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An empirical game-theoretical approach to model a price war in the Brazilian airline industry

[An empirical game-theoretical approach to model a price war in the Brazilian airline industry]

José Maria Ferreira Jardim da Silveira*, Alessandro V. M. Oliveira

Universidade Estadual de Campinas (UNICAMP), Brazil, Instituto Tecnológico de Aeronáutica (ITA), Brazil

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Resumo

Este paper desenvolve uma modelagem da competição em preços pós-liberalização na ligação aérea entre Rio de Janeiro e São Paulo, e que culminou na quebra de uma estrutura cooperativa entre empresas que vigia há quase quarenta anos - o "Pool da Ponte Aérea". Neste paper, desenvolvemos e estimamos os parâmetros de um jogo de dois estágios à la Stackelberg com informação incompleta. A partir do modelo, buscamos promover um maior entendimento da racionalidade de guerras de preço no transporte aéreo.

Palavras-Chave: teoria dos jogos, econometria, racionalidade, guerras de preço.

Abstract

This paper develops a model of post-liberalization price competition between airlines on the route Rio de Janeiro - São Paulo. The intense price competition episode culminated in the rupture of a thirty-nine year-old cooperative structure - the air shuttle service cartel. By modeling and estiamting parameters of a two-stage Stackelberg game with incomplete information, we aim at contributing to the understanding of price war rationality in the airline industry.

Key words: game theory, econometrics, price competition, airline, cartel.

* Email: jmsilv@eco.unicamp.br.

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1. Introduction

Profound changes have occurred in the competitive environment of Brazilian air transport industry since the Department of Civil Aviation, the country's aeronautic authority, accelerated the liberalisation process by giving more degrees of freedom in price formation and market access to domestic airlines at the end of 1997. One of the routes that felt most intensively the effects of these changes was Rio de Janeiro - São Paulo, the densest flow in the national aviation system.

In March of 1998, a few months after the publication of governmental acts related to the liberalisation, a quite important competitive dispute erupted with characteristics of a price war, in such a way that had never happened before in that market. Traditionally the route was closely associated with the cooperative structure formed by a cartel of national companies (Varig, Vasp and Transbrasil), constituting a thirty-nine year-old walk-on shuttle service, one of the most durable private institutions of air transport system in the world.

The competitive movements in that month were initiated by the regional airlines that also operate on the route (TAM and Rio-Sul). The first move was performed by TAM, which decreased its single fare from BRL 158 to BRL 119 [3]. In the following day of TAM's decision, another regional, Rio-Sul, overtook this twenty-seven percent reduction and established its price at the level of BRL 115. On the average, regional airlines' fare was set at BRL 117 [4]. The reaction to their move by the cartel took place one week later. Given the fare strategy of the opponents, a very important short-run decision had to be made: to also reduce its fare, or to maintain it at the same pre-liberalisation level. The first option was also chosen and its price decreased from BRL 158 to BRL 115. One of the most vigorous episodes of price war was thus triggered on the most important domestic route. The set of strategies described was undoubtedly remarkable as it preceded and possibly led to the cartel's split announced by Varig in April 1998.

[3] Values in current 1998 prices in local currency (BRL), which means a fare equivalent to U$ 80. The travel time is about 45 minutes and the distance between the cities is 365 km.
[4] Weights were determined using the number of seats offered on the occasion. Values were constructed using available data on frequencies and airplane average number of seats (Clemente, 1999).

The goal of this paper is to analyse the circumstances faced by the airlines in the course of the price war in March 1998. A correct interpretation of this period can be extremely important to the understanding of its effects on economic welfare and to assess the impacts of liberalisation. Above all, it is its intention to contribute to the investigation of price war rationality in the airline industry.

The paper consists of three sections: in the first one, the game is modelled using the Stackelberg in prices solution as a benchmark; in the second one, some features of incomplete information are introduced; in the third section, a tree-diagram of the price war game is presented and its solution and interpretation are presented.

