energies

MDPI

Article

Development of Brazilian Biodiesel Sector from the Perspective of Stakeholders

Bárbara Françoise Cardoso [1,*], Pery Francisco Assis Shikida [1] and Adele Finco [2]

[1] Centre for Applied Social Sciences, Western Paraná State University, Rua da Faculdade 645, Jardim Santa Maria, 85903-000 Toledo, Brazil; peryshikida@hotmail.com

[2] Department of Agricultural, Food and Environmental Sciences, Polytechnic University of Marche, Piazza Roma 22, 60121 Ancona, Italy; a.finco@univpm.it

* Correspondence: barbarafcardoso@gmail.com; Tel.: +55-45-999-889-247

Academic Editor: Robert Lundmark
Received: 17 January 2017; Accepted: 9 March 2017; Published: 20 March 2017

Abstract: In Brazil, the main program with respect to biodiesel is the National Program of Biodiesel Production and Use (NPBP). It is also considered the regulation mark of biodiesel production in Brazil and its directives are social inclusion and regional development. Considering these directives, this paper aims to analyse the perspective of biodiesel sector stakeholders in Brazil to understand whether NPBP directives are in consonance with the reality of the sector for its development. A questionnaire was created with 48 questions in order to understand the importance of 13 variables for the stakeholders, and the responses were treated by factor analysis (FA). The results showed the existence of a trade-off related to technological advances in biodiesel production that confronts NPBP directives, that is, the biodiesel sector tends not to evolve in terms of the use of advanced technologies. If policies change so as to develop the biodiesel sector using advanced technologies, NPBP should change its directives in order to involve family farmers in another way in the Brazilian economy.

Keywords: Brazilian program on biodiesel; perspective of stakeholders; factor analysis (FA)

1. Introduction

According to Popp et al. [1], the world's population is growing and, consequently, so is agricultural production. Meanwhile, a quarter of all agricultural land has already suffered degradation, and there is a deepening awareness of the long term consequences of a loss of biodiversity with the prospect of climate change. Higher food, feed, and fibre demand will place an increasing pressure on land and water resources, whose availability and productivity in agriculture may, themselves, be under threat from climate change. Global energy demand is increasing, too, as is the environmental damage due to fossil fuel use. Continued reliance on fossil fuels will make it very difficult to reduce emissions of greenhouse gases that contribute to global warming.

Many countries support production and the use of biofuels for transportation to enhance domestic energy security, spur economic development and reduce emissions of greenhouse gases and other pollutants, as well as alternative markets for agricultural products, as oilseeds, animal fat, and used cooking oil (UCO); diversification of energy sources, especially renewable energy; and the carbon credit market [2,3]. According to Zezza [4], without public support biofuel production, especially biodiesel, would probably not be disseminated among developed countries, which impacts directly on the economic, social, and environmental sustainability of the production.

In 2015, liquid biofuels were about 4% of the total biofuels used in road sector transport, especially ethanol and biodiesel. The contribution of the biofuels for the transport sector is more highlighted in some European countries, in the United States, and in Brazil. In the aviation sector, worldwide, great advances have been carried out related to the use of biofuels [5–7].

It is important to highlight that biodiesel production is still made of first-generation technologies, i.e., the most part of raw material used is food crops [8,9]. The possibility of raw material diversification, with the use of non-food crops, agricultural waste, sewage treatment waste, and so on, has stimulated many countries to invest in biodiesel production. The greater investments in the biodiesel sector are in Brazil, the United States, and the European Union. In Brazil, the greater interest in biodiesel production is on low cost of the raw material; while in the United States the interest is in the possibility of reducing the fossil fuel dependence on the Middle East and Venezuela; and in the European Union the interest is in greenhouse gas emission reduction [10].

Among the liquid biofuels, biodiesel is one of the most important biofuels produced in the world. In 2015, according to the Renewable Energy Policy for the 21st Century—REN21 [5], global biofuels production was composed of 74% ethanol, 22% biodiesel, and 4% hydrogenated vegetable oil (HVO). The main producers were the United States, which produced 46% of all global biofuels, Brazil (24%), the European Union (15%), and others (15%). Biodiesel global production was about 30.1 billion litres. The United States were the main producer, which produced 4.8 billion litres (15.9% of biodiesel global production), followed by Brazil (3.9 billion litres—12.9%), Germany (2.8 billion litres—9.3%), France (2.4 billion litres—7.9%), and others (16.2 billion litres—53.8%) [5]. In Brazil, biodiesel is the second-most produced biofuel. In 2015, Brazilian biodiesel production was about 3.9 billion litres, shared by its five regions as: Midwest (44.4%), South (38.4%), Northeast (8.0%), Southeast (7.5%), and North (1.7%). Biodiesel production had increased 15% related to 2014, mainly due to the stimulus given to the sector through the increase of the biodiesel blending mandate, from 5% (B5) to 7% (B7) [5,11].

Brazilian biodiesel production is mainly from vegetable oil and animal fat. In the beginning of biodiesel commercial production, Brazil used more than 70% soybean oil as the main raw material. However, the dependence on this oilseed, and the large variety of potential oilseeds produced in Brazil, stimulated research about the use and diversification of raw material for biodiesel production [12]. The dependence from soybean oil for biodiesel production is evident.

Soybean is produced on a large scale in Brazil and does not affect food security, since soybean oil extraction is necessary for the production of bran, and the high productivity allows the production of oil for both food and biodiesel without significantly affecting the prices [13]. Furthermore, their expansion does not occur on lands that are already occupied by other food-crops and/or forests, that is, there is no change in land use. The second main raw material, animal fat, does not have this characteristic, since it has no direct food scope and it is used in the manufacture of soap and/or discarded by the meat packing plant.

