.49		100.0%	100.0%	100.0%	0.068

Note. Author calculations based on data from ANP (2022a).

For the next two years, 2013 and 2014, the industry exhibited a decline in the concentration rate, CR4 reached 42.3% and 40.9%, respectively, while CR8 registered 66.4% and 65.8%. Meanwhile, the HHI index remained the same in both periods, at 0.06, suggesting an unconcentrated industry. The top eight producer companies remained the same in both years, however, the order in the ranking changed (refer to Table 5) The number of economic groups decreased from 40 in 2013 to 35 by 2014, the drop of this number responds to acquisitions of some plants by other companies operating in the biodiesel market, due to business dynamism of the sector, as also observed by (Moreno-Pérez et al., 2017). It is worth noting that the increase in the volume of production can be attributed to the increase in mixture percentage from 5% to 7% in November 2014.

TABLE 5
Biodiesel industry concentration ratio in 2013 and 2014

2013						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	371,254.74	12.7%	12.7%	12.7%	12.7%	0.016
PETROBRAS	327,223.87	11.2%	11.2%	11.2%	11.2%	0.013
OLEOPLAN*	274,274.61	9.4%		9.4%	9.4%	0.009
BSBIOS	261,414.28	9.0%		9.0%	9.0%	0.008
CARAMURU	249,735.11	8.6%			8.6%	0.007
BIANCHINI	192,680.57	6.6%			6.6%	0.004
ADM	130,889.20	4.5%			4.5%	0.002
CARGILL	129,513.78	4.4%			4.4%	0.002
Subtotal	1,936,986.14		23.9%	42.3%	66.4%	
Others	980,502.13		76.1%	57.7%	33.6%	
Total	2,917,488.27		100.0%	100.0%	100.0%	0.061
2014						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	497,375.82	14.53%	14.5%	14.5%	14.5%	0.021
OLEOPLAN*	321,455.09	9.39%	9.4%	9.4%	9.4%	0.009
BSBIOS	314,316.58	9.18%		9.2%	9.2%	0.008
PETROBRAS	264,922.85	7.74%		7.7%	7.7%	0.006
CARAMURU	262,593.36	7.67%			7.7%	0.006
ADM	229,783.26	6.71%			6.7%	0.005
BIANCHINI	210,008.59	6.14%			6.1%	0.004
CARGILL	152,194.59	4.45%			4.4%	0.002
Subtotal	2,252,650.14		23.9%	40.9%	65.8%	
Others	1,169,559.76		76.1%	59.1%	34.2%	
Total	3,422,209.90		100.0%	100.0%	100.0%	0.061

Note. Author calculations based on data from ANP (2022a).

In 2015, the trend towards market deconcentration continued, CR4 felt 39.3% and CR8 to 64.7% (Table 6). Granol maintained its first-place in terms of annual production, although its share decrease by 2.2%, compared to the previous year. The HHI also continued to fall, reaching 0.056, indicating a tendency towards less concentration within the industry. The surprise that year was the entry of a new company, COFCO, which had not been part of the group of eight largest biodiesel producers before.

TABLE 6
Biodiesel industry concentration ratio in 2015

ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
GRANOL	484,708.07	12.3%	12.3%	12.3%	12.3%	0.015
OLEOPLAN*	378,178.92	9.6%	9.6%	9.6%	9.6%	0.009
BSBIOS	370,051.30	9.4%		9.4%	9.4%	0.009
ADM	314,441.35	8.0%		8.0%	8.0%	0.006
PETROBRAS	300,629.40	7.6%			7.6%	0.006
CARAMURU	291,998.50	7.4%			7.4%	0.006
BIANCHINI	233,662.94	5.9%			5.9%	0.004
COFCO	174,953.01	4.4%			4.4%	0.002
Subtotal	2,548,623.47		21.9%	39.3%	64.7%	
Others	1,388,645.06		78.1%	60.7%	35.3%	
Total	3,937,268.53		100.0%	100.0%	100.0%	0.056

Note. Author calculations based on data from ANP (2022a).