2. Model Development and Calibration and the Stackelberg Benchmark

The first step in the modelling is to state its basic assumptions:

> ASSUMPTION 1: *Consider a duopoly with two groups of airlines (called 'regional' and 'cartel') in a single-product market with some degree of product differentiation among them.*

Product differentiation was an important feature at that time on the route, as the cartel consisted of the three main important national airlines and had an impressive dominance over the flight frequencies in the market. Therefore, consumer's perceived product differentiation between players was considered to be due to 'shuttle-service' features - a service that usually has a much smaller passenger's schedule delay - and to conjoint marketing and sales efforts.

> ASSUMPTION 2: *Consider a two-stage game Γ where the first mover is the regional, followed by the cartel. It is a one-shot game for each player. The strategy variable available is the price. Strategy space for each player is $\{\sigma_1, \sigma_2\}$ = {price maintenance, price reduction}.*

Airlines are allowed to use only the price variable in order to play the game, as it is their unique strategy available in the short-run. Frequencies and airplane size are considered given, because changes in them needed previous and time-consuming submission to the aeronautical authorities[5].

The regional is considered the pro-active player (leader), as it really began the competition and was followed by the cartel. In the section 3 it will be demonstrated that this leadership assignment to the regional is in accordance with its estimated game payoffs.

ASSUMPTION 3: *Consider linear demand schemes with asymmetries among players being determined only by intercepts; own and cross-sensitivities to price are the same between them* [6].

This assumption means adopting the following simple demand scheme:

$$q_i = a_i - bp_i + cp_j \qquad i\,,\, j = \{1,2\} \tag{1}$$

Where q_i is the demand for the player i (i=1 meaning the regional and i=2 meaning the cartel); p_i is player i's price and p_j is opponent's price; a_i, b and c are the parameters to be estimated.

ASSUMPTION 4: *Each player has complete information in the game.*

Although this assumption is going to be relaxed in the next section, it is now extremely convenient in order to find a partial solution for the game. In game theory terminology, the feature of complete information means that all the players know all the relevant information about each other, including the payoffs that each receives from the various outcomes of the game (Mas-Colell, Whinston and Green, 1995). In such a game, the solution is deterministic as there is no relevance in introducing probabilities associated with the strategies played.

By using Assumption 1 and 2 it is clear that the classical Stackelberg in prices benchmark is being considered (Tirole, 1997). With linear demand schemes (Assumption 3) and complete information (Assumption 4), and some first-order condition calculus, presented in the Mathematical Appendix, it can be demonstrated that the solution of the game is:

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[5] It can be noted that the liberalisation process was not completed on the occasion and in fact it is not yet.

[6] The own and cross-sensitivities to price are, respectively, $(\partial q_i / \partial p_i)$ and $(\partial q_i / \partial p_j)$.

$$\psi = \{\psi_1, \psi_2\} = \left\{ p_1^* = \frac{(2b)a_1 + (c)a_2}{4b^2 - 2c^2}, \quad p_2^* = \frac{(c)a_1 + [(4b^2 - c^2)/2b]a_2}{4b^2 - 2c^2} \quad \text{if} \quad p_1 = p_1^* \right\} \qquad (2)$$

Where ψ is the profile of optimal strategies.

The next important step is to estimate (2). In order to do this task it is crucial to calibrate the demand schemes in (1). This econometric estimation used the OLS method in a model that combines cross-section and time series data (a pooled estimator, as in Johnston and Dinardo, 1997 and Greene, 1993). The two sections were distinguished by a dummy variable d (d=0 for the cartel and d=1 for the regional).