When it comes to Brazilian biodiesel production at the commercial scale, this started in March 2005, with 736.16 m^3 of production. Since then, biodiesel production has been increasing, with 3.2 million m^3 produced in October 2016 (accumulated throughout the year). Nevertheless, the increase of biodiesel production does not show Brazilian potential, since the production capacity of biodiesel plants is further than the real production. The difference between production capacity and the real production was 4.2 million m^3 in 2016. It is important to highlight that the production capacity and the real production are from biodiesel plants which are authorized for operation by the National Agency of Petroleum, Natural Gas and Biofuels (NAP), whose amount is different in each year. In November 2016, there were 50 biodiesel plants authorized for operation with 20480.81 m^3/day of production capacity [14]. Biodiesel plants are concentrated in the Brazilian Centre-South, being the greater production capacity in the Midwest (8121.25 m^3/day from 23 biodiesel plants), followed by the South region (8112.33 m^3/day from 14 biodiesel plants), Southeast (2311.10 m^3/day from seven biodiesel plants), Northeast (1265.13 m^3/day from three biodiesel plants), and North (671.00 m^3/day from three biodiesel plants).

On the other hand, the national biodiesel market still has some difficulties. Chagas [12] argues that it can be characterized as a competitive market, since it is conducted by auctions. He complements this by saying that the greatest challenge to the Brazilian biodiesel sector is to disassociate biodiesel production from soybean. In the short and medium term, the biodiesel sector must search for raw material that is more productive and is not a food-crop. However, other feedstock alternatives are not economically feasible and the reasons are: a lack of availability and defined production technologies, research net, competitive costs on farming, logistics, suitable workforce, and so on.

In the light of these barriers highlighted by Chagas [12], Brazil elaborated laws applied to agriculture and biodiesel production in order to improve the biodiesel sector coordination. The main program involving the biodiesel sector is the National Program of Biodiesel Production and Use (NPBP), whose directives are social inclusion and regional development. NPBP aims at the inclusion of family farming on the economy through raw material for biodiesel production, and regional development through raw material diversification.

In this context, this paper aims to analyse the perspective from biodiesel sector stakeholders in Brazil to understand whether NPBP directives are in consonance with the reality of the sector for its development. There is a trade-off related to technological advance on biodiesel production that confronts NPBP directives. If policies change so as to develop the biodiesel sector using advanced technologies, NPBP should change its directives in order to involve family farmers in another way in the Brazilian economy.

2. National Program of Biodiesel Production and Use (NPBP)

NPBP, which was instituted by the Decree on 23 December 2003, and whose activities came into force in 2004, was created with the aim of implementing sustainable biodiesel production and use on the Brazilian energy matrix, focusing on social inclusion and regional development. Its directives are: (i) implementing a technically and economically sustainable program that promotes social inclusion through the generation of employment and income; (ii) ensuring competitive prices, biodiesel quality and supply through governmental mechanisms and control; and (iii) producing biodiesel from different oilseeds from different regions through governmental incentives [15,16].

To ensure social inclusion and regional development, Social Fuel Seal (SFS) was created by the Normative Rule MAD 1, from 5 July 2005 [17]. This seal was substantiated in the inclusion of social policies, the use of oilseeds according to the regional features, assurance of oilseeds raw material supply for biodiesel production, assurance of biodiesel quality for the consumer, and the pursuit of competitiveness of biodiesel related to diesel oil [17].

The SFS is granted by the Ministry of Agrarian Development (MAD) to biodiesel producers who acquire the minimum percentage of agricultural raw material from family farmers, sign a contract with these farmers, and give them technical assistance. This percentage is related to the total of raw materials that the biodiesel plants need for their production. The minimum percentage established by the Normative Rule MAD 1/2005 was 10% for the North and Midwest regions; 30% for the Southeast and South; and 50% for the Northeast and Semi-arid regions [17]. Nevertheless, it is important to highlight that the minimum percentage varies among Brazilian regions and it is changed as far as there are advances in the NPBP regulation. The most current change occurred in 2012 by the Ordinance MAD 60, from 6 September 2012, which established the minimum percentage as: 15% for acquisitions from the North and Midwest regions; 30% for Southeast, Northeast and Semi-arid regions; and 40% for acquisitions from the South region [18].

To incentivize family farmers to produce oilseeds for biodiesel production, the Federal Government has facilitated the credit line of the National Program to Strengthen Family Farming (PRONAF), in which it grants to farmers more than a single costing operation. This incentive was known as PRONAF Biodiesel [19]. This program grants financing to family farmers to purchase seeds and machinery with a low interest rate.

For biodiesel plants to obtain the SFS they have to create a project involving raw material acquisition from family farming, in accordance with the current norms on the minimum biodiesel blend mandate, and to undergo audits to be carried out by a team defined by the MAD [20].

Biodiesel plants that have the SFS also have another incentive, which is a priority on biodiesel auctions. According to Machado Filho [21], these auctions represent the governance structure when the asset transacted has some specifications. In Brazil, biodiesel auctions were created to incentivize the supply and to generate biodiesel demand. NAP is the governmental body responsible for the realization of the auctions.

According to the Ministry of Mines and Energy (MME) [16], the aims of the auctions are to provide economic support to the agro-industrial system of biodiesel production and to create conditions for sector consolidation. Auctions operate as a transparent mechanism of commercialization, since all transacted amounts, their suppliers, and their prices are public knowledge. The kind of auction used in Brazil is the Dutch auction, that is, a minimum reference price is fixed and the producers offer their lots by a price equal or lower compared to the reference price. The lots that have the lowest prices are sold.

NAP has carried out the biodiesel auctions since 2005 so that biodiesel refineries and distributors can have access to the minimum amount of biodiesel which must be blended into diesel oil (BX) for compliance with the current law. NAP, Brazilian Petroleum (PETROBRAS) (Rio de Janeiro-RJ, Brazil), and Alberto Pasqualini Refinery (REFAP) (Canoas-RS, Brazil) hold a gathering of the information about the amount of diesel oil bought by each distributor. According to this gathering, the amount of biodiesel necessary to the current biodiesel blending mandate is sold [22,23].

From all the volume auctioned, 80% is commercialized in an open auction only for biodiesel producers which have a SFS, and the other 20% is auctioned to any biodiesel producers authorized by NAP. Biodiesel producers are responsible for handing over biodiesel lots sold by the distributors that bought it. Auction frequency is variable; it can be done more than once a month and when there is demand for biodiesel [24].