In the following year, a new economic group joined the top 8 producers. Potencial began operating in 2013, producing 70,447.5 m3. In 2016, their production volume increased to 195,846.3 m3, representing 5.2% of annual production. Bsbios secured the leading position concentrating 10.4% of production (Table 7), which reinforces the ongoing trend of diminishing concentration among the major biodiesel producers. Oleoplan was closely behind with 10.1%, and together they accounted for 20.5% of all biodiesels produced that year. The CR8 and HHI still indicate moderately low concentration in this industry.

TABLE 7
Biodiesel industry concentration ratio in 2016

ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
BSBIOS	395,626.20	10.4%	10.4%	10.4%	10.4%	0.01
OLEOPLAN*	383,925.34	10.1%	10.1%	10.1%	10.1%	0.01
ADM	369,140.82	9.7%		9.7%	9.7%	0.01
GRANOL	341,926.98	9.0%		9.0%	9.0%	0.01
CARAMURU	298,057.58	7.8%			7.8%	0.01
PETROBRAS	293,090.52	7.7%			7.7%	0.01
BIANCHINI	217,255.38	5.7%			5.7%	0.00
POTENCIAL	195,846.27	5.2%			5.2%	0.00
Subtotal	2,494,869.08		20.5%	39.2%	65.6%	
Others	1,306,469.92		79.5%	60.8%	34.4%	
Total	3,801,339.00		100.0%	100.0%	100.0%	0.057

Note. Author calculations based on data from ANP (2022a).

Except for the year 2017, when ADM had the highest production volume followed by Oleoplan, Bsbios remained the first in CR8 from 2018 to 2021 (Table 8), responsible for 10.2%, 10.2%, 10.47%, and 13.25%, respectively. Bsbios, Oleoplan, ADM, Granol, Caramuru, Potencial, Petrobras, and Bianchini were part of the CR8 in the years 2016, 2017, 2018, and 2019, and their share was, respectively, 65.6%, 62.2%, 61.8%, and 59.8%, while the HHI index stayed around 0.05-0.06. Both indexes reveal that the industry remained in a state of small concentration, consolidating this trend since 2010. The data shows that the industry continued to be dominated by the same firms throughout the years, with are part of a well-structures supply chain and have incorporated biodiesel as one of the products in their portfolio. Even with the changes of some names in CR8 at 2020 and 2021, it hat no significant impact on CR8 numbers.

TABLE 8
Biodiesel industry concentration ratio in 2017, 2018, 2019, 2020 and 2021

