Daniel Henrique Alves Reis

A Stochastic Frontier Estimator of Oligopsony Power in the Brazilian Citrus Industry

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Daniel Henrique Alves Reis

A Stochastic Frontier Estimator of Oligopsony Power in the Brazilian Citrus Industry

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ATA DE DEFESA PÚBLICA DE DISSERTAÇÃO

Aos 19 dias do mês de dezembro de 2019, no horário de 13:30 horas às 15:00 horas, foi realizada, em sessão pública na sala 2107 da FACE, a defesa da dissertação *A Stochastic Frontier Estimator of Oligopsony Power in the Brazilian Citrus Industry,* de autoria do discente Daniel Henrique Alves Reis, do Programa de Pós-Graduação em Economia – PPGECON da Universidade Federal de Goiás.

A Comissão Examinadora, constituída pelo Professor Paulo Roberto Scalco, da Universidade Federal de Goiás (UFG)/PPGECON/(Membro Interno/Orientador), Professor Cleyzer Adrian da Cunha, da Universidade Federal de Goiás (UFG/PPGECON) (Membro Interno/Examinador) e pelo Professor Alcido Elenor Wander, da Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (Membro Externo/Examinador), emitiu o seguinte parecer/recomendações:

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Eu, Paulo Roberto Scalco, orientador do discente, lavrei a presente Ata, que segue assinada por mim e pelos demais membros da Comissão Examinadora.

Prof. Dr. Paulo Roberto Scalco (Orientador/Presidente/PPGECON/UFG)

Prof. Dr. Cleyzer Adrian da Cunha (Examinador/Membro Interno/PPGECON/UFG)

Alcido Elenor Wander

Prof. Dr. Alcido Elenor Wander (Examinador/Membro Externo/EMBRAPA)

Goiânia, 19/12/2019.

Dedico este trabalho aos meus pais, minha irmã
e minha namorada por serem meus pilares nesta jornada.
Da mesma forma, dedico ao meu orientador pela paciência
e dedicação nas intermináveis horas de dúvida.

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“Devo florescer onde
Deus me plantar ”
(Autor Desconhecido)

Resumo

O objetivo deste trabalho foi desenvolver um modelo de estimação de poder de oligopsônio com apenas dados de preços de insumos utilizando a abordagem de Fronteira Estocástica (SF). Usando a teoria da dualidade e através do teorema do envelope, mostramos que as elasticidades de uma função primal e dual são as mesmas. Assim, é possível estimar o poder de mercado com dados de quantidade ou preço. O modelo SF para medir o poder de mercado, embora recente, se destaca por sua robustez e tem sido amplamente aplicado. O modelo desenvolvido neste trabalho foi aplicado à indústria cítrica brasileira que, além das maiores do mundo, é altamente concentrada. Foi medido o poder de oligopsônio na compra de laranja pelos produtores de suco de laranja entre 1997 e 2018. Os resultados mostram que o preço recebido pelos produtores de laranja é 5,9% menor que o valor líquido do produto marginal do suco de laranja.

Palavras-chave: Poder de Oligopsônio. Abordagem de Fronteira Estocástica. Suco de Laranja.

Abstract

The objective of this study was to develop a model to estimate oligopsony power with only input price data using the Stochastic Frontier (SF) approach. Using the duality theory and through the envelop theorem we show that elasticities of a primal and a dual function are the same. Thus, it is possible to estimate the market power with quantity or price data. The use of SF model to measure market power although recent it stands out by its robustness and has been wildly applied. The model developed in this study was applied to the Brazilian Citrus Industry that beyond the biggest in the world stands for to be highly concentrated. It was measured the oligopsony power in the purchase of oranges by the producers of orange juice from 1997 to 2018. The results show that the price received by the orange producers is 5.9% lower than the net value of the marginal product of orange juice.

Keywords: Oligopsony Power. Stochastic Frontier Approach. Orange Juice.

Illustration List

Table List

Abbreviation List

CADE	Administrative Council of Economic Defense
GIM	General Identification Method
IDF	Input Distance Function
IEA	Agricultural Economy Institute
IO	Industrial Organization
KBL	Kumbhakar, Baardsen and Lien
ODF	Output Distance Function
PTA	Production Theoretical Approach
RTS	Return to Scale
SCP	Structure-Conduct-Performance
SDE	Secretariat of Economic Law
SFA	Stochastic Frontier Approach

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1 Introduction

The market power is a central theme in Industrial Organization (IO). To investigate the market power through the years researchers have been creating alternative to deal with the absence of data. Lerner (1934) developed the Lerner Index (L) to measure the market power, $L = (P - MC)/P$, where P is the market price of an output and MC is the marginal cost of the firm. Estimating L requires an estimating of MC which is usually not observable. The New Empirical Industrial Organization (NEIO) emerges with Bresnahan (1982) and Appelbaum (1982) as an alternative to measure the market power without directly the need of the MC.

Within the NEIO different authors developed methods to estimate the market power in an oligopsony framework which is more rarely than oligopoly studies due to availability of data in general at wholesale level. For every paper that investigates oligopsony power has 15 on oligopoly power. Schroeter (1988), Azzam and Pagoulatos (1990) and Azzam (1997) stand out as seminal studies investigating oligopsony power (SCALCO; LOPEZ; HE, 2017).

In this framework Panagiotou and Stavrakoudis (2017) developed a model to estimate oligopsony power to measure the mark-down exerted in the beef packing industry on purchase of living cattle. This model allows us to estimate the market power only with quantity data. The model proposed by the authors is based on the new class of models on NEIO develop by Kumbhakar, Baardsen and Lien (2012) that use Stochastic Frontier (SF) models to measure market power.

The new class of models take into account the term of inefficiency of the firm generally used in the framework of production, cost or profit function to measure the makert inefficiency. The SF models have several advantages when compared to NEIO models, as allowed estimating, in a single model of unified structure, a mark-up measure and an indicator of market power. Also, we can obtain measures of elasticity, return to scale, and efficiency.

The most important development of the SF model is the is the flexibility on data requirement. The model allows through duality theory to estimate the models using quantity or price data only. Kumbhakar, Baardsen, and Lien (2012) start from a cost function (dual form), which requires data on input price, and using the envelope theorem reached an Input Distance Function (IDF) (primal form) which requires only data on input quantity. They showed that the elasticities of the two functions are the same.

In this context, the overall objective of this study was to develop a new model to estimate market power in oligopsony framework using only input price data instead input quantity. The model is based on Stochastic Frontier approach and starts from Panagiotou and Stavrakoudis (2017) model that measure oligopsony power in the U.S. Beef packing Industry with stochastic frontier approach using only input quantity.

The idea of this paper was used by Muth and Wohlgenant (1999) to estimate an oligopsony power in the absence of input quantity and it was used input price data as well. Considering the robustness of the stochastic frontier approach to estimate market power, there is still none approach that allow us to estimate market power in a oligopsony structure with only price data.

This model will be applied to Brazilian citrus industry. Brazil is, the biggest worldwide producer of orange juice of the word, biggest exporter, has the biggest company and has a highly concentrated market. This market still stands out to have the longest case of investigation in Brazil antitrust office, an accusation of cartel formation of industries by the orange producers, lasting 17 years.

To the best of our knowledge no analysis has been done to measure of degree of market power in the market of purchase of orange by citrus industry. Thus, it will be measured the oligopsony power in the purchase of fresh oranges by the producers of orange juice from 1997 to 2018.

It was found some evidences of non-competitive market in the Brazilian Citrus Industry with degree of oligopsony power of, on average, 5.90%, the Lerner Index, on average, 6.3% over the period analyzed and with a maximum of 14.7% in 2000 which is the period of the Industry pledge guilty in the investigation of cartel formation (1999-2006).

