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THEORETICAL MODEL OF PRICING BEHAVIOR ON THE POLISH WHOLESALE FUEL MARKET

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Abstract

In this paper, we constructed a theoretical model of strategic pricing behavior of the players in a Polish wholesale fuel market. This model is consistent with the characteristics of the industry, the wholesale market, and the players. The model is based on the standard methodology of repeated games with a built-in adjustment to a focal price, which resembles the Import Parity Pricing (IPP) mechanism. From the equilibrium of the game, we conclude that the focal price policy implies a parallel pricing strategic behavior on the market.

Keywords: wholesale fuel market, strategic behavior, focal pricing game, parallel pricing

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Introduction

One of the central questions for competition authorities is how to distinguish competitive from uncompetitive conduct without specific knowledge of players' private information. If one assumes that prices are strategic variables, and the realizations of these prices in a well-defined market may be observed, the primary concern is regarding how prices are formed if the market has certain distinguished features. This question may be formulated as follows: what strategies do firms use to form prices, or more specifically, what type of game may generate observable price levels at equilibrium?

The overall objective of this paper is to discover strategic patterns in the conduct of the players, if any may be revealed using public information. In this study, we constructed a simple, theoretical model of strategic behavior of the players, which was consistent with the characteristics of the industry, market, and players.

We focused our study on the wholesale fuel market in Poland, as it has not been thoroughly studied from the perspective of strategic interactions between major players. In addition, this study provides significant research on wholesale fuel markets, because it presents a perspective of competition studies.[1]

Few studies exist regarding the competitiveness of the Polish refining sector in general (we may point to Bejger, Bruzda, 2002; Miłobędzki, 2008), and no such studies, to our knowledge, have been devoted to the examination of the pricing behavior of players that focus on the strategic interactions among players.

The remainder of the paper is structured as follows: the next section briefly outlines the hypothetical price's creation mechanism; Section 3 demonstrates the theoretical model of the strategic interactions supporting the mechanism; Section 4 concludes the results.

1. Wholesale prices – hypothetical mechanism of creation

This research is based on the statistical data from the period of time between 1.01.2004–31.12.2013, and this time frame was deemed relevant for all important market characteristics. The theoretical model of conduct derived in this study is based on the time series of the wholesale prices of the main players: PKN ORLEN Group and LOTOS Group. First, the hypothetical price creation mechanism was examined on the basis of publically available information. An analysis of the market and traders' statements was conducted, and the following

[1] See e.g. Report to Directorate-General Energy and Transport of the European Commission (2009), p. 8.

conclusion may be inferred: the pricing mechanism of the players corresponds to the well-known Import Parity Pricing (IPP) formula.

Although official players' or competition authorities' documents about the parity pricing mechanism in the Polish liquid fuel market are not publicly available, many sources consider parity pricing to be accurate.[2] Theoretically, the IPP is the maximum level that the domestic producers' wholesale price may reach if no import barriers exist. A minimum of two countries may be mentioned where IPP pricing is officially documented as the domestic refineries' pricing schema, i.e. Portugal[3] and Australia.[4]

Another relevant feature of the pricing mechanism is the method of publically announcing prices. In a sample period, both players announced the wholesale prices of various products on their websites. These prices were announced once a day (the exact hour of publishing rotated during the sample period).

The primary data set includes wholesale (irregular) daily prices on two major products, motor gasoline and diesel oil.[5] The series are as follows: PKN PB95, PKN ON, LOTOS PB95, and LOTOS ON in PLN for cubic meters and the 1.01.2004–31.12.2013 sample period. Table 1displays the basic statistics for the individual series (in levels), which shows obvious similarities of statistical figures for similar fuels.