2017						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
ADM	435,959.66	10.2%	10.2%	10.2%	10.2%	0.010
OLEOPLAN*	435,056.42	10.1%	10.1%	10.1%	10.1%	0.010
BSBIOS	409,758.80	9.6%		9.6%	9.6%	0.009
CARAMURU	306,202.27	7.1%		7.1%	7.1%	0.005
POTENCIAL	301,145.41	7.0%			7.0%	0.005
GRANOL	284,428.11	6.6%			6.6%	0.004
PETROBRAS	259,314.27	6.0%			6.0%	0.004
BIANCHINI	237,039.05	5.5%			5.5%	0.003
Subtotal	2,465,816.01		20.3%	37.0%	62.2%	
Others	1,824,023.68		79.7%	63.0%	37.8%	
Total	4,289,839.69		100.0%	100.0%	100.0%	0.051
2018						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
BSBIOS	545,814.65	10.2%	10.2%	10.2%	10.2%	0.010
OLEOPLAN*	537,145.69	10.1%	10.1%	10.1%	10.1%	0.010
ADM	476,096.08	8.9%		8.9%	8.9%	0.008
GRANOL	453,588.02	8.5%		8.5%	8.5%	0.007
CARAMURU	356,048.51	6.7%			6.7%	0.004
POTENCIAL	326,624.06	6.1%			6.1%	0.004
PETROBRAS	315,895.75	5.9%			5.9%	0.004
BIANCHINI	285,499.34	5.3%			5.3%	0.003
Subtotal	3,296,712.09		20.3%	37.7%	61.8%	
Others	2,039,816.58		79.7%	62.3%	38.2%	
Total	5,336,528.68		100.0%	100.0%	100.0%	0.05
2019						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
BSBIOS	604827.061	10.2%	10.2%	10.2%	10.2%	0.011
OLEOPLAN*	592655.245	10.0%	10.0%	10.0%	10.0%	0.010
ADM	465175.683	7.9%		7.9%	7.9%	0.006
GRANOL	457557.867	7.8%		7.8%	7.8%	0.006
CARAMURU	408635.665	6.9%			6.9%	0.005
POTENCIAL	342201.065	5.8%			5.8%	0.003
BIANCHINI	334586.756	5.7%			5.7%	0.003
PETROBRAS	322228.713	5.5%			5.5%	0.003
Subtotal	3,527,868.06		20.3%	35.9%	59.8%	
Others	2,374,593.05		79.7%	64.1%	40.2%	
Total	5,902,461.10		100.0%	100.0%	100.0%	0.05
2020						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
BSBIOS	755263.349	11.74%	11.74%	11.74%	11.74%	0.014
OLEOPLAN*	609458.767	9.48%	9.48%	9.48%	9.48%	0.009
GRANOL	499764.896	7.77%		7.77%	7.77%	0.006
ADM	462216.925	7.19%		7.19%	7.19%	0.005
CARAMURU	425756.707	6.62%			6.62%	0.004
POTENCIAL	411061.066	6.39%			6.39%	0.004
OLFAR	361024.064	5.61%			5.61%	0.003
BIANCHINI	311265.911	4.84%			4.84%	0.002
Subtotal	3,835,811.69		21%	36%	59.6%	
Others	2,596,196.78		79%	64%	40%	
Total	6,432,008.47		100.00%	100.00%	100.00%	0.05
2021						
ECONOMIC GROUP	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)	H-H rate
BSBIOS	895463.149	13.25%	13.25%	13.25%	13.25%	0.018
POTENCIAL	772628.844	11.43%	11.43%	11.43%	11.43%	0.013
OLFAR	549666.959	8.13%		8.13%	8.13%	0.007
OLEOPLAN*	546316.117	8.08%		8.08%	8.08%	0.007
GRANOL	523317.037	7.74%			7.74%	0.006
CARAMURU	440390.954	6.52%			6.52%	0.004
ADM	370046.894	5.48%			5.48%	0.003
COFCO	317203.419	4.69%			4.69%	0.002
Subtotal	4,415,033.37		25%	41%	65.3%	
Others	2,343,349.00		75%	59%	35%	
Total	6,758,382.37		100%	100%	100%	0.06

Note. Author calculations based on data from ANP (2022a)

The analysis of CR index between 2010 and 2021 (Figure 3) reveals a pattern in the structure of the biodiesel industry, characterized by a reduction in the level of concentration over the studied period, as well as a decrease in the number of economic groups producing biodiesel (Figure 4), consolidating the participation of the same firms. Indeed, the finding reinforce the conclusions of other studies, which also highlight the significant presence of large producers within well-established supply chains (Santos & Padula, 2012). This trend underscores the continued consolidation of the biodiesel industry by the major players. As seen over the years, under analyze, the percentage of biodiesel to diesel (B) increased from B5 to B13 and then back to B10 in November 2020 did lead to a higher demand for biodiesel. However, it did not change the trend of moderately low concentration observed in the CR numbers.