To develop all these questions, this study has been divided into six chapters. The first and the last sections concern the introduction and the final considerations; the second section presents an overview of NEIO classes of models and the Brazilian Citrus Industry; the third section covers the empirical model used in the paper; the fourth section contains the describes the data; and the fifth contains results of empirical models used.

2 Literature Review

2.1 New Empirical Industrial Organization

The disuse of the Structure-Conduct-Performance (SCP) is due to the use of accounting data to measure the industry behavior and market power causing bias in the analysis and the MC not be directly observable. In this context the New Empirical Industrial Organization (NEIO) presenting as an alternative to calculating the market power without the need of calculating the marginal cost, only with the use of supply and demand relations.

In 1982 borns to NEIO with a publication of the articles of Applebaum (1982) and Bresnahan (1982). Applebaum verifies the existence of market power from the elasticities of the inverse demand and conjectural elasticities and still measure the degree of market power through generalization of the Lerner index (PEREKHOZHUK et al., 2017).

Bresnahan (1982) verifies the existence of market power from the demand curves of the product. The author suggests that a rotation of the demand curve around the equilibrium point of the market generating a displacement of the marginal revenue curve in such a way that it is possible to verify if the company exerts market power. If the market is competitive the rotation will have no effect on the equilibrium price, but if there is market power the equilibrium price will change.

The Bresnahan and Applebaum papers, in addition to starting the New Empirical Industrial Organization (NEIO), divide it into two to classes of models with different methodological approaches used. Applebaum article generates the Theoretical Approach to Production (PTA) while Bresnahan work come up with the General Identification Method (GIM) (PEREKHOZHUK et al., 2017).

The great difference between PTA and GIM approach is while the first one is wildly used for measuring the degree of market power from flexible production functions and the other proved that it is possible to identity the exercise of market power even if profit, cost, revenue or production data are unavailable (PEREKHOZHUK et al., 2017).

The two classes of NEIO models differ in a lot of features in respect to econometric estimation, data and kind of functions used. These two classes of models produce important papers to the Industrial Organization. Some examples are showed in table 1.

Perloff and Shen (2012) identify some weakness presented by NEIO models, as multicollinearity, coefficient of parameters not significant, wrong sign of parameters or implausible magnitude and the estimations were very sensible to addition or deletion of observations. And still to estimate market power with NEIO models is necessary at least two equations.

Table 1 – Papers NEIO

Papers	Class NEIO
(BRESNAHAN, 1982)	GIM
(APPELBAUM, 1982)	PTA
(LAU, 1982)	GIM
(PANZAR; ROSSE, 1987)	GIM
(BAKER; BRESNAHAN, 1988)	GIM
(SCHROETER, 1988)	PTA
(AZZAM; PAGOULATOS, 1990)	PTA
(SCHROETER; AZZAM, 1990)	PTA
(AZZAM, 1997)	PTA

Source: Own compilation

In this context, Kumbhakar, Baardesen and Lien (2012) develop a method that allowed to estimate market power through a Stochastic Frontier Approach (SFA). This innovated method is more robust than the previous ones and marks the beginning of a new class of model within the NEIO, the Stochastic Frontier models (KUMBHAKAR; BAARDSEN; LIEN, 2012).

The SF model to estimate market power use the framework of efficiency of production and cost to obtain measure of competitiveness. In a SF framework the parameter traditionally associate with inefficiency now measures the markup of the Industry and the market power can be obtain directly from this measure.

The SFA to measure market power has several advantages in comparison with the other models within the NEIO. Stands out the measured of market power, mark-up estimated from a single equation. And still this measure of market power is not only an estimate of the average parameter of the competition level of the industry, but the method also allows estimating a measure of the degree of market power at a firm level and over time. In the same way, it is possible to estimate the returns to scale and it is possible to estimate directly the Lerner Index (L).

The main advantage of these models is the flexibility of requirement of data. Kumbhakar et al. (2012) show that is possible to estimate market power with input quantity or input price data. They use the duality theory to show the elasticities of a par of related functions (primal and dual) are the same, thus, the researcher can estimate market power with a primal or dual approach depending on data availability.

Kumbhakar et al. (2012) star from a Cost function wich the data requirement is price of input and using the duality theory and through the envelop theorem reach a Input Distance Function which the requirement is quantity of input. These two funcitions are dual according to Shepherd (1970).

Although recent, the KBL model has been widely used in Industrial Organization (IO) and by different kinds of sector of economy to estimate market power. The first sector the SF model was applied were the Norwegian Sawmilling. Then, was also applied to food, banks industries and European iron market. Some examples of the application can be seen on table 2.

Table 2 – SF Applications

Papers	**Sector applied**
(KUMBHAKAR; BAARDSEN; LIEN, 2012)	Norwegian Sawmilling
(BAIRAGI; AZZAM, 2014)	Bank Industry
(COCCORESE, 2014)	Bank Industry
(GERMESHAUSEN; PANKE; WETZEL, 2014)	Iron Market
(DAS; KUMBHAKAR, 2016)	Bank Industry
(SCALCO; LOPEZ; HE, 2017)	Food Industry
(PANAGIOTOU; STAVRAKOUDIS, 2017)	Food Industry
(LOPEZ; HE; AZZAM, 2018)	Food Industry

Source: Own compilation

Panagiotou and Stavrakoudis (2017) are pioneers in the use of the Stochastic Frontier approach to estimate the oligopsony power. They measured the oligopsony power exerted by the beef packing Industry in the USA. It was estimated an Output Distance Function (ODF) which the requirement of data is quantity of inputs, however, this data is not available to all markets.

Accounting all the advantages of an stochastic frontier approach to estimate market power and in all this contexts it is justify the develop of an stochastic frontier model to estimate degree of market power in an oligopsony market with absence of quantity data requirement, in the dual form, with price requirement. The model developed here will be apply to the Brazilian Citrus Industry, more specific known to be highly concentrated.

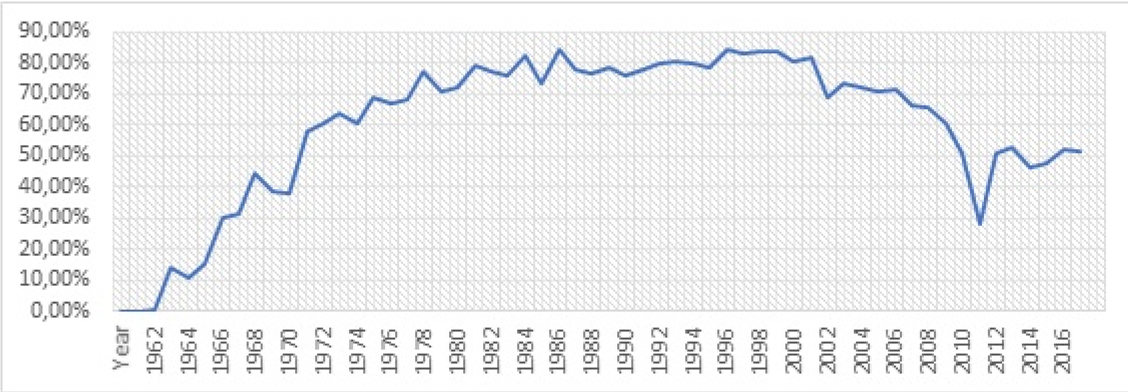
2.2 Brazilian Citrus Industry

The production of Citrus Industry includes the derivatives of grapefruit, tangerines, lemons and limes, and mainly, oranges among others. Among these derivatives stands out the production of orange juice, with the most quantity and the most value produce by the sector. The production of orange juice represents more than 80% of citrus fruit processing. Of all the oranges produced worldwide, 20% of the total is sold as the fruit in nature and the remainder is used in the process industry to make juice (FOOD; (FAO), 2019).