In the beginning of 2005, Law 11097, from 13 January 2005 was sanctioned [25]. This law provides biodiesel introduction in the Brazilian energy matrix, changing Law 9478, from 6 August 1997[26]. From 2005, NAP started to be called National Agency of Petroleum, Natural Gas and Biofuels (keeping the same abbreviation—NAP; until 2004, it was known as National Agency of Petroleum) and it received the function to control and inspect activities related to biodiesel production and commercialization, as well as to execute the directives established by the National Council of Energetic Policy (NCEP), which included the biofuels sector [25]. "Under the performance of this new function, NAP edited norms of specification on biodiesel and biodiesel blending mandate, promoted adaptation of regulatory norms and carried out auctions to stimulate biodiesel supply for the mixture" [14] (p. 1).

Law 11097/2005 proposed a minimum biodiesel blending mandate of B5 by 2013, and the mandatory use of at least B2 after 2008 would be obligatory. Nevertheless, the sale of B*X* (*X*% of biodiesel blend to diesel oil) is obligatory in all resale points, but BX can be higher than that established by legislation [25]. However, the biodiesel sector performance was satisfactory enough to make NCEP anticipate goal B5 for 2010; this schedule was complied with adequately by the sector [14,25]. More recently, Law 13033, from 24 September 2014, was sanctioned, whose established goal was B6 from July 2014 and B7 from November 2014 [27].

In 2012, Decree 7768, from 27 July 2012 was instituted [28], which provides for the reduction of the incidence of PIS/PASEP (Social Integration Program/Public Service Employee Savings Program) and COFINS (Contribution for the Financing of Social Security) tax rates on biodiesel production and commercialization. The greater benefits were for biodiesel from raw materials produced in the North, Northeast, and Semi-arid regions, and from family farmers [28].

3. Methodology

3.1. Factor Analysis

Factor analysis (FA) is a multivariate statistical technique used in common variability analysis among variables groups. Mingoti [29] (p. 99) argues that the main aim of FA is "describing the original variability of the random vector **X**, in terms of a smaller number m of random variables, namely common factors and that are related to the original vector **X** through a linear model". That is, FA analyses the correlation existent among variables to group them into a smaller number of variables (factors).

Factors are estimated by a linear combination of the original variables:

$$F_j = \boldsymbol{\omega}_{j1}X_{1+}\boldsymbol{\omega}_{j2}X_2 + \boldsymbol{\omega}_{j3}X_3 + \cdots + \boldsymbol{\omega}_{ji}X_i \quad (1)$$

where F_j are factors not correlated; $\boldsymbol{\omega}_{ji}$ is the vector of the factor score coefficients; X_i are the original variables; and $\boldsymbol{\omega}_{ji}X_i$ are factor scores.

The correlation rate between original variables and factors is called the factor load, and its square represents the percentage of variation of a variable, which is explained by the factor in which it is related to. Variations on a variable can be explained by a set of factors, as follows [30]:

$$Z_i = l_{i1}F_1 + l_{i2}F_2 + \cdots + l_{im}F_m + \varepsilon_i \quad (2)$$

where Z_i are the standard variables; l_i are factor loads; F_j are the factors that are not related among them; and ε_i is a error that represents the share of exclusive variation from the variable i, with $i = 1, 2, \ldots, m$.

To estimate the FA model it is necessary to make some assumptions: (i) all of the factors have averages equal to zero; (ii) all of the factors are not correlated and have variances equal to one; (iii) all of the errors have averages equal to zero; (iv) all of the errors are not correlated and do not have the same variance, necessarily; and (v) the errors and the factors are independent, that is, they represent distinct sources of variation [29,30].

When the FA model makes all of these assumptions it is, namely, an orthogonal factorial model in which the orthogonality is concerned with "the fact that the m factors are orthogonal among them" [29] (p. 103). That is, factors are obtained by the remaining variance after the extraction of the antecedent factors [30]. Assuming an orthogonal model, the variance of Z_i is disaggregate in two parts, the first being one represented by the variability explained by the factors, called communality; and the second one is represented by errors, which are features of each variables, named specific variance or unicity [29,30], as follows:

$$var(Z_i) = l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2 + \Psi_i = h_i^2 + \Psi_i \quad (3)$$

where $var(Z_i)$ represents the variance of the standard original variables; $h_i^2 = l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2$ is the communality; and Ψ_i is the unicity.

Communality is one of the ways to analyse the model adequacy. It represents variability explained by factors, in which each value of the variables must be over 0.50 to consider the variable acceptable [30].

Factor extraction can be done by the common FA or principal component analysis. In the first extraction method, the factors are obtained through the common variance between the variables (communality), disregarding the specific variances (variances of each single variable) and those related to the error (variances of random factors). In the second extraction method, the factors are obtained through the linear combination between the variables, maintaining the maximum of the variance explained by such a combination and considering the total variance [29,30].

The choice of the number of factors can be done through the criterion of the latent root, the scree plot, the percentage of variance explained, and the factors established a priori. The latent root criterion is the most used and consists of the selection of factors that have eigenvalues above the unit. This criterion maintains new dimensions that represent the variance information of the original variable [29] (p. 105).

The type of factor rotation, which can be by orthogonal or oblique rotation, is another criterion to be determined a priori. In orthogonal rotation, the factors are maintained with no correlation between them, while in oblique rotation a correlation between the factors is maintained. There are three methods of orthogonal rotation: varimax, quartimax, and equimax; and two methods of oblique rotation: direct oblimin and promax [30].

Due to the characteristics of each criterion, for this research we opted for the adoption of: (i) the common FA method, because it seeks to reduce the number of factors, maintaining the variability of the original variables; (ii) the latent root criterion to determine the number of factors to be analysed, since in this criterion the new dimensions represent the variance of the original variables; and (iii) varimax rotation, since this criterion allows each variable to have high factor loads only for one factor.