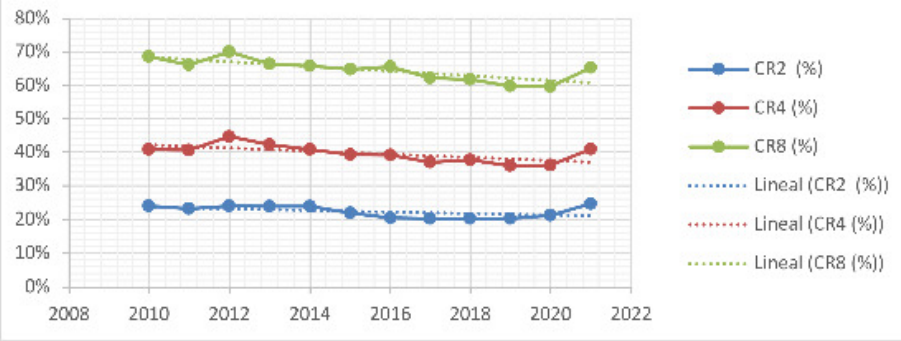

FIGURE 3

Pattern of concentration in the biodiesel industry from 2005 to 2022

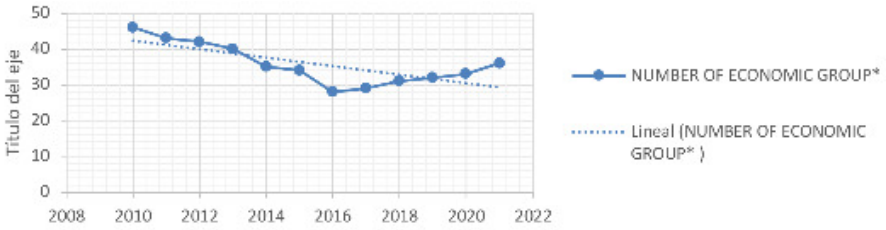

FIGURE 4

Pattern of concentration in the biodiesel industry from 2005 to 2022

Note. *One or more unit producer under the same NRLE - National Register of Legal Entities

The trend of decreasing number of firms in the biodiesel industry observed between 2010 and 2021 (Figure 4), aligns with the findings of Moreno-Pérez et al. (2017) during the for the period of 2012 to 2016. The authors acknowledges that this phenomenon is a response to acquisitions of some plants by other companies operating in the biodiesel market. The literature on business economics considers horizontal growth through mergers and acquisitions as a strategy to increase the bargaining power of firms, among other objectives (Moatti et al., 2015), this dynamic, even today, is present in the Brazilian biodiesel industry. This similarity in results further strengthens the evidence of consolidation and concentration in this market.

According to Santos and Padula (2012), between 2005 and 2010, large biodiesel plants had a predominant participation in the market. This trend has continued even after 2010, as evidenced by the fact that among the top 10 producers from 2010 to 2021, only Biocapital, in 2010, was not a large plant, with a capacity of 146,000 m3/year (Table 9). Changes in the biodiesel auction format in 2012 played an important role in increasing competition. For the first time, distributors were allowed to select the plants that best fit their needs in terms of logistics, price, and quality. These characteristics benefit firms that compete more efficiently and effectively, with the gains in scale being an essential element to achieve this result, primarily achieved by larger companies.

TABLE 9
Top 10 economic group in 2010 to 2021

Top 10 2010 – 2021	Capacity in Dezember 2021(m3/day)	Capacity per year (365 days)
OLFAR	3450	1,259,250
GRANOL	3283	1,198,295
BSBIOS	2600	949,000
OLEOPLAN*	2600	949,000
POTENCIAL	2500	912,500
ADM	1862	679,630
BRASIL ECODIESEL*		640,000
CARAMURU	1535	560,275
PETROBRAS	1390	507,350
FIAGRIL	1213	442,745
BIANCHINI	1150	419,750
COFCO	1100	401,500
JBS	970	354,050
CARGILL	700	255,500
CAMERA	650	237,250
BIOCAPITAL	400	146,000

Note. * https://www.infomoney.com.br/negocios/brasil-ecodiesel/. Elaborated by the authors based on ANP (2022d)

This study, along with previous ones (Tanaca & Souza, 2010; Leonardi et al., 2011; Santos & Padula, 2012; Cavalheiro, 2014; Moreno-Pérez et al., 2017), indicates that the industrial dynamics of biodiesel can be viewed in two distinct periods. The first period, from 2005-2011, was initiated by the PNPB and saw a rapid increase in biodiesel production and a gradual de-concentration of the market due to the entry of new firms (Santos & Padula, 2012; Moreno-Pérez et al., 2017). The second period is marked by changes in biodiesel commercialization, in which productive expansion was carried out by fewer, but larger plants, as highlighted by Moreno-Pérez et al. (2017) and supported by this analysis.