Brazil has the largest worldwide production of orange, consequently, the biggest production of orange juice and is the biggest exporter of the orange juice, destined mostly to Europe, United States and Japan. Brazil is responsible on average for 70% of the orange juice exported to the world over 1960 to 2019 and the product generally comes from São Paulo state (COMEX, 2019) as can be seen in figure 1.

The production of orange is most located in São Paulo due to climatic conditions and favorable soil to the cultivation of citrus fruits. The state is responsible for almost 80% of

Figure 1 – Percentage of orange juice exports from Brazil



Source: Own compilation based on FAO data

the Brazilian production of orange. The citrus industry from São Paulo over 1997 to 2019 is responsible for almost 98% of the Brazilian exports of orange juice, making themselves the most important market not only in Brazil but the world (IBGE, 2018; COMEX, 2019)

The orange production, is characterized by 68% of the farms are considered small orchard, with less than 20,000 trees, 27% of farms is median orchard, between 20,000 to 100,000 trees, and 5% has larges orchard, with over 100,000 trees. Then, most of the orange production is made by small farmers which characterizes the selling market of oranges, a lot of producers (IBGE, 2018).

The industry of citrus fruit processing was born in the 1960's in São Paulo where was located the production of orange. The main product was always the orange juice with most of it destined to exportation. Today, São Paulo complex agro-industrial citrus is modern and worldwide leader in production and exportation (TROCCOLI; ALTAF, 2010).

The Brazilian expertise in the orange juice market made possible to explore the whole fruit and other byproducts taken from orange are the oils extract from the orange peel and the bran from the pulp. However, the main gross of the industry continues to come from production of juice and most of it from the exportation. The development of citrus industry can be seen in three stages according to Paulillo and Almeida (2010).

The first stage of the development of the citrus industry dates from 1960 to 1990. In the 1960's, the exportation of the concentrated orange juice substitutes the exportation of orange in nature. This process was favorably due to the positive condition of the international market. In the 1970's and 1980's started the conflicts about the definition on the price of the orange between the thousands of producers and the few industries. The market already was characterized by few companies responsible for almost the whole production of orange juice, highly concentrated, an oligopsony (TROCCOLI; ALTAF, 2010).

Decreasing the asymmetry and gain power over negotiations unions of farmers were formed to negotiate with industries, with the large number of producers and their heterogeneity several associations were born. In response the industries made associations of processors to strong power in negotiations and stood out the Brazilian Association of Citrus Exporting Companies (*Abecitrus*) that later was source of conflict between producers and industries (TROCCOLI; ALTAF, 2010).

As a result of negotiation between associations, the contracts between producers and processors become standard, ballasted with the conditions of international market, in order to diminish the power of the industry. These agreement suits to all actors involved. Thereafter, during 1985 to 1989 prices of orange in nature reached the highest level with a favorable international market (PAULILLO; ALMEIDA, 2010)(GONÇALVES; VICENTE, 2010).

The second stage of the industry was in the 1990's, the conflicts between the farmers and industries flourished, making the most significant aspect of this is stage the institutional crises of the sector. In the first half of the decade the price of orange drops due mismatch of supply and demand and intensification of phytosanitary problems. Along with those problems the production of orange juice on Florida gain relevance in the U.S. market, main destination of orange juice exports from Brazil in the period (TROCCOLI; ALTAF, 2010).

In the early 1990's context still, the vertical integration of the production by the processors led to the weakening of the unions of producers and expanding the asymmetry between processor of orange juice and the producers. The favorable conditions of the international orange juice market started follow apart and then the prices of the standard contracts as well (ITO; ZYLBERSZTAJN, 2016).

In this context of dropping prices the producers felt harmed and start the litigious against 12 industries on Secretariat of Economic Law (*SDE*) with the accusation of cartel formation and imposition on the orange prices by the associations of processors, in 1994. This turned into a process between citrus growers and juice processors on Administrative Council of Economic Defense (*CADE*), Brazilian antitrust office, in 1995 (ITO; ZYLBERSZTAJN, 2016).

Solving the litigious CADE, in 1995, proposed the Commitment to Termination of Anticompetitive Practices on the industries to finish the investigation on cartel formation. As penalties the standard contracts were suspended and the industry was prohibited from attending meetings organized by association, body or public institution (GONÇALVES; VICENTE, 2010).

As consequence of the proposed of CADE, the contracts were no longer multilateral, but back to bilateral, individually between the producer and industry. However, contractual problems were still present due to insufficient competition. And the meetings of industry through associations continues to occur (ITO; ZYLBERSZTAJN, 2016).

As a result of the process of 1995 on CADE the citrus industry were prohibited the realizations of meetings in associations which they never did. This conduct took the unions of producers of orange engage with another litigious on CADE in 1999 with the allegation of cartel formation by the industries[1] but this time the process were against the Association Citrus Exporters Company (*Abecitrus*) (ITO; ZYLBERSZTAJN, 2016).

The new investigation has become the longest case in the history of the Brazilian antitrust office. This processes had several process had several judicial questions about the investigation and the case was suspended. In 2016, the companies investigated agreed to drop the lawsuit to close case and singed the Termination of Conduct Terms, pleading guilty of cartel formation from 1999 to 2006 and pay a fine to farmers unions of R$ 301 million reais[2] (CADE, 2016).

The case lasted 17 years, by the time of end of the process some companies no longer existed, the most significant defendant, Association Citrus Exporters Company (*Abecitrus*), was dissolved in 2008. Some industries, also involved, was merged in the third stage of the citrus industry.

The third stage dates from 2000's till nowadays and is characterized by the market restructuring with fusions and acquisitions in the industries. In the second stage the entrance of new industries on the marked diminished with the crises on the sector. However, in the third stage acquisitions started to happened making the market more concentrated (PAULILLO; ALMEIDA, 2010).

In 2004, Cargill, third in capacity of production, sold their units to biggest ones in Cutrale and Citrosuco. In 2005, Citrovita bought the Sucorrico elevating his market share. These process makes the four biggest companies hold approximately 85% of the capacity of processing Brazilian orange juice (PAULILLO; ALMEIDA, 2010) as can be seen in table 3.

In 2010, was announced the fusion of two of the four biggest processors of orange juice, Citrosuco and Citrovita which would become not only the largest orange juice industry of Brazil but in the world. The emerging industry would have capacity of production between 40 and 50% of the orange produce in Brazil. The merger led a HHI of 0.39 which is the highest in the history of the industry.

The Brazilian antitrust office, Administrative Council of Economic Defense (*CADE*), approved the fusion because it would not harm the producers on Brazil. However, some conditions were imposed before the fusion materializes as the company could not increase the vertical integration for five years, share some information with the producers of orange for ten years and sing long term contracts with the producers. These medicines were taken in an effort to diminish the asymmetry of information and hold an interdependence in the market (RAGAZZO; MACHADO, 2013).

The Herfindahl-Hirschman Index[3] (HHI) points out that most of the time the Citrus

[1] Administrative Proceedings 08012.008372/1999-14, 08012.001255/2006-66 and 08012.010505/2007-30

[2] The value corresponded approximately US$ 89 million dollar at the time.