Table 1. Descriptive statistics of the series of prices

	PKN PB95	PKN ON	LOTOS PB95	LOTOS ON
Mean	3,521.64	3,400.70	3,530.19	3,375.92
Median	3,374.00	3,184.00	3,381.00	3,153.00
Maximum	4,757.00	4,663.00	4,768.00	4,667.00
Minimum	2,425.00	2,117.00	2,428.00	2,121.00
Std. Dev.	573.84	657.40	572.05	664.37
Coef. Of var. (%)	1,6.29	1,9.33	16.20	19.68
Skewness	0.36	0.45	0.35	0.45
Kurtosis	1.98	1.81	1.97	1.87
Number of Obs.	2,281	2,094	2,343	2,343

All values in PLN.

Source: own calculation.

[2] The Polish Oil Industry and Trade Organisation Annual Report (2011), p. 24.

[3] See: Portuguese Competition Authority Report (2009).

[4] See: Report of the Australian Competition & Consumer Protection (2007).

[5] Unleaded 95 octane gasoline with 10 ppm sulphur content and diesel oil for road transport with 10 ppm sulphur content.

2. Theoretical model of conduct – a background

The primary concern of this study was to specify a reasonable model of strategic interactions, which may be consistent with the characteristics of the industry, wholesale market, and players. Taking into account the extensive research of the industry,[6] the relevant factors influencing a potential game played by the market participants may be identified: a high concentration of duopolistic markets, a homogenous product, significant barriers to entry, the capacity constraints for domestic production, inelastic demand,[7] a specific pricing mechanism, and an almost perfect price transparency.

Based on these characteristics, a restriction may be imposed on the set of models of appropriate games by virtue of the specification of the essential elements required of a game model: price is a primary strategic variable for the players; there are no threats of significant entry into the market in the sample period; capacities should be treated as exogenous parameters during the game period; a single period of a game is defined as one day, and a single period's (stage) game is defined as a non-zero sum game with simultaneous moves in a finite pure action's spaces.

The first section of the previous statement fails to impose any dynamic or non-dynamic structure yet, but reflects a fact that a daily price announcement is considered as a generic period of the choice for the strategic variable levels, which are mutually unobservable by the players. To confirm the theoretical mechanism of simultaneous actions, one should obtain the precise time of the publication of the prices for both the player and sample period. Unfortunately, it was not possible due to a lack of data. As a substitute, the website pages of both players during a randomly chosen period of time between the 12.07.2014 and 16.08 2014 have been monitored. In total, 22 observations of the exact point in time of the wholesale prices publication on the players' websites were collected. As a result, we discovered that the difference in the time of publication did not exceed11 minutes, and the median of the differences was equal to 7 minutes. This information supports the assumption regarding the simultaneous moves of the players. The finiteness of the game[8] was deducted from the observations of the price's grid of PB 95 (as an example) in the sample period. Table 2 summarizes this information. All the values of prices were integer numbers with larger granularity in the case of LOTOS.

[6] See: Bejger (2015a).

[7] Income and price elasticity of demand for liquid fuels have been a subject of research several times. For a survey see: Kyoung-Min Lim et al. (2012). In the case of Poland, Adamczyk et al. (2014) estimated the price elasticity of demand for gasoline at the retail level. Their estimation was –0.1 for the period of 2003–2012.

[8] In a sense of countable pure strategy spaces.

Table 2. Empirical distributions of prices' grid (PB 95)

LOTOS PB		PKN PB
n	grid	n
561	1	799
626	2	881
1,156	5	601
2,343	Total	2,281

Grid is a the largest prime number divisor of a wholesale price, in PLN.

Source: own calculation.

Taking into account the above-mentioned parameters, one should consider what type of a strategic game is well-suited here. One may consider the standard Bertrand model as a building block of one-shot games enriched with additional elements, eliminating equilibrium in the marginal costs, as the only solution. Especially well-suited here are the models based on the well-known Edgeworth (1925) paper. Edgeworth's modification led to various models, for example, Levitan and Shubik (1972); Kreps and Scheinkman (1983); Osborne and Pitchik (1986); Deneckere and Kovenock (1992). As those models are essentially static, a proper dynamic specification should be considered as well. In this particular market, one may consider a highly popular Maskin and Tirole (1988) model and a supergame approach to oligopolistic competition. As the reference works in that stream of studies, we may point to Tirole (1998) and Vives (2001). For the empirical research conducted here, the works of Brock and Scheinkman (1985); Lambson (1987); Green and Porter (1984); Rotemberg and Saloner (1986); Dudey (1992); and Lu and Wright (2010) may inspire the choice of a price as a strategic variable and imposed capacity constraints. However, in analyzing the above-mentioned models, one may conclude that the structure of any of those models does not accurately encompass all of the essential elements required, which were extracted from the market research and enumerated earlier in the text.