It is important to note that prior to 2012, the commercialization of biodiesel was restricted to auctions organized by ANP for purchase by Petrobras only. In this scenario, fuel distributors did not have any participation in choosing their biodiesel supplier. The acquisition by Petrobras was made indiscriminately, without regard for quality, supplier, distance, or relationship. The decision was based solely on the lowest price offered by biodiesel producers. Those changes in auction rules improved market competition by enabling biodiesel producers to compete not only on price but also on quality and logistics. However, the dominance of large biodiesel producers remained, making small producers continue to play a supporting role in this industry since the inception of PNPB.

Even if the changes one auction format increased competition among biodiesel producers, it did not change the number of fuel distributors in the market. On the demand side, the market is concentrated among distributors authorized by ANP (as shown in Table 10), a situation typified as an oligopsony (with CR4 higher than 65%).

TABLE 10
Biodiesel industry concentration ratio in 2021 based on buyers

DISTRIBUTORS	PRODUCTION (cubic meters)	PERCENTAGE (%)	CR2 (%)	CR4 (%)	CR8 (%)
PETROBRAS DISTRIBUIDORA S.A.	1,879,186.13	28%	28%	28%	28%
RAIZEN COMBUSTÍVEIS S.A.	1,386,463.58	20%	20%	20%	20%
IPIRANGA PRODUTOS DE PETRÓLEO S.A	1,299,620.02	19%		19%	19%
PETRÓLEO SABBÁ S.A.	207,791.43	3%		3%	3%
ALESAT COMBUSTÍVEIS S. A.	161,099.92	2%			2%
ATEM' S DISTRIBUIDORA DE PETRÓLEO S.A.	144,350.54	2%			2%
CIAPETRO DISTRIBUIDORA DE COMBUSTÍVEIS LTDA	102,640.14	2%			2%
LARCO COMERCIAL DE PRODUTOS DE PETRÓLEO LTDA.	94,645.34	1%			1%
Subtotal	5,275,797.09	77%	48%	70%	77%
Others	1,541,042.14	23%	52%	30%	23%
Total	6,816,839.23	100%	100%	100%	100%

Note. Authors calculations based on ANP (2022e) data.

In 2021, the biodiesel industry exhibited a significant level of concentration on the buyer side, with a CR8 value of 77%. A comprehensive analysis of the concentration level of both buyers and sellers, based on CR8, indicate that the biodiesel industry has remained a bilateral oligopoly, also known as an oligopoly plus oligopsony, since 2010.

Conclusions

The aim of this article was to analyze the dynamics of the biodiesel industry in Brazil between 2010 and 2021. The CR and HHI index showed that the biodiesel industry maintained a moderately low concentration pattern in the period, with a small variation in CR4 and CR8, and an unconcentrated industry from the HHI index perspective. However, the joint analysis of the sellers and buyers' sides identified that the biodiesel industry can be defined as an Oligopoly plus Oligopsony, or a Bilateral Oligopoly.

As the Industrial Organizations theory propose the evolution of concentration within an industry expresses the characteristics of the flow of firms into it and the ability of leading firms to protect and expand their market shares, this trend is well noted in biodiesel industry, as the data shows a present of the same firms since 2010 in the top producers. Indeed, the dynamic of the biodiesel industry is based on an industrial standard that revolves around large-scale production of grains for the generation of bran and oil. In this context, biodiesel serves as an alternative co-product derived from this primary activity.

The industry dynamics reveal that the industry is led by large producers who concentrate the production of biodiesel. Notably, Bsbios, Oleoplan, Granol, ADM, and Caramuru were among the eight largest producers of biodiesel between 2010 and 2021, with Granol being present at CR8 since 2005. Consequently, the industry has not only remained concentrated but also has remained concentrated in the hands of the same companies over the last decade, with a feeble participation of small producers. This finding highlights the symbiotic relationship between the biodiesel sector and the well-established grain industry, contributing to the continuous consolidation and dominance of large biodiesel plants in the market.