[3] The Herfindahl Index measures the degree of industrial concentration, ranging from 0 to 1. The higher the value, the greater the market power of large companies. According to Tremblay and Tremblay (2012) from 0 to 0,1 the

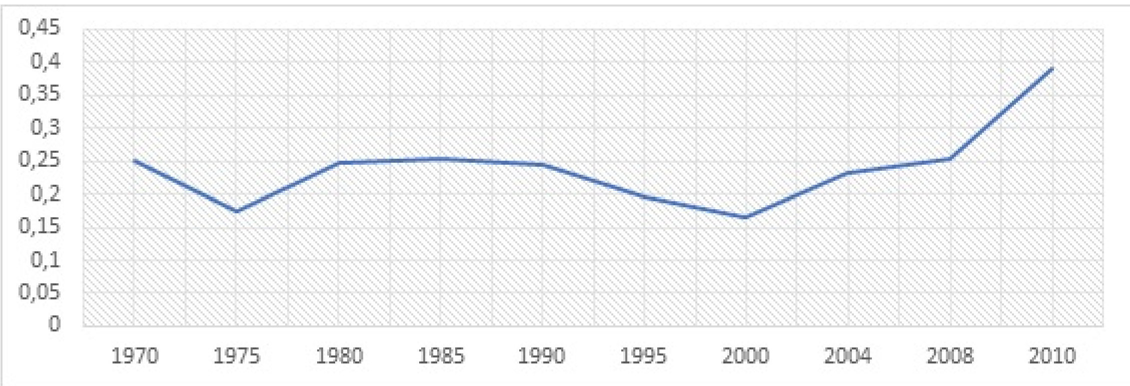
Table 3 – Market Share of industries producers of orange juice in São Paulo state (%) from 1970 to 2010

Companies	**1970**	**1980**	**1990**	**1995**	**2002**	**2004**	**2008**	**2010**
Citrosuco	39.47	24.00	33.40	27.07	20.90	24.12	28.46	48.34
Cutrale	23.68	35.00	28.13	23.44	21.70	29.33	32.36	36.30
Cargill	15.79	15.62	14.69	12.76	13.00	*	*	*
Coinbra	7.89	14.06	10.53	16.29	13.00	11.75	10.53	10.53
Citrovita	**	**	**	n/d	14.00	19.68	23.82	***
Outros	13.17	10.30	13.25	20.44	17.40	15.12	4.83	4.83
Total	100	100	100	100	100	100	100	100
2 biggest companies	63.15	59.00	61.53	50.51	42.60	53.45	60.82	84.64
4 biggest companies	86.83	88.68	86.75	79.56	69.60	84.88	95.17	97.88
Herfindahl Index	0.251	0.175	0.253	0.245	0.164	0.233	0.254	0.390

Source: Agricultural Economy Institute (*IEA*)
*In 2004, Cargill was bought by Cutrale and Citrosuco;
** The company start their operations in 1991;
*** Fusion between Citrosuco and Citrovita.

Industry is highly concentrated with short periods of a moderately concentrated. From 1970 to 1990 the HHI was around 0.250, the 1990's shows a decrease of the industrial concentration and in this century is evident a strong process of concentration with the process of fusions and acquisitions and can be seen in figure 2.

Figure 2 – Herfindahl-Hirschman Index of Brazilian Citrus Industry



Source: Own compilation based on Agricultural Economy Institute (*IEA*) data

São Paulo presented itself as a relevant market to estimate the degree of oligopsony power in the industry because it is the most relevant processor of orange juice in the world, contain the biggest company, it is a highly concentrated market, the history of the market with all disputes between producers and industry, with companies pleading guilty for cartel formation

industry is classified as unconcentrated, from 0,1 to 0,18 moderately concentrated and grater than 0,18 is highly concentrated from 1999 to 2006 makes a strong case to measure the market power. In this work we estimate the degree of oligopsony power in the citrus industry with the stochastic frontier estimator on the period from 1997 to 2018.

All studies referred to above focused on market concentration and how they related to price formation. To the best of our knowledge no analysis has been conducted to measure of degree of market power in the market of purchase of orange by citrus industry.

3 Theoretical Framework

3.1 Individual Firm

In this paper we propose a model stochastic frontier estimator of degree of oligopsony power that allows to measure the market power using data on input price. Panagiotou and Stavrakoudis (2017) developed a stochastic frontier model in the context of stochastic frontier but their model requires data on quantity of inputs which is not available to all markets. In this context our model makes itself relevant and a very useful tool in markets where proxies of prices of inputs are available.

We use as strategy in the development of our model the same used by Kumbhakar, Baardsen, and Lien (2012) where using the duality theory and through the envelop theorem they show that elasticities of a cost function and a input distance function (IDF) are the same but the requirement of data are price of input and quantity of input respectively. So, we start from the model proposed by Panagiotou and Stavrakoudis (2017) .

We start from a profit function for a firm where Π_i is the profit of the firm i, represented by:

$$\Pi_i = P \cdot f(x_1, \mathbf{x_z}) - W_1 \cdot x_1 - \mathbf{W_z} \cdot \mathbf{x_z}, \quad i = 1, \dots N. \tag{3.1}$$

Where P is the deflated price of the output (at the wholesale level) and this are market prices and they are given, $f(.)$ is the production function, x_1 is the specialized input quantity on the firm level, $\mathbf{x_z}$ is the vector of other inputs (e.g. labor, energy, capital) used by the firm to produce the output q, W_1 is the deflated price of the specialized input and $\mathbf{W_z}$ is the vector of the deflated prices of other inputs, this are market prices, that is, given prices. We assume the industry is an oligopsony, then $W_1 = W_1(X_1)$ is the inverse supply curve for that product.

Assuming the firm maximizes profit, the demand for the specific input will be given by the first-order condition (FOC) of the profit equation (3.1), where the marginal cost of the input equals the marginal revenue product. X_1 is the total quantity of the whole Industry:

$$P \cdot \frac{\partial f(.)}{\partial x_1} - W_1 - \frac{\partial W_1}{\partial X_1} \cdot \frac{\partial X_1}{\partial x_1} \cdot x_1 = 0. \tag{3.2}$$

Rewriting:

$$P \cdot \frac{\partial f(.)}{\partial x_1} = W_1 \cdot (1 + \frac{1}{W_1} \cdot \frac{\partial W_1}{\partial X_1} \cdot x_1 \cdot \frac{\partial X_1}{\partial x_1} \cdot \frac{X_1}{X_1}). \tag{3.3}$$

Let $\varepsilon = (\frac{W_1 \cdot \partial X_1}{X_1 \cdot \partial W_1})$ be the price elasticity of the demand and $\phi_i = (\frac{x_1 \cdot \partial X_1}{X_1 \cdot \partial x_1})$ the weighted share of the individual demand with respect to the total demand, conjectural elasticity. Then equation (3.3) can be written as:

$$W_1(1+\frac{\phi_i}{\varepsilon}) = P \cdot \frac{\partial f(.)}{\partial x_1} = P \cdot \frac{\partial q_i}{\partial x_1} = MVP_{xi}. \tag{3.4}$$

Where MVP_{xi} is the marginal value of product of the firm i. Since ϕ_i varies from 0 to 1 and (ϕ_i/ε) is negative but grater then -1, which is an interior solution, we get the following inequation from (3.4):

$W_1 \leq MVP_{xi}$, or

$W_1 \leq P \cdot MP_{xi}$

where MP_{xi}, marginal product, composed by the production function of the firm i.

$$W_1 \leq P \cdot \frac{\partial q_i}{\partial x_1}. \tag{3.5}$$

If we multiply both sides (3.5) by $(\frac{1 \cdot x_1}{P \cdot q_i})$ we get:

$$(\frac{1 \cdot x_1}{P \cdot q_i}) \cdot W_1 \leq (\frac{1 \cdot x_1}{P \cdot q_i}) \cdot P \cdot \frac{\partial q_i}{\partial x_1}.$$

$$\frac{W_1 \cdot x_1}{P \cdot q_i} \leq \frac{\partial\, ln\, q_i}{\partial\, ln\, x_1}. \tag{3.6}$$

Like Kumbhakar, Baardsen, and Lien (2012), Germeshausen, Panke, and Wetzel (2014), Das and Kumbhakar (2016) and Panagiotou and Stavrakoudis (2017) we can transform the inequality in (3.6) into an equality by adding a non-negative, one-sided term u, that represents the mark-down exerted by an oligopsonic firm:

$$\frac{W_1 \cdot x_1}{P \cdot q_i} + u_i = \frac{\partial\, ln\, q_i}{\partial\, ln\, x_1}. \tag{3.7}$$

Rewriting:

$$\frac{W_1 \cdot x_1}{P \cdot q_i} = \frac{\partial\, ln\, q_i}{\partial\, ln\, x_1} - u_i. \tag{3.8}$$

The term u_i in the stochastic frontier literature represents the technical inefficiency of a production function of the firm (Kumbhakar and Lovell, 2003). In this work, we are not dealing with the production problem, but the market power problem, so it is clear that the term u_i represents the technical inefficiency of the market, in an oligopsonic structure the market power exerted on the supply offers, the mark-down.