After the estimation of the FA model, it is necessary to do some tests in order to verify the adequacy of the model. These tests are the Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test. KMO test is calculated by [31]:

$$\mathrm{KMO} = \frac{\sum_{i \neq j} R_{ij}^2}{\sum_{i \neq j} R_{ij}^2 + \sum_{i \neq j} Q_{ij}^2} \tag{4}$$

where R_{ij} is the sample correlation between the variables X_i and X_j; and Q_{ij} is the partial correlation between X_i and X_j.

The KMO value varies between 0 and 1. The value 0.50 is the limit to the acceptance, the values below it being considered unacceptable; values between 0.50 and 0.59 are miserable; 0.60–0.69 are mediocre; 0.70–0.79 are middling; 0.80–0.89 are meritorious; and above 0.90 are marvellous. Values below 0.50 mean that the factors do not satisfactory explain variations of the original variables [31].

Bartlett's sphericity test shows the total significance of all correlations. This test shows if the correlation matrix is an identity matrix. If this occurs, FA is inadequate to the data treatment. Bartlett's sphericity test is calculated by [32]:

$$T = -\left[n - \frac{1}{6}(2p + 11)\right]\left[\sum_{j=1}^{p} ln\left(\hat{\lambda}_i\right)\right] \tag{5}$$

where T is the statistic of the test; n is the number of observations; p is the number of variables; ln is the Napierian logarithmic function; and $\hat{\lambda}_i$ are the eigenvalues of the correlation matrix, with $i = 1, 2, \ldots, p$.

When a questionnaire is used to collect data, using a Likert scale, Cronbach's alpha must be analysed. This coefficient is calculated as [33]:

$$\alpha = \frac{n}{n-1}\left(\frac{V_t - \sum_{i=1}^{n} V_i}{V_t}\right) \tag{6}$$

where n is the number of variables extracted from the questionnaire; V_i is the variance of each item; and V_t is the total variance of the questionnaire. Cronbach's alpha values vary between 0 and 1; the nearer to 1, the greater the level of reliability.

3.2. Survey Data Collection

In order to analyse the perspective of biodiesel sector stakeholders in Brazil to understand whether NPBP directives are in consonance with the reality of the sector for its development, a questionnaire was created.

The questionnaire consists of 48 questions grouped into 13 variables, which are all related to NPBP directives. Variables and their descriptions are:

- *X1: Technical assistance to raw material producers*, which includes the level of mechanization and agricultural raw material productivity; and technical assistance to agricultural raw material producers.
- *X2: Diversification, purchasing from family farming and supply guarantee*, which is included to ensure production and constant supply of biodiesel; diversification of the type of raw material used in the biodiesel production; and acquisition of raw material from family farming.
- *X3: Production technologies*, which includes development of technological innovations of processes and products; development of technologies that reduce greenhouse gas emission and negative environmental impacts during the biodiesel production process; development of technologies that reduce water waste during the biodiesel production process; development of technologies that reduce the generation of waste during the biodiesel production process; and use of advanced technology in the biodiesel production process.
- *X4: Growth strategies*, which includes development of storage capacity and resolution of problems related to transportation; establishment of partnerships with raw material suppliers; establishment of partnerships with research institutions; establishment of vertical integration; and industrial marketing promotion.

- *X5: Differentiation in the biodiesel production*, which includes improvement of production techniques; physicochemical analysis of biodiesel; investing in process improvement; and investing in product development.
- *X6: Differentiation in the biodiesel plants*, which includes patents on new biodiesel production processes; acquisition of certification for biodiesel; investment in research and development (R & D); and obtaining support from research institutions.
- *X7: Incentives for biodiesel production*, which includes a minimum biodiesel blend mandate; subsidy for raw material production; subsidy for biodiesel production; and investment in infrastructure.
- *X8: General national policies*, which includes social policy influence; economic policy influence; and environmental policy influence.
- *X9: Specifics policies on biofuels*, which includes influence of national policies on biofuels; and influence of international policies on biofuels.
- *X10: Labour union and biodiesel associations*, which includes labour unions; and associations that represent biodiesel plants.
- *X11: Tax and international trade*, which includes Mercosur influence; current tax on biodiesel; current biodiesel legislation; customs barriers for the purchase and sale of raw materials and/or biodiesel; and tariff policies influence.
- *X12: Biodiesel plant competitiveness*, which involves ensuring the quality and productivity of human resources; competitive prices for biodiesel sale; competitive costs of biodiesel production; feedstock quality; and biodiesel quality.
- *X13: Support organizations*, which includes obtaining support from financial credits institutions; supporting organizations (agricultural cooperatives); consumer acceptance; and obtaining support from universities.

Each description corresponds to a question from the questionnaire. To group each one we built an index through FA, as follows:

$$I_i = \frac{\sum_{i=1}^{N}(w_i f_i)}{\sum_{i=1}^{N} w_i} \quad (7)$$

where I_i is the index representing the group of variables; N is the number of the factors; w_i is the proportion of the variance explained for each factor; and f_i are the factor scores.

The questionnaire was created in Google Forms and sent by email to ensure the responders' anonymity. Before we sent the questionnaire to the stakeholders, a semantic analysis was made by specialists, among them: professors, researchers, and some stakeholders. The questionnaire was structured to obtain the importance level of the variables using a Likert scale: (1) not important; (2) a little important; (3) indifferent; (4) important; and (5) very important. The sampling was based on contact availability, trying to diversify the respondents, and resulting in 112 questionnaires applied between May and June 2015 for 16 Brazilian Federative Units (Figure 1).

Eighty-one valid questionnaires were obtained, that is, 72.3%. The responses were treated by FA.

Figure 1. Brazilian Federative Units that received the questionnaire (in grey).

4. Results and Discussion

The survey responses reveal that variables which are included in *X*1 were considered by the respondents as indifferent to biodiesel sector development, as well as the variables in *X*6 and *X*10. Apart from *X*2 and *X*5, which were considered between important (4) and very important (5), and *X*4, which was considered between a little important (2) and indifferent (3), the other variables were between 3 (indifferent) and 4 (important) (Figure 2). It is important to highlight that 69.2% of the variables were considered as indifferent, while 30.8% were considered important and very important (15.4% for each one).