On the basis of the previous discussion, especially in regards to the mechanism of price creation, one may ask a question: what type of strategic interaction are the players involved in if they know[9] some reference price level (the IPP level) relevant for the market they operate? Would the players, in fact, 'coordinate' around that level or play different strategies? Most of the previously mentioned game theory models of duopolistic (oligopolistic) competition assume a price level which is 'focal' or 'collusive', but this price rarely becomes public information. On the contrary, in our case, such a 'focal' price is exogenous[10] for the players, and is roughly

[9] We assume they may calculate it with enough precision.

[10] There is no Granger causality from Polish market's prices to world spot prices.

established. How does this knowledge alter the strategic situation of the players? One may suspect that the outcome is a type of ʻcoordination' game. Schelling's (1960) work may be pointed to in reference, but we must strongly distinguish between his concept and our research. Whereas in coordination game the players are involved in coordination problem in a sense that they all prefer to reach some outcomes, and they coordinate to the 'focal' one (pure matching game), in most economic situations we cannot openly assume that players want to coordinate at some common level of price or quantity. Nevertheless, the concept of a reference point in strategic interactions, rather than a point loosely based on the Schelling's focal point, is established in literature.[11] There is substantial empirical evidence of the use of focal point prices by firms. Scherer (1980)found that price lining is widespread at the retail level in the US. Using the data from the US-credit card market during the 1980s, Knittel and Stango (2003) demonstrate that nonbinding price ceilings, which serve as external focal points, increase the probability that firms engage in tacit collusion. Faber and Janssen (2011) investigated the focal point effects of oil companies suggesting petrol and diesel prices to their retailers. We sought to utilize the concept at that point in time, but slightly modified the question: what are the strategic implications of the IPP price considered as the ʻfocal price' for the player's daily actions (price levels)?

3. The model of a simple game of a focal price

The assumption and construction of the game intended to accurately reflect the industry and the domestic wholesale market, consistent with the postulate of minimal parameterization.

Assumptions.

Consider a market with 2 players described by installed capacities k_1, k_2 where $k_1 > k_2 > 0$. These capacities are exogenously imposed (they are not strategic variables), and serve to fulfill domestic demand only (a possible export is neglected) for a representative product (gasoline or diesel oil). The players may produce up to capacity levels. We assume that the industry demand, recognized by the players during the period of the game, is denoted by the following function:

$$D(p) = \begin{cases} (k_1 + k_2)\ if p = p^f \\ (k_1 + k_2)\ if p < p^f \\ \left(\frac{1}{p^f}\right)\left(p^f + \varepsilon\Delta p\right)\left(k^1 + k^2\right) if p > p^f \end{cases} \quad (1)$$

[11] Most of the work in the field is experimental, see: Dierynck and Roodhooft (2012), Huck et al. (2000), Mechta et al. (1994), Bacharach and Bernasconi (1997), as examples.

where: p is a domestic wholesale price, p^f~ IPP, Δp is $(p - p^f) > 0$, and ε is the price elasticity of demand, which in this environment plays a role of a measure of substitution of domestic capacities' utilization by import. The explanations of these main components are provided below.

On the basis of the analysis of the relevant market, we assume that the IPP price level is common for both players, is ʿobserved' by both players prior to the announcement of their own wholesale price,[12] and is treated by the players as the ʿfocal' price. Even though an observer does not know the exact formulas for IPP calculation, we believe that both players use such formulas and calculate the IPP on the same or very similar levels due to the identical industry's environment and macroeconomic conditions. The level of that price, p^f, therefore, is common knowledge for both players. We did not include the stage of the observation of p^f directly in the game, though.