3.2 Industry

So far the model developed by Panagiotou and Stavrakoudis (2017) allow us to estimate the mark-down at the firm level which it is not our case. Here we deal with the problem on an aggregate level, the industry level. Appelbaum (1982) assumed that in equilibrium the conjectural variation elasticities do not vary across firms, which will be used in this work, this means that $\phi_i = \Phi$ for every citrus industry. Following Azzam and Pagoulatos (1990), the invariance of the conjectural variation across firms enables us to drop the subscript i on the marginal product, where the weight of each firm is the share in whole market.

Multiplying through (3.4) by (x_1/X_1) and summing across the N firms of the industry we obtain the aggregate supply relation:

$$\sum_{i=1}^{N} \frac{x_1}{X_1} \cdot W_1 + \sum_{i=1}^{N} \frac{x_1}{X_1} \cdot W_1 \cdot \frac{\phi_i}{\varepsilon} = \sum_{i=1}^{N} \frac{x_1}{X_1} \cdot P \cdot MP_{xi}. \tag{3.9}$$

Rearranging the constant terms:

$$W_1 \cdot \sum_{i=1}^{N} \frac{x_1}{X_1} + W_1 \cdot \frac{\Phi}{\varepsilon} \sum_{i=1}^{N} \frac{x_1}{X_1} = P \cdot \sum_{i=1}^{N} \frac{x_1}{X_1} MP_{xi}. \tag{3.10}$$

And since $\sum_{i=1}^{N} \frac{x_1}{X_1} = 1$, from (3.10) we get:

$$W_1 + W_1 \cdot \frac{\Phi}{\varepsilon} = P \cdot MP_x. \tag{3.11}$$

Where $MP_x = \sum_{i=1}^{N} \frac{x_1}{X_1} MP_{xi}$ is the weighted marginal product of individual firms, according Azzam and Pagoulatos (1990). Hence, the industry is analogue to the firm (3.4):

$$W_1 \cdot (1 + \frac{\Phi}{\varepsilon}) = P \cdot MP_x \quad or \quad W_1 \cdot (1 + \frac{\Phi}{\varepsilon}) = MVP_x. \tag{3.12}$$

In the same way of equation the firm the equality of (3.5) can be written as inequality:

$$W_1 \leq MVP_x. \tag{3.13}$$

.

The inequality (3.13) has the same direction as the inequality of the firm (3.6). Following the same procedure we multiply both sides of (3.13) by $(\frac{1 \cdot X_1}{P \cdot Q})$:

$$\frac{W_1 \cdot X_1}{P \cdot Q} \leq \frac{\partial \, ln Q}{\partial \, ln X_1}. \tag{3.14}$$

In equation (3.14) the term $(\partial \, ln Q / \partial \, ln X_1)$ is the elasticity of an Output Distance Function (ODF) also represented by ε_{QX1}.

Adding a term u, mark-down of the industry, in equation (3.14) in order to transform the inequality in equality, but at the industry level:

$$\frac{W_1 \cdot X_1}{P \cdot Q} + u = \frac{\partial\, ln Q}{\partial\, ln X_1} \Rightarrow \frac{W_1 \cdot X_1}{P \cdot Q} = \frac{\partial\, ln Q}{\partial\, ln X_1} - u. \tag{3.15}$$

Thus far, the model developed here (3.15) is the same as Panagiotou and Stavrakoudis (2017). The term $(\partial\, ln Q/\partial\, ln X_1)$ is the partial derivate of an Output Distance Function (ODF) with respect to the quantity of inputs or the elasticity of an ODF and requires data on quantity of input which is not available to all markets.

The Cost function requirement of data is price of input and according to duality theory of Shepard (1970) the cost function is dual to the Input Distance Function (IDF), so we start from an ODF to get an IDF, then through envelop theorem it is possible to estimate the function we data on input price.

Equation (3.14) may be rewritten as:

$$\frac{P \cdot Q}{W_1 \cdot X_1} \geq \frac{\partial\, ln X_1}{\partial\, ln Q}. \tag{3.16}$$

Where $(\partial\, ln X_1/\partial\, ln Q)$ is the elasticity of an Iutput Distance Function (IDF) also represented by ε_{X1Q}.

The Output Distance Function (ODF) became the Input Distance Function (IDF), which is the dual function of the cost function. Solving the inequality:

$$\frac{P \cdot Q}{W_1 \cdot X_1} = \frac{\partial\, ln X_1}{\partial\, ln Q} + u. \tag{3.17}$$

The efficient production technology for a representative Industry may be describe by a standard production function, viz., $Q = f(\mathbf{X}, T)$, where Q is output produced by industry, $\mathbf{X}$ is the vector of input used, composed by X_1 the specialized input quantity on industry level and $\mathbf{X_z}$ is the vector of other inputs quantities, and T is the technology index. $f(\mathbf{X}, T)$ is finite, non-negative, real valued, single valued for non-negative and finite $\mathbf{X}$, everywhere twice continuously differentiable, weak monotonic, quasi-concave, and weak essential. The input requirement set is assumed to be closed and non-empty.

Following Kumbhakar, Baardsen, and Lien (2012) and Das and Kumbhakar (2016) and according to duality theory, all characteristics of the production technology, implied by the production function $Q = f(\mathbf{X}, T)$, can be uniquely represented by a minimum total cost function $C(\mathbf{W}, Q, T)$ where C is the minimum total cost and $\mathbf{W}$ is the vector of price of the inputs, composed by W_1, the price of the specialized input, and W_z, the vector of other inputs prices. This function is positive and non-decreasing in Q and $\mathbf{W}$, and homogeneous, concave and continuous in $\mathbf{W}$.

We have a structure of multiple inputs $(X_j \;\; j = 1, 2, ..., J)$. We start from a transformation function and express the efficient production technology as $h(Q, \mathbf{X}, T) = 1$. This primal approach allows us to obtain the production function, the output and input distance functions, simply by using normalizations of the transformation function as demonstrated by Kumbhakar (2011). As shown below it also enables us to estimate mark-downs either using price or quantity information. This approach has shown very useful to deal with the absence of data.

Here we assume the transformation function, $h(.)$, is a translog function associated with IDF and can be written as:

$X_1 = h(Q, \tilde{\mathbf{X}}, T) \Rightarrow \; ln\, X_1 = h(\; ln\, Q, \; ln\, \tilde{\mathbf{X}}, T)$, when $\tilde{\mathbf{X}}, T) = (\frac{X_j}{X_1}), j = 2, 3, ..., J$.