This means that the variables which the literature and the Brazilian laws argue to be important for the biodiesel sector development were not considered important for the stakeholders of the Brazilian biodiesel sector. This fact shows the need for policies aimed at biodiesel production to better suit the reality of the sector [34].

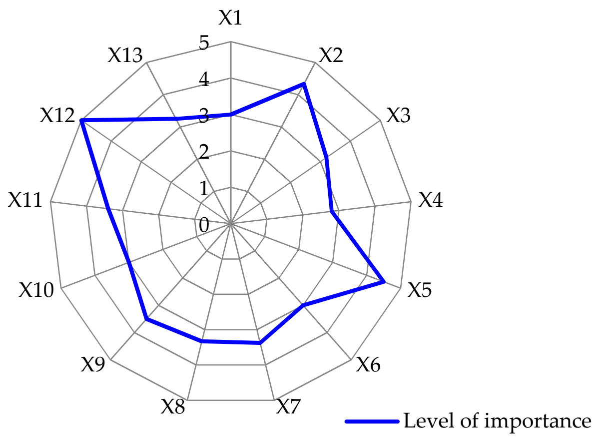

Figure 2. Level of importance of the variables according to stakeholders' perspective.

FA was carried out with the answers of stakeholders in the biodiesel sector. The results are in consonance with the requirements. Firstly, adequacy tests were analysed and they were satisfactory, as showed in Tables 1 and 2.

Table 1. Adequacy of the tests results.

Tests	Values	
KMO	0.67	
Bartlett's sphericity	X^2 = 93,390	*p*-value = 0.000
Cronbach's alpha	0.67	

Table 2. Anti-image matrix.

Variables	*X*2	*X*3	*X*4	*X*6	*X*7	*X*8	*X*9	*X*10	*X*11	*X*12
*X*2	*0.618*	−0.014	−0.112	0.051	−0.114	0.031	−0.009	−0.085	0.030	−0.045
*X*3	−0.014	*0.664*	0.026	0.029	0.084	−0.251	−0.065	0.022	−0.178	−0.256
*X*4	−0.112	0.026	*0.603*	−0.073	0.056	0.115	0.098	0.077	−0.239	−0.343
*X*6	0.051	0.029	−0.073	*0.716*	0.020	−0.096	−0.089	−0.152	0.047	−0.327
*X*7	−0.114	0.084	0.056	0.020	*0.609*	−0.087	−0.199	0.058	−0.120	−0.156
*X*8	0.031	−0.251	0.115	−0.096	−0.087	*0.662*	−0.072	−0.178	0.001	−0.009
*X*9	−0.009	−0.065	0.098	−0.089	−0.199	−0.072	*0.736*	−0.054	−0.059	−0.083
*X*10	−0.085	0.022	0.077	−0.152	0.058	−0.178	−0.054	*0.668*	0.095	−0.159
*X*11	0.030	−0.178	−0.239	0.047	−0.120	0.001	−0.059	0.095	*0.674*	−0.070
*X*12	−0.045	−0.256	−0.343	−0.327	−0.156	−0.009	−0.083	−0.159	−0.070	*0.674*

The values of the main diagonal must be above 0.50 so that the degree of correlation can be valid for the FA, while the other values should be low, characterizing a low partial correlation. By Table 2 we can note that both conditions are satisfied.

The eigenvalue criterion was considered to choose a number of factors, that is, the factors in which the eigenvalue was over 1 were considered in the analysis. In this way, four factors were obtained (Table 3). They explained 60.217% of the cumulative variance.

Table 3. Factors (*F*) and their variances, factor loadings, and communalities.

Variables/Factors	*F*1	*F*2	*F*3	*F*4	Communalities
*X*4	*0.793*	0.134	−0.123	−0.220	0.711
*X*11	*0.681*	−0.251	0.220	0.230	0.628
*X*12	*0.616*	0.520	0.184	0.067	0.688
*X*10	−0.150	*0.763*	0.062	0.025	0.609
*X*6	0.272	*0.684*	0.021	0.068	0.547
*X*7	0.118	−0.051	*0.794*	−0.122	0.661
*X*9	−0.006	0.161	*0.667*	0.186	0.506
*X*2	0.141	0.203	0.347	*−0.602*	0.544
*X*3	0.394	0.169	0.159	*0.591*	0.558
*X*8	−0.108	0.375	0.300	*0.573*	0.570
Eigenvalues	2.415	1.388	1.141	1.078	-
Variance explained (%)	17.695	16.391	14.124	12.007	-

It is important to highlight that communality values are all above 0.50, which means that the variability of variables is represented by the factors [30].

Factor 1 (*F*1), called *Strategy, Competitiveness and International Trade*, is composed of *X*4 (growth strategies), *X*11 (tax and international trade), and *X*12 (biodiesel plant competitiveness). The factor loadings all have the same positive sign, which means that when one index tends to increase the level of importance, the others also tend to increase.

Indeed, uncertainties regarding raw material quality, biodiesel produced, and production cost and sale price make biodiesel plants seek strategies that aim to reduce these uncertainties [35–37]. Actually, Machado Filho [21], Williamson [38], and Zylbersztajn [39] argue that firms must seek governance structures (market, contracts, vertical integration, auctions, etc.) that best suit the features of the products. When it comes to the Brazilian biodiesel sector, auctions showed to be the most suitable governance structure to coordinate the stakeholders of this sector, since it is a new sector (about 10 years of large-scale production). On the other hand, biodiesel supply is still unstable, which means the auctions should be made more than once a month.

Furthermore, biodiesel plants must purchase part of their raw material from family farming located in certain regions, according to NPBP directives. It is important to highlight that biodiesel production is concentrated in the Midwest region, where soybean production is concentrated, too. Thus, seeking raw material diversification, it is important for biodiesel plants to make partnerships with raw material suppliers and research institutions to reduce the uncertainties about raw material and biodiesel quality and production cost and sale price [24,40].

Another aspect is international trade, created by the current legislation in the national and international context (the case of soybean exports from Brazil to the European Union, for example [41]). It can increase further uncertainties, making the biodiesel plants seek more industrial marketing promotion to prove that their production is sustainable and comply with the current legislation.