Data on quantities – expressed in total passengers by airline per year - and on prices – expressed by the calculated yield – were obtained in the yearbook of the Department of Civil Aviation (1985-1998); the deflator index used was IPC-FIPE. The final result was the following[7]:

$$\underset{(18.0)}{q_i = 2{,}060} - \underset{(-2.9)}{5.95.p_i} + \underset{(1.9)}{2.69.p_j} - \underset{(-10.0)}{1{,}231.d} \qquad (3)$$

Combining the results in (2) and (3), the solution of the Stackelberg model can be readily determined as a_1=829, a_2=2,060, b = 5.95 and c = 2.69:

$$\psi = \{\psi_1; \psi_2\} = \{p_1^* = 121 \quad , \quad p_2^* = 200 \quad \text{if} \quad p_1 = p_1^*\} \qquad (4)$$

The equilibrium prices in the model, expressed by (4), represent an important benchmark to the analysis. It can be understood by the following reasoning: the prices in the pre-liberalisation phase (p_1=158, p_2=158), given the demand parameters estimated, were not players' strategic optimum and one kind of adjustment was evidently necessary. The liberalisation process generated the opportunity for that adjustment; therefore, if the expectations on demand conditions in the market were of a stability of parameters, the rational moves for both players would be the one expressed by ψ in (4). It is quite important to note that the regional actually played the strategy stated by the Stackelberg equilibrium (TAM, the

[7] The values in brackets are the t-Student statistics.

regional leader, established its price at BRL 119), which means that the model indicates in a reasonable way its rationality.

Nevertheless, the cartel did not actually play as expressed in (4). Its actual price was BRL 115, which leads to the conclusion that something – either a factual or a conjectural circumstance - could be making it more difficult for it to react optimally. As it will be seen in the next section, a simple belief of change in market conditions was sufficient to have this effect.

3. Introduction of Incomplete Information Features

Consider now a relaxation of Assumption 4:

> ASSUMPTION 4': *There is a nature's move in the game regarding a change in the parameters due to the possibility of the cartel's rupture. It is therefore a game of incomplete information. There are two possibilities: either nature substantially alters demand conditions in the game or it lets them unchanged. None of the player knows exactly what is the nature's choice so they have to associate a system of beliefs with it.*

The mechanism of nature's move is a classic tool in incomplete information games since J. Harsanyi. Fudenberg and Tirole (1989) descript his framework: "Harsanyi's construction of a transformed game introduced nature as a (n+1)st player, whose strategy consists in choosing characteristics for each of the original players (…)". This is precisely how incomplete information feature is introduced in this game. Thus, nature's strategy space is: $\{\sigma_{N1}, \sigma_{N2}\}$ = {no change in demand scheme, change in demand scheme}.

However, a problem remains to be solved: there are infinite ways of representing an expected change in demand parameters. In order to find a reasonable variation that is consistent both with the environment faced by players and the strategies actually played, some restrictions have to be imposed: first, the Stackelberg equilibrium should be the actual result after the consideration of parameters variation (or at least it must be a good approximation to actual strategies); and second, the change must indicate a expectation of difficulty to the cartel in relation to its rival, because of the potentiality of its rupture.

ASSUMPTION 5: *Consider a belief of change in the parameters with the following effects: 5.i) a decrease in the product differentiation asymmetries, making the players in a more equalised position; 5.ii) an increase in players sensitivities to price in order to account for an increase in the perceived rivalry – this change must not conflict with Assumption 3 with respect to the price parameters (same own and cross-sensitivities of price for both players).*

By considering Assumption 5, the set of changes Θ in the parameters is then proposed:

$$\Theta = \begin{cases} \tilde{a}_1 = a_1 + \varphi^i a_2 \\ \tilde{a}_2 = a_2 - \varphi^i a_2 \end{cases} , \quad \begin{cases} \tilde{b} = (1+\varphi^s)b \\ \tilde{c} = (1+\varphi^s)c \end{cases} \tag{5}$$

Where φ^i is the percent of loss in the cartel's demand – a change in its intercept – due to its rupture and to the consequent decrease in product differentiation (5.i); and φ^s is the change in the sensitivities that reflects the increase in the competition (5.ii).