And we also assume the above IDF uses the normalization that $h(Q, \mathbf{X}, T)$ is homogeneous of degree -1 in $\mathbf{X}$ which means:

$$\sum_{j=2}^{J} \frac{\partial \; ln\, h}{\partial \; ln\, X_j} = -1. \tag{3.18}$$

To apply the duality theory, we start from the Lagrangian for cost minimization using the transformation function:

$$L = \mathbf{W}'\mathbf{X} + \lambda(h(Q, \mathbf{X}, T) - 1). \tag{3.19}$$

The First order conditions to the optimization problem (3.19):

$$\frac{\partial L}{\partial X_j} = 0 \Rightarrow W_j + \lambda \cdot \frac{\partial h(.)}{\partial X_j} = 0 \Rightarrow W_j = -\lambda \cdot \frac{\partial h(.)}{\partial X_j}. \tag{3.20}$$

Multiplying (3.20) by X_j in both sides and by $(h(.)/h(.))$ the right side:

$$W_j \cdot X_j = -\lambda \cdot h(.) \cdot \frac{\partial h(.) \cdot X_j}{\partial X_j \cdot h(.)} \Rightarrow W_j \cdot X_j = -\lambda \cdot h(.) \cdot \frac{\partial \; ln\, h}{\partial \; ln\, X_j}. \tag{3.21}$$

Summing across the inputs to obtain the cost function:

$$C = -\lambda \cdot h(.) \sum_j \frac{\partial \; ln\, h}{\partial \; ln\, X_j} \Rightarrow -\lambda = \frac{C}{h(.)} \cdot \frac{1}{\sum_j \frac{\partial \; ln\, h}{\partial \; ln\, X_j}}. \tag{3.22}$$

Since $h(.)$ is homogeneous of -1 in $\mathbf{X}$ (3.18):

$$\lambda = \frac{C}{h(.)}. \tag{3.23}$$

From the Envelope Theorem, the marginal cost for output Q is:

$$\frac{\partial L}{\partial Q} = MC = \frac{\partial C}{\partial Q} = \lambda \cdot \frac{\partial h(.)}{\partial Q}. \tag{3.24}$$

Where MC is the marginal cost of the industry. Substituting (3.23) into (3.24):

$$\frac{\partial L}{\partial Q} = MC = \frac{\partial C}{\partial Q} = \frac{C}{h(.)} \cdot \frac{\partial h(.)}{\partial Q}. \tag{3.25}$$

If we multiply both sides of (3.25) by (Q/C) we get:

$$\frac{\partial C}{\partial Q} \cdot \frac{Q}{C} = \frac{C}{h(.)} \cdot \frac{\partial h(.)}{\partial Q} \cdot \frac{Q}{C}. \tag{3.26}$$

Simplifying (3.26):

$$\frac{\partial\, ln\, C}{\partial\, ln\, Q} = \frac{\partial\, ln\, h(.)}{\partial\, ln\, Q}. \tag{3.27}$$

$$\varepsilon_{CQ} = \varepsilon_{hQ}. \tag{3.28}$$

The elasticity of the transformation function and the cost function are equal. Then, ε_{hQ} can be computed using estimated parameters of the IDF transformation function $(X_1 = h(Q, \mathbf{X}, T)\, \forall X_j = 2, 3, ...J)$. That is, the cost elasticity of output (ε_{CQ}) can be estimated from a IDF and there is no need to estimate the use of quantity of inputs. Then equation (3.17) can be written as:

$$\frac{P \cdot Q}{W_1 \cdot X_1} = \frac{\partial\, ln\, X_1}{\partial\, ln\, Q} + u = \frac{\partial\, ln\, C}{\partial\, ln\, Q} + u. \tag{3.29}$$

The elasticity of the production function $(\varepsilon_{X_1 Q})$ is equal to the cost elasticity of output (ε_{CQ}) as was shown though a transformation function. Econometrically the Cost function shown the same elasticity of an Input Distance function. Hence, allow us to use an cost function instead a production function to estimate the market power in the industry where only proxies of input prices are available.

Adding a the stochastic $(v\ iid)$ term we get:

$$\frac{P \cdot Q}{W_1 \cdot X_1} = \frac{\partial\, ln\, C}{\partial\, ln\, Q} + u + v. \tag{3.30}$$

We can observed that the models (3.15) and (3.30) follow the stochastic frontier literature, the variable that captures the disturbance in both models, the mark-down, u, has the expected signal. Following Kumbhakar and Lovell (2003), the production functions are characterized by inequality $y_i \leq f(x_i, \beta)$, to make an equality they add the inefficiency term $y_i + u_i = f(x_i, \beta) \Rightarrow y_i = f(x_i, \beta) - u_i$. The cost functions are characterized by inequality $E_i \geq c(y_i, w_i, \beta) + u_i$, to make an equality they add the inefficiency term $E_i = c(y_i, w_i, \beta) + u_i$. The cost function has the disturbance with positive signal, following equation (3.30), and the production function has the disturbance with negative signal, equation (3.15).

The composed error term $(u+v)$ in the (3.30) is not different from that of a stochastic production frontier model. Hence, (3.30) can be estimated using the maximum likelihood method that is commonly used to estimate a stochastic production frontier. The maximum likelihood method is based on the distributional assumption of the errors. Following the literature, the distributional assumptions are that u is a normal variable truncated at zero from below, i.e. $u \sim N^{+}(0,\sigma_u^2)$, and v is the usual two-sided normal noise term, i.e. $v \sim N(0,\sigma_v^2)$. In this work, unlike the stochastic frontier analysis approach, the one-sided term u in (3.30) does not account for the inefficiency in production, but for the mark-down in the orange market for a citrus industry.

As mentioned before, our objective is measure the market power in with data on input price in the stochastic frontier approach. The ODF requires data on input quantity which is not always available but through the Duality Theory we can obtain the cost function and estimate the model with proxy on the price input. This approach has shown very useful to estimate market power either with quantity or price data, proving its value to the New Empirical Industrial Organization literature.

The translog Cost function can be written as:

$$ln\,C = \beta_0 + \sum_{j=x}^{J} \beta_j \, ln\,W_j + \frac{1}{2}\sum_{j=x}^{J}\sum_{k=1}^{J} \beta_{jk} \, ln\,W_j \cdot \, ln\,W_k + \beta_Q \, ln\,Q + \frac{1}{2}\beta_{QQ}(\, ln\,Q)^2 + \\ + \sum_{j=1}^{J} \beta_{jQ} \, ln\,W_j \cdot \, ln\,Q + \beta_T\,T + \frac{1}{2}\beta_{TT}\,T^2 + \sum_{j=1}^{J} \beta_{jT} \, ln\,W_j \cdot T + \beta_{QT} \, ln\,Q \cdot T.$$

The symmetry of the second derivade of the cost function implies $\beta_{ij} = \beta_{ji}$. Then, the expression for cost elasticity becomes:

$$\frac{\partial \, ln\,C}{\partial \, ln\,Q} = \beta_Q + \beta_{QQ} \, ln\,Q + \sum_{j=1}^{J} \beta_{jQ} \, ln\,W_j + \beta_{QT}\,T. \tag{3.31}$$

The cost function is homogeneous of degree one in input prices and therefore the relevant parametric restriction for (3.31) is $\sum_{j=1}^{J} \beta_{jQ} = 0$. Hence, the equation (3.31) becomes:

$$\frac{\partial \, ln\,C}{\partial \, ln\,Q} = \beta_Q + \beta_{QQ} \, ln\,Q + \sum_{j=1}^{J} \beta_{jQ} \, ln\,\tilde{W}_j + \beta_{QT}\,T. \tag{3.32}$$

Where $\tilde{W}_j = \frac{W_j}{W_J}$, $\forall\ j = 1,2,...,J$

Finnaly, substituting (3.32) into (3.30) we get:

$$\frac{P \cdot Q}{W_1 \cdot X_1} = \beta_Q + \beta_{QQ}\, ln\, Q + \sum_{j=1}^{J} \beta_{jQ}\, ln\, \tilde{W}_j + \beta_{QT}\, T + u + v. \tag{3.33}$$

The model (3.33) is the model that will be estimated in this work.