When $p > p^f$, the import of the fuels becomes rational for external players or/and for incumbents. We seek to replicate that by the third part of $D(p)$ function, where the capacities of the players are not fully utilized for the price level higher than a focal one. As was mentioned above, the elasticity ε, (negative in value), describes the rate of the substitution of domestic capacity by import (offered by incumbents, perhaps) in this context.

The players are symmetrically effective due to the similar refining technology and the use of the same main raw material (REBCO crude oil, mostly), and exhibit the similar marginal cost of production c. Furthermore, the players incur unknown fixed costs $F_1 > F_2$, which are proportional to the capacities installed. The pure actions space of the player i, P_i contains price levels p_i from the range $[1; p_i(k_i)]$ where $p_i(k_i)$ is the price level for which capacity utilization is 0. The prices are selected from a discrete price grid. On the basis of the preliminary assumption, one may define for distinct action profiles $\{p_1, p_2\}$:

– the volumes of sales for players,
– the values of payoffs.

For simplicity, let ε = |ε|. The quantities sold by player 1 are given by the function:

[12] The values of the primary and most variable components affecting the IPP, i.e. the USD/PLN exchange rate and the reference product's prices listed in the Amsterdam−Rotterdam−Antwerp hub are known in the afternoon on day t.

$$D_1(p_1, p_2) = \begin{cases} k_1 if p_1 = p_2 = p^f \\ k_1 if p_1 = p^f \wedge p_2 < p^f \\ min((k_1 + (-(1/p^f)\varepsilon k_2(p^f - p_2))), (k_1 + k_2))\ if p_1 = p^f\ p_2 > p^f \\ k_1 if p_1 < p^f \wedge p_2 = p^f \\ k_1 if p_1 < p^f \wedge p_2 < p^f \\ min((k_1 + (-(1/p^f)\varepsilon k_2(p^f - p_2)), (k_1 + k_2)\ if p_1 < p^f \wedge p_2 > p^f \\ k_1 - (-(1/p^f)\varepsilon k_1(p^f - p_1))\ if p_1 > p^f \wedge p_2 = p^f \\ k_1 - (-(1/p^f)\varepsilon k_1(p^f - p_1))\ if p_1 > p^f \wedge p_2 < p^f \\ k_1(-(1/p^f)\varepsilon k_1(p^f - p_1))\ if p_1 > p^f \wedge p_2 > p^f \end{cases} \quad (2)$$

For simplicity, we formulated function (2) explicitly for player 1 only.[13] Definition (2) maybe explained as follows. As we may see, there are nine distinct cases. We categorize them from 1 to 9. Case 1 replicates the full utilization paradigm for the actual focal price. As one may grasp from the review of the market, the players have produced fuels in the full capacity utilization regime. Case 2 represents the insensitivity of the residual demand of player 1 to a lower price level of the competitor due to the inability of player 2 to appropriate a portion of the demand on one hand (full capacity k_2 utilization at $p_2 < p^f$), and the inability to start an import due to the lack of profitability on the other. In case 3, player 1 takes over a portion of the second player's demand, as $p_2 > p^f$, which implies the possibility of importing. As price elasticity of the demand for fuels is very small, a reduction in consumer demand is not accounted for. Instead, we model the flow of the demand from player 2 to player 1 in the form of additional imports, realized by player 1 with the elasticity of substitution ε. Cases 4 and 5 are similar – due to the capacity constraint, player 1 cannot serve a possibly increased demand, and the import is not profitable. Situation 6 resembles case 3 with similar argumentation. In cases 7 to 9, player 1 observes a decrease in the volumes sold, which are substituted by the imports held by player 2 or one of the independent players.