*F*2 is composed of *X*10 (labour union and biodiesel associations) and *X*6 (differentiation in the biodiesel plants), and can be named *Support Organization and Differentiation*. These indices have the same positive sign, which means that when the level of importance of labour unions and associations increases, the level of importance from differentiation strategies also increases. Labour unions and biodiesel associations function to represent, corporatively, biodiesel plants in the face of public policies, ensuring their rights. The main rule of biodiesel associations is to facilitate the join investment in R & D of biodiesel plants and seek the support of the research institutes, and certification and patent creation [37,42,43].

In Brazil, there are two large biodiesel associations that support biodiesel plants and other related sectors, as well as vegetable oil plants and some companies of the transport sector, those that use biodiesel as fuel. The first biodiesel association is the Brazilian Union of Biodiesel and Bio-kerosene (UBRABIO) (Brasília-DF, Brazil), founded in 2007. It is a national private non-profit organisation trade, which acts as an interlocutor to mobilise and unite its forces, resources, and knowledge in search of developing the Brazilian biofuels sector. The second one is the Brazilian Association of Biodiesel Producers (APROBIO) (São Paulo-SP, Brazil), founded in 2011. It is an entity of corporate and institutional representatives of Brazilian biodiesel producers.

The third factor (*F*3), called *Policies and Incentives*, is composed of *X*7 (incentives for biodiesel production) and *X*9 (specific policies on biofuels). These indices also have the same positive sign, meaning that the level of importance of these indices go in the same direction. Policies on biofuels aim at their development to ensure energy security, reduction of petroleum dependence and greenhouse gas emissions. However, according to Zezza [4], in most countries, especially those that are developed, biofuels are not feasible without public support. In this way, Brazil boosts production stimulating biodiesel plants through SFS and the raw material producers, both through directives from NPBP [17,18], and establishing a minimum biodiesel blend mandate of B7 through Law 11033/2014 [27].

When it comes to *F*4, it is composed of *X*2 (diversification, purchasing from family farming, and supply guarantee), *X*3 (production technologies) and *X*8 (general national policies), and can be named *Diversification and Family Farming, Supply, Technologies and National Policies*. On the contrary of the other three factors, *F*4 showed a peculiarity that is represented by opposite signs of factor loadings. The sign of factor loadings of indices *X*3 and *X*8 shows that both go in the same direction. However, the negative sign of the factor loadings of index *X*2 means that the level of importance of the raw material diversification, acquisition of raw material from family farming, and biodiesel supply guarantee go in the opposite direction related to technologies and economic, social, and environmental policies established by Brazil.

Since these policies are related to sustainability, this peculiarity deserves greater attention. Lora and Venturini [8] and Santos et al. [9] explain that biodiesel from the first generation technology, which is made from food-crops, is still the most used in Brazil. In this context, raw material diversification, seeking the use of non-food sources (such as sewage, algae, dairy effluents, etc.), requires the use of advanced technologies [8,44]. In this way, the general policies, which aim at socioeconomic and environmental development influence on the search for sustainable biodiesel production [45,46], which implies the use of non-food sources and, therefore, advanced technologies.

Furthermore, *F*4 shows an incompatibility of the binomial "technology and policy" with "diversification and raw material acquisition and supply guarantee". Indeed, the current different interests present in diversification, purchasing from family farming, and supply guarantee are already controversial and incongruent points by themselves.

As family farmers normally produce food crops at a small scale for subsistence, they do not have enough land area to produce food and/or non-food crops at a large scale. In addition, they do not work with sewage treatment, algae, or do not have a large dairy industry to offer its effluents for biodiesel production. The specific reality of some raw materials for biodiesel production and their regional specificities (soybean, for instance) are not suitable for biodiesel production based on feedstock production of family farmers like in the Brazilian States, where large agricultural properties are predominant, as in the Midwest [47]. Thus, the pursuit of biodiesel sustainable production "marginalises" family farmers.

To go about this situation, regional specificities and features of potential raw materials must be considered in public policy elaboration, since each raw material has its own peculiarities. To produce biodiesel from second, third, and fourth generation technologies, investments in technologies are also necessary [42]. In this way, advances in policies aimed at Brazilian sustainable development, which proposes the use of non-food sources to biodiesel production, tend to marginalise family farmers.

On the other hand, policies on animal fat, which is the second kind of feedstock most used in the Brazilian biodiesel production, should have more attention of the policy-makers. This raw material is produced at a large scale and has great potential for biodiesel production. Indeed, Brazil is the second global producer of beef and poultry and the fourth producer of pork.

5. Conclusions and Policy Implications

The greatest achievement of this paper was the illuminating the incongruence among Brazilian policies. On the one hand, NPBP aims to support family farmers, including them in the Brazilian economy through incentives, and facilitating their access to credit lines via PRONAF. On the other hand, national policies that aim at sustainability foresee the use of non-food feedstock for biofuel production in order to minimise the conflict "food versus fuel". In this way, family farmers would be "marginalised" by the system, with regard to raw material supply. This trade-off confronts NPBP directives, which comprise the main national policy on biodiesel. Considering that NPBP directives aim at social inclusion of family farmers in the Brazilian economy, the biodiesel sector tends not to evolve in terms of the use of advanced technologies. If policies change so as to develop the biodiesel sector using advanced technologies, NPBP should change its directives in order to involve family farmers in another way in the Brazilian economy.

It is expected that the Brazilian government will create policies on waste recovery and give it the same importance as that given to raw material production. In addition, stakeholders of the biodiesel sector see large possibilities for advances in this sector, especially in the agricultural matrix for raw material production for biodiesel. They highlight rapeseed, which can be produced in the winter as an alternative for crop rotation.

The Brazilian government should invest in biotechnology to improve crops in order to increase agricultural productivity in a sustainable way and with preservation of the environment. It can be used in favour of the improvement of the NPBP using the genetic engineering tools for real increments of oil in grains of oilseeds, and to confer genetic resistance to herbicidal, pest, and disease molecules, directly related to the developing of cultivars of the main oilseeds crops.