According to Panagiotou and Stavrakoudis (2017) is possible to calculate the measure of degree of market power (θ) using the measure of markup calculate previously (3.33). We use:

$$\theta = \frac{MVP_X - W_1}{MVP_X}. \tag{3.34}$$

Rearranging (3.34):

$$\theta = \frac{P \cdot \frac{\partial f(.)}{\partial X_1} - W_1}{P \cdot \frac{\partial f(.)}{\partial X_1}}.$$

Multiplying the denominator by $(Q/X_1) \cdot (X_1/Q)$:

$$\theta = \frac{P \cdot \frac{\partial f(.)}{\partial X_1} - W_1}{\frac{Q}{X_1} \cdot P \cdot \frac{\partial f(.)}{\partial X_1} \cdot \frac{X_1}{Q}}.$$

Multypling the numerator and denominator by $X_1/P \cdot Q$:

$$\theta = \frac{\frac{X_1}{P.Q} \cdot [P \cdot \frac{\partial f(.)}{\partial X_1} - W_1]}{(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1})}.$$

$$\theta = \frac{[(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1}) - \frac{W_1 \cdot X_1}{P \cdot Q}]}{(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1})}.$$

Using (3.15):

$$\theta = \frac{[(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1}) - (\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1} - u)]}{(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1})}.$$

Then:

$$\theta = \frac{u}{(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1})}. \tag{3.35}$$

Considering the relationship between the degree of market power (θ) and the market down term (u) is given by the equation below and from (3.28) ($\varepsilon_{CQ} = \varepsilon_{h_Q} = \varepsilon_{X_1 Q}$), we get:

$$\theta = \frac{u}{(\frac{\partial\, ln\, f(.)}{\partial\, ln\, X_1})} \Rightarrow \theta = \frac{u}{(\frac{\partial\, ln\, Q}{\partial\, ln\, X_1})}$$

$$\theta = u \cdot \frac{\partial \, ln \, X_1}{\partial \, ln \, Q} \Rightarrow \theta = u \cdot \frac{\partial \, ln \, C}{\partial \, ln \, Q}. \tag{3.36}$$

After estimating u from (3.33) and with the help of the expression in (3.32), we can proceed with the estimation of θ as:

$$\hat{\theta} = \hat{u} \cdot (\hat{\beta}_Q + \hat{\beta}_{QQ} \, ln \, Q + \sum_{j=1}^{J} \hat{\beta}_j Q \, ln \, \tilde{W}_j + \hat{\beta}_{QT} \, T). \tag{3.37}$$

The measure of the degree of market power (3.34) can be expanded as:

$$\theta = \frac{MVP_X - W_1}{MVP_X} \Rightarrow \theta = 1 - \frac{W_1}{MVP_X}.$$

Solving the equation above we get:

$$(1 - \theta) = \frac{W_1}{MVP_X}. \tag{3.38}$$

Hence, after estimating θ with the help of equation (3.38) the Lerner index of oligopsony power for the industry can be estimated as:

$$L = \frac{MVP_x - W_1}{W_1}. \tag{3.39}$$

Rewriting:

$$\frac{(\frac{MVP_x}{MVP_x}) - (\frac{W_1}{MVP_x})}{(\frac{W_1}{MVP_x})} = \frac{1 - (1 - \theta)}{(1 - \theta)}$$

$$\hat{L} = \frac{\hat{\theta}}{(1 - \hat{\theta})}. \tag{3.40}$$

Likewise the measure of degree of market power (θ) it is possible to calculate the Return to Scale of the Industry (RTS) directly from the measure of markup:

$$RTS = \frac{1}{\hat{u}}. \tag{3.41}$$

4 Data

The data set consists of an annual aggregated time series for the São Paulo orange juice industry over the period 1997-2018 ($n = 22$). Data from the different variables used in the model (3.33) were obtained from different sources, from Brazilian Foreign Trade Statistics (Comex Stat), Agricultural Economics Institute (IEA), Annual Report on Social Information (RAIS) and Institute of Applied Economic Research (IPEA DATA). The sample period was dictated by the stabilization of Brazilian currency and data availability. Table 5 presents the descriptive statistics of the sample.

The variables used comes from equation (3.33) and can be divided into two groups, dependent and independent variables. The first one is the ratio between the revenue of exportation of orange juice from São Paulo state and the cost of the orange in nature that goes to industry $(P \cdot Q/W_1 \cdot X_1)$, this information is deflated with the inflation rate of the period to current values of 2018.

Table 4 – Variable definition and descriptive statistics*

Variable	Description	Mean	Std. Dev.	Min	Max	Source
$P \cdot Q$	Revenue value of Exportation Orange juice (billion R$)	6.489	1.324	4.822	9.650	Comex Stat
$W_1 \cdot X_1$	Cost of Orange in nature (billion R$)	4.089	1.221	1.673	6.404	IEA
Q	Orange Juice (billion kg)	1.724	0.364	1.139	2.303	Comex Stat
W_1	Price orange in nature (R$/ kg)	0.393	0.120	0.164	0.620	IEA
W_2	Proxy on price of labor (salaries thousand R$/ annual)	40.24	3.278	36.00	48.33	RAIS
W_3	Proxy on price of Energy (price of Diesel fuel R$/ lt)	2.882	0.295	2.443	3.504	ANP
W_4	Proxy on price of cost of capital (Long term interest rate - TJLP - %)	8.105	2.429	5.000	13.22	IPEA DATA
T	Time trend (1=1997, 22=2018)	11.50	6.494	1	22	-

Source: Own compilation
Note: * The values are deflated with the inflation rate of the period to current values of 2018.

The independent variables are the quantity of orange juice exported from São Paulo in kilograms (Q). The vector $\mathbf{W}$ of inputs price includes, the price of orange in nature in kilograms (W_1), a proxy on price of labor that is averaged annual salaries in the orange juice industry (W_2), a proxy on price of energy that is averaged annual price of diesel fuel in São Paulo State (W_3) and a proxy on price of cost of capital that is the average annual Brazilian long term interest rate (W_4), this information is deflated with the inflation rate of the period to current values of 2018. And still, a time trend (T) to account the technological improvement on the period.

The monetary variables were deflated with the General Price Index - Internal Availability

(*IGP-DI*) with prices at current values of 2018. Estimating the parameters were used Stata 12.

5 Results and discussion

The estimates of the parameters of the translog cost function employed in estimating (3.33) are presented in Table 6. The estimates of price of orange and proxy on price of labor in the citrus industry are statistically significant at the level of 1% and 5% of significance respectively.

Table 5 – Stochastic Frontier Results

Parameters	**Estim. Coef.**	**Std. Err.**	**p-Value**
$\hat{\beta}_Q$	-32.10	29.35	0.274
$\hat{\beta}_{QQ}$	0.834	1.223	0.495
$\hat{\beta}_{1Q}$	-2.012	0.297	0.000
$\hat{\beta}_{2Q}$	1.766	0.815	0.030
$\hat{\beta}_{3Q}$	-1.157	0.858	0.177
$\hat{\beta}_{TQ}$	0.0180	0.033	0.583
σ_u^2	0.0430	2.202	0.984
σ_v^2	0.346	0.112	0.002
λ	0.124	2.301	0.957

Source: Own compilation

Table 7 present the estimates and standard deviations of the relevant parameters of the model: mark-down term u expressed in (3.33), degree of market power θ in (3.37), Lerner index L in (3.40), and return to scale in (3.41). The estimated value of the mark-down parameter u is 0.9666, indicates the presence of non-competitive behavior in the São Paulo exportation orange juice market. This result supports the studies conducted on the market that shown a concentrated buying orange market.