Using Θ to reconcile actual price reductions and Stackelberg solution (2) it is required a solution to the following system:

$$W = \begin{cases} \dfrac{(2\tilde{b})\tilde{a}_1 + (\tilde{c})\tilde{a}_2}{4\tilde{b}^2 - 2\tilde{c}^2} = 117 \\ \dfrac{(\tilde{c})\tilde{a}_1 + \left[\left(4\tilde{b}^2 - \tilde{c}^2\right)/2\tilde{b}\right]\tilde{a}_2}{4\tilde{b}^2 - 2\tilde{c}^2} = 115 \end{cases} \tag{6}$$

The system W can be solved with the conventional algebraic tools, as there are two equations and only two variables (φ^i and φ^s):

$$\{\varphi^i, \varphi^s\} = \{0.26, 0.40\} \tag{7}$$

Therefore, the solution (7) can be used in order to calculate the new parameters in case nature's choice is to change demand schemes: $\tilde{a}_1$ =1,371, $\tilde{a}_2$ =1,517, $\tilde{b}$ = 8.30 and $\tilde{c}$ = 3.75.

4. The Solution ofr the Price War Game

Given the results in sections 1 and 2, it is now possible to complete the modelling and to solve the price war game. The following tree-diagram depicts the game Γ in its extensive form, Γ_E. Payoffs were calculated using both the estimated and calculated parameters:

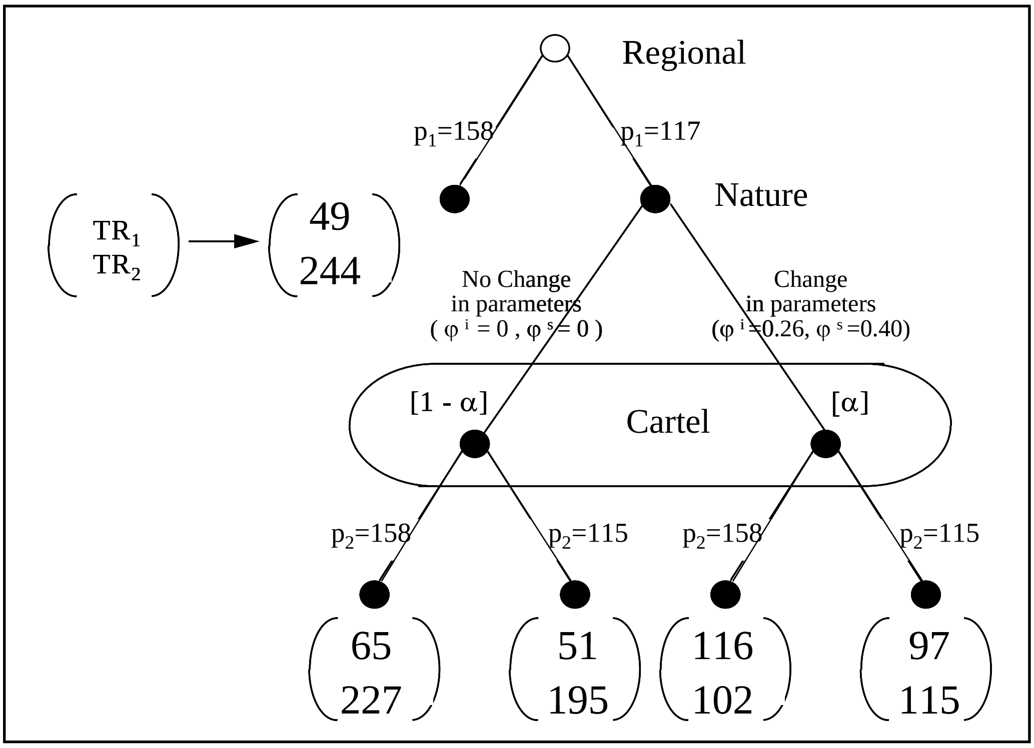

Figure 1 – The Price War Game (payoffs in BRL million)

Where TR_i is the total revenue of player i. It can be seen it is indeed a leader-follower game with an intermediate nature's choice and it still adopts all assumptions, including number 4'.