Acknowledgments: The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and Araucária Foundation for the funding given to the first author for her Ph.D. thesis development, which resulted in this paper. In addition, they would also like to thank Matheus Henrique Lazzarin for the English grammar revision.

Author Contributions: Bárbara Françoise Cardoso collected data for analysis, performed modelling, analysed the results and wrote the paper. Pery Francisco Assis Shikida performed the modelling and analysed the results. Adele Finco analysed the results and substantially revised the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Popp, J.; Lakner, Z.; Harangi-Rákos, M.; Fári, M. The effect of bioenergy expansion: Food, energy, and environment. *Renew. Sustain. Energy Rev.* **2014**, *32*, 559–578.
2. Popp, J.; Harangi-Rákos, M.; Gabnai, Z.; Balogh, P.; Antal, G.; Bai, A. Biofuels and their co-products as livestock feed: Global economic and environmental implications. *Molecules* **2016**, *21*, 26.
3. Finco, A. *Biofuels Economics and Policy: Agricultural and Environmental Sustainability*; Franco Angeli: Milan, Italy, 2012.
4. Zezza, A. *Bioenergie: Quail Opportunità per L'agricoltura Italiana*; Edizione Scientifiche Italiane: Naple, Italy, 2008. (In Italian)
5. Renewable Energy Policy Network for the 21st Century. In *Renewables 2016 Global Status Report*; REN21 Secretariat: Paris, France, 2016.
6. Brazilian Union of Biodiesel and Bio-kerosene (UBRABIO). Combustível do Transporte Sustentável. *Biodiesel em Foco* **2015**, *6*, 1–44. Available online: http://www.ubrabio.com.br/sites/1800/1891/RevistaBiodieselemFoco/BiodieselemFocoEd06Setembro2015web.pdf (accessed on 16 November 2016). (In Portuguese)
7. Searchinger, T.; Heimlich, R. *Avoiding Bioenergy Competition for Food Crops and Land*; World Resources Institute: Washington, DC, USA, 2015.
8. Lora, E.E.S.; Venturini, O.J. *Biocombustíveis*; Interciência: Rio de Janeiro, Brazil, 2012; Volume 1. (In Portuguese)
9. Santos, S.F.; Borschiver, S.; Souza, V. Fatores determinantes para a sustentabilidade da cadeia produtiva do biodiesel no Brasil. In *Novas Condições e Espaços Para o Desenvolvimento Científico, Tecnológico e Industrial e a Cooperação Internacional, Proceedings of the Congresso Latino-Iberoamericana de Gestão de Tecnologia, Port, Portugal, 27–31 October 2013*. Available online: http://www.altec2013.org/docs/PROCEEDINGS_ALTEC2013_v3.pdf (accessed on 13 November 2016). (In Portuguese)
10. Shikida, P.F.A.; Finco, A.; Cardoso, B.F.; Galante, V.A.; Rahmeier, D.; Bentivoglio, D.; Rasetti, M. A comparison between ethanol and biodiesel production: The Brazilian and European experiences. In *Liquid Biofuel: Emergence, Development and Prospects*; Padula, A.D., Santos, M.S., Santos, O.I., Borenstein, D., Eds.; Springer: London, UK, 2014; Volume 27, pp. 25–53.
11. National Agency of Petroleum, Natural Gas and Biofuels (NAP). Biodiesel: Produção de Biodiesel (Metros Cúbicos). Available online: http://www.anp.gov.br/wwwanp/dados-estatisticos (accessed on 14 November 2016).
12. Chagas, A.L.S. *Relatório Estudos Setoriais: Biocombustíveis*; EBC: Ribeirão Preto, Brazil, 2012. (In Portuguese)
13. Maluf, R.S.; Speranza, J.S. Preço dos alimentos, modelos de agricultura e abastecimento alimentar no Brasil: Os casos da soja e do feijão. Relatório Técnico. 2014. Available online: http://r1.ufrrj.br/ceresan/wp-content/uploads/2016/docs/CERESANRelatTecnico7EstudoprecosAAid(2).pdf (accessed on 16 February 2017). (In Portuguese)
14. National Agency of Petroleum, Natural Gas and Biofuels (NAP). Biodiesel. Available online: http://www.anp.gov.br/?id=472 (accessed on 14 November 2016).
15. Brazil. Decree from 23 December 2003. Brasília, Brazil. Available online: http://www.planalto.gov.br/ccivil_03/dnn/2003/Dnn10093.htm (accessed on 10 October 2016).
16. Ministry of Mines and Energy (MME). Biodiesel: Programa Nacional de Produção e Uso de Biodiesel. Available online: http://www.mme.gov.br/programas/biodiesel (accessed on 26 October 2016). (In Portuguese)
17. Brazil. Normative Rule number 1 of the Ministry of Agrarian Development (MAD), from 5 July 2005. Brasília, Brazil. Available online: http://www.lex.com.br/doc_395583_INSTRUCAO_NORMATIVA_N_1_DE_5_DE_JULHO_DE_2005.aspx (accessed on 18 October 2016).
18. Brazil. Ordinance Number 60 of the Ministry of Agrarian Development, from 6 September 2012. Brasília, Brazil. Available online: http://www.mda.gov.br/sitemda/sites/sitemda/files/user_arquivos_64/portal.mda_.gov_.br__1.pdf (accessed on 18 October 2016).