As future research, conducting an analysis of industrial concentration based on sales at auctions would be a valuable avenue. Such research would not only have the purpose of corroborate and validate the findings of this study but also shed light on the dynamics of prices in auctions and investigate whether the changes in auctions carried out in 2012 had any impact on this issue. Furthermore, understanding the role of small farmers in this industry could be another promising area of research, since biodiesel production has been dominated by large firms. Understanding the involvement and challenges faced by small farmers in this context could provide valuable insights into the overall structure and inclusiveness of the industry.

References

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. (April, 20th, 2022a) Produção de biodiesel. < Painel Dinâmico de Produtores de Biodiesel — Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (www.gov.br)>

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. (April, 20th, 2022b) Instrução n°1. Accessed in April 2022.

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. (April, 20th, 2022c). Dados Dinâmicos. Accessed in April 20th, 2022.

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. (April, 20th, 2022d). Painel Dinâmico de Produtores de Biodiesel. Accessed in April 20th 2022.

ANP - AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS. (April, 20th, 2022e) Aquisição leilões. Accessed in April 20th 2022.

Bain, J. S. (1951). Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936-1940. The Quarterly Journal of Economics, 65(3), 293-324. 1951.

Bain, J.S. (1959). Industrial Organization. New York: John Wiley & Sons, Inc. 1959.

References

Bhattacharya, M., & Bloch, H. (2000). The dynamics of industrial concentration in Australian manufacturing. International Journal of Industrial Organization, 18(8), 1181-1199. < https://www.sciencedirect.com/science/article/abs/pii/S0167718799000053>

Brasil. (April, 20 th ,2022a) Programa Nacional de Produção e Uso do Biodiesel (PNPB). MAPA – Ministério da Agricultura, Pecuária e Abastecimento. http://www.biodiesel.gov.br>. Accessed in Jan, 2022.

Brasil. (April, 20 th , 2022b) RenovaBio. MME - Ministério de Minas e Energia. . Accessed in February 2022.

Caves, R. (1998) Industrial Organization and New Findings on the Turnover and Mobility of Firms. Journal of Economic Literature, 36(4), 1947-1982.

Cavalcante Filho, P. G., Buainain, A. M., & de da Silva César, A., Conejero, M. A., Ribeiro, E. C. B., & Batalha, M. O. (2019). Competitiveness analysis of "social soybeans" in biodiesel production in Brazil. Renewable Energy, 133, 1147-1157., G. S. (2019). A cadeia produtiva agroindustrial do biodiesel no Brasil: um estudo sobre sua estrutura e caracterização. DRd-Desenvolvimento Regional em debate, 9, 772-799.

Cavalheiro, E.A. (2014). The biofuel industry concentration in Brazil between 2005 and 2012. In: Padula, A.D., Santos, M. S., Benedetti Santos, O.I. & Borenstein, D.(Eds.), Liquid Biofuels: Emergence, Development and Prospects. Lecture Notes in Energy 27. Springer-Verlag, London, pp. 73–91.< https://link.springer.com/chapter/10.1007/978-1-4471-6482-1_4>

Cowling, K. & Waterson, M. (1976). Price-cost margins and market structure. Economica 43, 267–274. < https://www.jstor.org/stable/2553125 >

Cremonez, P. A., Feroldi, M., Nadaleti, W. C., de Rossi, E., Feiden, A., de Camargo, M. P., ... & Klajn, F. F. (2015). Biodiesel production in Brazil: current scenario and perspectives. Renewable and Sustainable Energy Reviews, 42, 415-428.

Curry, B. & George, D. (1983) Industrial Concentration: A Survey. The Journal of Industrial Economics, 31(3): 203-255. < https://www.jstor.org/stable/2097885>

Da Silva César, A., Conejero, M. A., Ribeiro, E. C. B., & Batalha, M. O. (2019). Competitiveness analysis of "social soybeans" in biodiesel production in Brazil. Renewable Energy, 133, 1147-1157. .