It is clear in Figure 1, that the strategy of price reduction is dominant for the regional. This is so because the payoff of BRL 49, in the upper branch, is lower than any other payoff it would receive. Thus, it is a consequence of this player's rationality that, after the liberalisation, it would trigger a price war by reducing its price and achieving a higher payoff than the pre-liberalisation phase. It indicates its first mover advantage, that is, a profit-seeking rationality for it to start the game.

As a consequence of the rational move of the regional, the game continues along the tree and can achieve any of the two nodes in the cartel's information set. If demand parameters are held constant by nature, the game will be in the left node; on the other hand, if demand parameters are changed by nature, as stated by (5) and (7), the game will be in the right node.

As it is an incomplete information game, none of the players can infer in which of the nodes the game will be. The element of uncertainty is characterised by the circle around the two nodes below the first player move, depicted on Figure 1. These nodes, jointly considered, represent the information set for the cartel.

The solution of the game can only be found if it is considered a system of beliefs (probabilities, or expectations, associated with each node in the information set) of the cartel about nature's move. It is not necessary to create a system of beliefs to the regional because price reduction is a dominant strategy for it.

It can be seen in Figure 1 that for both nodes in the cartel's information set it is assigned a probability (α, 1-α). This represents its set of beliefs on nature's move. The first task in order to solve the game is to analyse it as if it there were pure strategies, that is, an association of probabilities equal to one for a node and to zero for the other one. If the left node is to be chosen by the nature with a hundred percent of chance, than it will be rational for the cartel to choose the maintenance of its price (BRL 158) - that is because the payoff BRL 227 is higher than BRL 195. On the other hand, if the right node is to be certainly chosen by nature, the rationality is inverted and it is expected for it to choose the price reduction strategy (price war), since BRL 115 is higher than BRL 102.

What would be a threshold of expectation for the cartel? This can be answered using the procedure of calculating α by making that player indifferent to any of the strategies available, that is finding the α that equals its expected payoffs, as in (8):

$$227\ (1-\alpha) + 102\ (\alpha) = 195\ (1-\alpha) + 115\ (\alpha) \longrightarrow \alpha = 0.71 \qquad (8)$$

Therefore, the incomplete information game can now be solved:

$$\psi = \begin{cases} \psi_1 = \text{reduce prices} \\ \psi_2 = \left\langle \begin{array}{l} \text{maintain prices if } \psi_1 = \text{reduce prices and if } \alpha < 0.71 \\ \text{reduce prices if } \psi_1 = \text{reduce prices and if } \alpha > 0.71 \end{array} \right. \end{cases} \quad (9)$$

This solution can be interpreted by the following reasoning: the Stackelberg equilibrium is a strong benchmark to the players when making their decision about to reduce or not their price in the market. In spite of that, there is an element of uncertainty, related to the nature's move, which makes their possible strategies more difficult to determine. Independent of the nature and of the beliefs associated with it, the first mover is induced to trigger the price war. Finally, it is rational for the follower to choose a move accordingly to its belief on nature's move; thus, if it associates more than 71 % of chance for a change in demand parameters by nature, it is reasonable to think it will certainly play reducing its price.

The probability of 0.71 is surely high. Thus if in reality it was observed that the player actually reduced its price, there must be strong and evident reasons for it. The main factor was mentioned before: the imminence of rupture of the cooperative structure that had been constituting a cartel for almost forty years on that important Brazilian route.

Conclusions

The present paper developed a price war model of the post-liberalised Rio de Janeiro – São Paulo route. The research subject chosen was considered remarkable as it culminated in the rupture of a thirty-nine year-old cooperative structure – the air shuttle service, a cartel of the three main national airlines on the occasion.