The estimate degree of market power θ, oligopsony power, of 0.059, suggesting that, on average, the price received by the orange producers is 5.90% lower than the net value of the marginal product of orange juice. The estimate Lerner Index of market power takes the value of 0.063, indicating that, on average, the orange juice net marginal value product is 1.063 above the price of orange in nature, that it W_1.

Lastly, the estimate of return to scale indicates that, on average, the increase of 1% of quantity produce increase the average cost of production in 0,65%. These results indicate that the Citrus Industry operates in a region of economies of scale, this may be the highly concentrated market.

The Lerner Index it is very useful to explain the movements of the market during the period investigated, 1997-2018, and how they impacts on the competitive behavior. In Graphic 3 it interesting to show the Lerner index follow the behavior of the ratio of revenue and the cost of specific input, orange in nature. When the ratio raises the index raises as well. When the industry increases their ratio of revenue they are expending their market power.

Table 6 – Estimates of Degree of market power, Lerner Index, Mark-down and Return to Scale

Variable	**Description**	**Mean**	**Std. Dev.**	**Min**	**Max**
$\hat{\theta}$	Degree of Market Power	0.059	0.021	0.034	0.128
$\hat{L}$	Lerner Index	0.063	0.025	0.035	0.147
$\hat{u}$	Mark-down	0.966	0.001	0.963	0.969
RTS	Return to Scale	0.651	0.209	0.289	1.049

Source: Own compilation

The behavior of Lerner index can also be explained to the events that impacted the market of exportation of orange juice. In 1997 the Lerner index was 0.075. The second litigious on CADE, Brazil antitrust office, between the producers of orange and the processors starts in 1999 with the accusation of cartel formation by citrus industry and this match the moment of the raise and highest Lerner index during the whole period analyzed, with almost 0.15 in 2000, which corresponds to the period that the industries pledge guilty in the investigation of cartel formation (1999-2006) and can be also be influenced by the international fall in orange in nature prices.

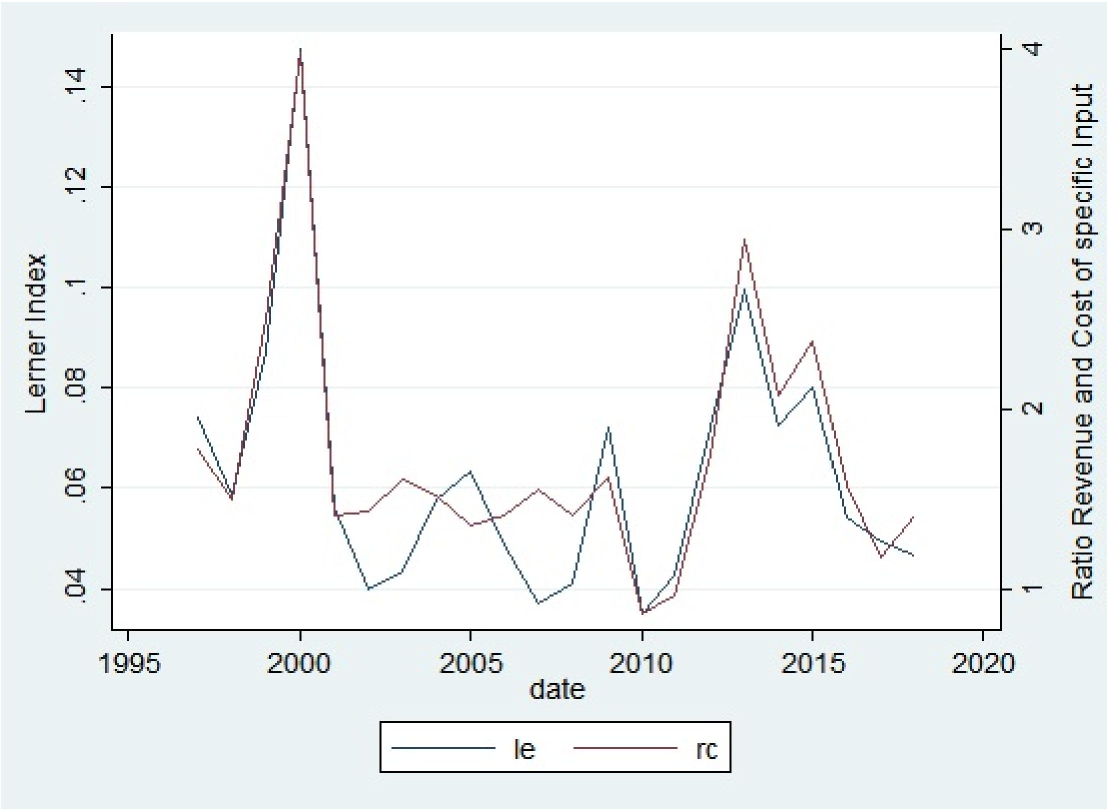
The prices international prices of the orange started to increase from 2001 and consequently the ratio revenue and cost of specific input decrease. In response to that movement, the Lerner index was the smaller in the period till 2010 varying from 0.037 to 0.75. The market power of the industry was not high if with analyze the highly concentrated marked, where biggest four industries holds 90% of the production.

In 2010 occur an interesting movement in the market. The international prices of orange increase more than 40% since the previous year due to a small crop in consequence of unfavorable weather conditions. Consequently, the Lerner index reached its lowest level with 0.035 and lowest ratio revenue and cost of specific input too. However, 2010 was the year of the fusion between Citrovita and Citrosuco forming the biggest processor of orange juice not only in São Paulo but in the world.

Following the fusion between of two huge companies the ratio revenue and cost of specific input began to increase and the Lerner index as well. The maturation of the fusion of the processors have an influence on the market behavior once in 2013, three years after the fusion, the Lerner index was 0,10. This movement was associated with the retreat of the international orange price due to a big stock of orange.

The empirical results of this work suggest that orange in nature price was 5,9%, on average, lower than their net marginal value product, indicating evidence of noncompetitive behavior in the São Paulo Citrus Industry. The highly concentrated market can be an explanation of this outcome. The results found in the variable u, mark-down parameter strengthening this way our argument for the potential presence of noncompetitive behavior in the industry over the period examined in this work.

Figure 3 – Lerner Index and Ratio of Revenue and Cost of specific input



Source: Own compilation

6 Final remarks

The aim of this work was to develop a model to estimate market power in an oligopsony framework with price data using SF approach. Here, like Muth and Wohlgenant (1999) we start from a model that the data requirement is input quantity which is not always available to all markets to obtain a model that allow us to estimate oligopsony power with only input price requirement.

The model developed was applied to measure oligopsony power in the Brazilian Citrus Industry. Our empirical results suggest that, on average over 1997 to 2018, the net value of the marginal product of orange is 5.90% higher than the price of the orange. Hence, based on the empirical outcome of this study, one can conclude that there is significant evidence that the producers of orange receive lower prices because the Brazilian Citrus Industry might be on imperfect competition.

Other evidence found of non-competitive behavior is Lerner Index of degree of oligopsony power that , on average, was 6.3% and with reach their highest in 2000 with almost 15% which correspond the time the industry pledge guilty in the investigation of cartel formation (1999-2006) by Brazilian Antitrust Office (*CADE*).

Finally, the model developed here can be applied to any market. It stands out due to his flexibility of data requirement. Oligopsony power can be estimated either with quantity or price data. Hence, the stochastic frontier approach shows its robustness to measure market power in a single equation and the possibility to obtain directly the Lerner index and measure of degree of market power.

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