De Oliveira, F. C., & Coelho, S. T. (2017). History, evolution, and environmental impact of biodiesel in Brazil: A review. Renewable and Sustainable Energy Reviews, 75, 168-179.

Donsimoni, M. P., Geroski, P., & Jacquemin, A. (1984). Concentration indices and market power: two views. The Journal of Industrial Economics, 419-434. < https://ideas.repec.org/a/bla/jindec/v32y1984i4p419-34.html>

George, K.D.; Joll, C & Lynk, E.L. (1992) Industrial Organization- competition, growth and structural change. New York:Routledge.

Hall, M.& Tideman, N. (1987) Measures of Concentration. Journal of the American Statistical Association, 62(317), 162-168. < https://www.jstor.org/stable/2282919>

Hannah, L. & Kay, J. (1977) Concentration in Modern Industry. Macmillan, London.

Henley, A., 1994. Industrial deconcentration in UK manufacturing since 1980. Manchester School 62, 40–59. < https://onlinelibrary.wiley.com/doi/10.1111/j.1467-9957.1994.tb00645.x>

Leonardi, A., Scarton, L.M., Padula, A.D. & Coronel, D.A. (2011). A concentração do mercado de biodiesel no Brasil. Perspect. Econ. 7 (1), 55–63. < https://revistas.unisinos.br/index.php/perspectiva_economica/article/view/1298>

Moatti, V., Ren, C.R., Anand, J., Dussauge, P., 2015. Disentangling the performance effects of efficiency and bargaining power in horizontal growth strategies: an empirical investigation in the global retail industry. Strateg. Manag. J. 36, 745–757. < https://doi.org/10.1002/smj.2244>

Moreno-Pérez, O. M., Marcossi, G. P., & Ortiz-Miranda, D. (2017). Taking stock of the evolution of the biodiesel industry in Brazil: Business concentration and structural traits. Energy Policy, 110, 525-533. < https://www.sciencedirect.com/science/article/abs/pii/S030142151730561X>

Padula, A.D., Santos, M.S., Ferreira, L., Borenstein, D. (2012). The emergence of the biodiesel industry in Brazil: current figures and future prospects. Energy Policy 44, 395–405. http://dx.doi.org/10.1016/j.enpol.2012.02.003.

Possas, M. L. (1990) Estruturas de mercado em oligopólio. São Paulo: Hucitec.

Santos Alves, C. E., Belarmino, L. C., & Padula, A. D. (2017). Feedstock diversification for biodiesel production in Brazil: Using the Policy Analysis Matrix (PAM) to evaluate the impact of the PNPB and the economic competitiveness of alternative oilseeds. Energy Policy, 109, 297-309.

Santos, M.S. & Padula, A.D. (2012). Industrial dynamics of biodiesel industry in Brazil. Gest. Contemp., Porto Alegre 12, 293–312.

Santos, Manoela Silveira dos (2013) Instituições e estratégia como prática: uma análise das estratégias de aquisição de matéria-prima dos produtores de biodiesel da Região Sul do Brasil. [Phd. Thesis, Universidade Federal do Rio Grande do Sul] Lume – Repositório digital UFRGS. https://lume.ufrgs.br/handle/10183/2/browse?value=Santos%2C+Manoela+Silveira+dos&type=author

Scherer, F.& Ross, D. (1990) Market Structure and Economic Performance. Houghon Mifflin.

Sutton, J. (1991). Sunk Costs and Market Structure. M.I.T. Press, Cambridge

Tanaca, E.K.T. & de Souza, J.D.F.(2010) Análise da concentração industrial dos leilões de biodiesel. XXX Encontro Nacional de Engenharia de Produção. Maturidade e desafios da Engenharia de Produção: competitividade das empresas, condições de trabalho, meio ambiente. São Carlos, SP, Brasil, 12 to 15 october 2010.

Notes

[**1**] Thresholds set by the US Department of Justice and the Federal Trade Commission.https://www.justice.gov/atr/horizontal-merger-guidelines-08192010 (accessed in June 2022)