A two-stage game with incomplete information was therefore constructed and calibrated. The basic theoretical benchmark used was the Stackelberg in prices solution, as the competition modelled was characterized as a typical leadership-follower relation and as players notably used prices as their main strategic variable. The incomplete information feature was introduced by a mechanism of nature's move. It represented the potentiality of change in player's demand parameters due to the cartel rupture, that is, to a potential decrease in the perceived asymmetries of product differentiation between airlines on the route. A system of beliefs was then associated with that move, in order to introduce players' expectations on what strategy to play and to better interpret players' moves in the game.

The main conclusion achieved is that price reduction was a dominant strategy to the regional airlines but not to the cartel; this may imply that the system of beliefs had crucial significance in determining the cartel's choice and thus, in leading the game towards the price war scenario actually observed. Only under the hypothesis that it had strong beliefs associated with the nature playing a change in the parameters – that is, a belief that this event had a probability higher than 0.7 –, is that it is reasonable to consider its rationality in the short-run. Thus this price war can be interpreted as being motivated by a mixture of profit-seeking rationality (by the first mover) and strong beliefs of product homogenisation (by the follower).

The positive aspect of the paper is thus to contribute to the interpretation of airline price wars rationality, a subject not extensively modelled so far in the literature. On the other hand, some negative aspects can be stated, as the *ad-hoc* definition of the nature's change in the parameters and the simplicity of the theoretical modelling as using linear demand schemes in a only one-shot game for each player, a feature treated in a more complex way by Rotemberg and Saloner (1986), for example.

Mathematical Appendix

Notation	
Π_I	Profits of player i;
TR_i	Total revenues of player i;
TC_i	Total costs of player i;
$\overline{TC}_i$	Total given costs of player i;
p_i	Price of player i;
q_i	Demand of player i;
a_i	Demand intercept of player i;
b	Demand own-sensitivity to price;
c	Demand cross-sensitivity to price;
$R_i(.)$	Reaction curve of player i;
p_i*	Optimum strategic price of player i.

Let us start with the cartel's profit expression (total costs are given in the short-run):

$$\Pi_2 = TR_2 - TC_2 = a_2 p_2 - bp_2^2 + cp_1 p_2 - \overline{TC}_2 \qquad (A1)$$

First-order condition:

$$\partial\Pi_2/\partial p_2 = a_2 - 2bp_2 + cp_1 = 0 \longrightarrow R_2(p_1) = [(a/2b) + (c/2b)p_1] \qquad (A2)$$

The reaction curve in (A2) determines cartel's best response, given the choice of the regional. It must be clear that the first mover can anticipate this calculus in order to determine its choice. Thus, the reaction curve $R_1(p_2)$ is obtained through a similar optimisation problem but with the difference is that $R_2(p_1)$ is anticipated. Thus, the total profits Π_1, according to a Stackelberg price leadership behaviour is:

$$\Pi_1 = TR_1 - TC_1 = a_1 p_1 - bp_1^2 + cp_1 R_2(p_1) - \overline{TC}_1 \qquad (A3)$$

First-order condition:

$$\partial\Pi_1/\partial p_1 = [(2b)a_1 + (c)a_2] + 2[-2b^2 + c^2]p_1 = 0 \longrightarrow p_1^* = \frac{(2b)a_1 + (c)a_2}{4b^2 - 2c^2} \qquad (A4)$$

The price p_2* can be calculated by substituting the result (A4) in the reaction curve (A2):

$$R_2(p_1) = p_2^* = \left\{(a/2b) + (c/2b)\left[\frac{(2b)a_1 + (c)a_2}{4b^2 - 2c^2}\right]\right\} \longrightarrow p_2^* = \frac{(c)a_1 + \left[(4b^2 - c^2)/2b\right]a_2}{4b^2 - 2c^2} \qquad (A5)$$

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