19. Ministry of Social Development and Fight against Hunger (MDS). Declaração de Aptidão ao PRONAF—DAP. Available online: http://www.mds.gov.br/segurancaalimentar/equipamentos/feirasemercados/arquivos/declaracao-de-aptidao-ao-pronaf-dap.pdf (accessed on 12 November 2016). (In Portuguese)
20. STCP Engenharia de Projetos Ltda. Estudo Referente aos Impactos Ambientais na Cadeia Produtiva, Distribuição e Uso do Biodiesel: Relatório final. In *Projeto BRA/00/020—Apoio às Políticas Públicas na Área de Gestão e Controle Ambiental (SQA)*; Ministry of the Environment/United Nations Development Programme: Brasília, Brazil, 2012. (In Portuguese)
21. Machado Filho, C.P. O papel dos leilões no agribusiness. In *Economia e Gestão dos Negócios Agroalimentares*; Zylbersztajn, D., Neves, M.F., Eds.; Pioneira: São Paulo, Brazil, 2000. (In Portuguese)
22. BiodieselBR. O Novo Diesel da Petrobras. 2006. Available online: http://www.biodieselbr.com/destaques/2006/h-bio-novo-diesel-petrobras.htm (accessed on 14 November 2016). (In Portuguese)
23. Brazilian Union of Biodiesel and Bio-Kerosene (UBRABIO). O Combustível da Sustentabilidade. *Biodiesel em Foco* **2010**, *1*, 1–20. Available online: http://www.ubrabio.com.br/sites/1700/1729/00000423.pdf (accessed on 16 November 2016). (In Portuguese)
24. Prado, J.N.; Vieira, W.C. Leilões de biodiesel conduzidos pela ANP. *Nexus Econ.* **2010**, *IV*, 67–88. Available online: https://portalseer.ufba.br/index.php/revnexeco/article/view/4862/3593 (accessed on 26 October 2016). (In Portuguese)
25. Brazil. Law Number 11097, from 13 January 2005. Brasilia, Brazil. Available online: https://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2005/Lei/L11097.htm (accessed on 30 October 2016).
26. Brazil. Law number 9478, from 6 August 1997. Brasília, Brazil, 1997. Available online: http://www.planalto.gov.br/ccivil_03/leis/L9478.htm (accessed on 10 October 2016).
27. Brazil. Law Number 13033, from 24 September 2014. Brasília, Brazil. Available online: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2014/lei/l13033.htm (accessed on 22 October 2016).
28. Brazil. Decree Number 7768, from 27 July 2012. Brasília, Brazil. Available online: http://www.planalto.gov.br/ccivil_03/_Ato2011–2014/2012/Decreto/D7768.htm (accessed on 20 October 2016).
29. Mingoti, S.A. *Análise de Dados Através de Métodos de Estatística Multivariada: Uma Abordagem Aplicada*; UFMG: Belo Horizonte, Brazil, 2005. (In Portuguese)
30. Hair Junior, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E. *Multivariate Data Analysis*, 7th ed.; Prentice Hall-Pearson: Upper Saddle River, NJ, USA, 2009.
31. Kaiser, H.F. A second generation little jiffy. *Psychometrika* **1970**, *35*, 401–415.
32. Bartlett, M.S. A note on multiplying factors for various chi-squared approximations. *J. R. Stat. Soc.* **1954**, *16*, 296–298.
33. Cronbach, L.J. Coefficient alpha and the internal structure of tests. *Psychometrika* **1951**, *16*, 297–334.
34. Olivério, J.L. O panorama brasileiro de biodiesel na visão da indústria de equipamentos. In *O Futuro da Indústria: Biodiesel*; Ferreira, J.R., Cristo, C.M.P.N., Eds.; MDIC: Brasília, Brazil, 2006; pp. 105–126. (In Portuguese)
35. McCormick, K.; Kåberger, T. Exploring a pioneering bioenergy system: The case of Enköping in Sweden. *J. Clean. Prod.* **2005**, *13*, 1003–1014.
36. Imasato, T. Estratégia, Legitimidade e Biocombustíveis: Uma Perspectiva Geopolítica. Ph.D. Thesis, Brazilian School of Public Administration and Business of the Getúlio Vargas Foundation, Rio de Janeiro, Brazil, 2010. (In Portuguese)
37. Quintella, C.M.; Teixeira, L.S.G.; Korn, M.G.A.; Costa Neto, P.R.; Torres, E.A.; Castro, M.P.; Jesus, C.A.C. Cadeia do biodiesel da bancada à indústria: Uma visão geral com prospecção de tarefas e oportunidades para P&D&I. *Química Nova* **2009**, *32*, 793–808. (In Portuguese)
38. Williamson, O. *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*; Free Press: New York, NY, USA, 1985.
39. Zylbersztajn, D. Estruturas de Governança e Coordenação do Agribusiness: Uma Nova Aplicação da Nova Economia das Instituições. Ph.D. Thesis, Department of Administration from the Faculty of Economics, Administration and Accounting, University of São Paulo, São Paulo, Brazil, 1995. (In Portuguese)
40. Rosillo-Calle, F.; Pelkmans, L.; Walter, A. A global overview of vegetable oils, with reference to biodiesel. In *A Report for the IEA Bioenergy Task 40*; IEA Bioenergy: Paris, France, 2009.
41. Cardoso, B.F.; Galante, V.A. Barreiras comerciais no comércio internacional: O caso da soja no Brasil. In *A Inserção Internacional do Agronegócio Brasileiro no Pós-Crise: A Atuação da OMC, Barreiras e Políticas Comerciais*; Schneider, M.B., Ed.; LedZe: Curitiba, Brazil, 2014. (In Portuguese)

42. Organisation for Economic Co-operation and Development (OECD). *Patents and Innovation: Trends and Policy Challenges*; OECD: Paris, France, 2004.
43. Pedroti, P.M. Os desafios do desenvolvimento e da inclusão social: O caso do arranjo político-institucional do Programa Nacional de Produção de Uso do Biodiesel. Discussion Paper no. 1858, 2013. Available online: http://repositorio.ipea.gov.br/bitstream/11058/2621/1/TD_1858.pdf (accessed on 12 November 2016). (In Portuguese)
44. Demirbas, A. *Green Energy and Technology: Biorefineries*; Springer: London, UK, 2010.
45. Demirbas, A. Importance of biodiesel as transportation fuel. *Energy Policy* **2007**, *35*, 4661–4670.
46. Amigun, B.; Musango, J.K.; Stafford, W. Biofuels and sustainability in Africa. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1360–1372.
47. Okada, S.I. Análise dos Pontos Críticos de Sucesso na Cadeia Produtiva do Biodiesel no Centro-Oeste Brasileiro: Um Subsídio à Gestão Estratégica. Master's Thesis, Federal University of Goiás, Goiânia, Brazil, 2008. (In Portuguese)