In the next step of the construction of the game, the payoff functions are defined. First, it is necessary to consider which measure of effectiveness of the decisions in an industry will be the most realistic compared to the motivations of the player's actions; additionally, it is necessary to consider which measure makes it possible to specify the use of the available information. We assume that both players, as listed companies, most certainly seek to maximize the financial result at the level of capital groups. However, at the levels of operational sectors, including manufacturing and wholesale fuel sales, the situation may be slightly different. It was decided

[13] Player 2 has a similar function $D_2(p_2, p_1)$ of course, with indices changed from 1 to 2.

against estimating the marginal (or average) cost function parameters of the players due to a lack of sufficient information (potentially large econometric model specification error) and, in our opinion, the special view of costs in this case. We assumed that both players did not have significant influence on the unit variable costs of production, and that these unit variable costs were similar for both players, due to comparable technology and common prices of basic inputs. Hence, we agreed that the income from the sale is a more appropriate measure of the financial viability of the action than profit. However, because of the huge capital expenditures needed to enter the core business, and the significant non-operational costs of the capital groups, both players were liable for the fixed costs F_i. It was necessary, therefore, to fully utilize the production capacity installed for each of the operational segments in order to minimize the fixed unit costs of production. Hence, we recognized that in addition to the financial performance measure, the payoff function should also consider the requirement of maximization of production capacity utilization. In order to address that assumption, we formulated payoffs as the revenues from sales weighted by the capacity utilization ratio. Specification of the payoff function for player 1, for cases 1 to 9 as defined in (2) is as follows:

$$R_1(p_1,p_2)=\begin{cases} p^f k_1\times((k_1)/(k_1)) \\ p^f k_1\times((k_1)/(k_1)) \\ (p^f\times(k_1+(-(1/p^f)\varepsilon k_2(p^f-p_2))))\times((k_1)/(k_1))\vee(p^f\times(k_1+k_2))\times((k_1)/(k_1)) \\ p_1k_1\times((k_1)/(k_1)) \\ p_1k_1\times((k_1)/(k_1)) \\ (p_1\times k_1+(p^f(-(1/p^f)\varepsilon k_2(p^f-p_2))))\times((k_1)/(k_1))\vee((p_1\times k_1)+(p^f\times k_2))\times((k_1)/(k_1)) \\ (p_1\times(k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1))))\times((k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1)))/(k_1)) \\ (p_1\times(k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1))))\times((k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1)))/(k_1)) \\ (p_1\times(k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1))))\times((k_1-(-(1/p^f)\varepsilon k_1(p^f-p_1)))/(k_1)) \end{cases} \tag{3}$$

We name the above payoffs $R^j{}_1(°)$ for $j = 1, ..., 9$.

On the basis of the above payoffs (for player 2 the function is similar), we constructed a simple game to find the Nash equilibria of such a strategic interaction. Because our goal was to study the actual market, we have assigned the value of parameters k_1, $k_{2,}$ and ε. We assumed $k_1 = 60$, $k_2 = 40$, and $\varepsilon = 1$. Those values reassemble the relevant industry's structure and the typical rate of reaction to a price change in the liquid fuels' markets, implied by Bejger (2015a) and the research referenced in footnote 7. The significant observation is that we may restrict the strategy spaces of the players to: $P_1 = P_2 = \{pd, pf, pu\}$, where pd is a price strictly smaller than the focal price, and *pu* is a price strictly higher than *pf*. We may confirm this observation when we analyze 3 groups of cases:

a) cases 1 to 3; for and every $p_2 > pf$: $R^3{}_1(°) > R^2{}_1(°) = R^1{}_1(°)$ – straightforward observation,
b) cases 4 to 6; for every $p_1 < pf$ and every $p_2 > pf$: $R^6{}_1(°) > R^5{}_1(°) = R^4{}_1(°)$ − after the substitution of parameters' values we find that $R^6{}_1 = 60p_1 - 40p^f + 40p_2$ and $R^5{}_1 = R^4{}_1 =$ $60p_1$, or $60p_1 - 40p^f + 40p_2 > 60p_1$ for every $p_2 > pf$ (both prices integer and positive),
c) cases 7 to 9; for every $p_1 > pf$ and every p_2: $R^7{}_1(°) = R^8{}_1(°) = R^9{}_1(°)$ − straightforward observation.

We now must rank the outcomes $R^j{}_1$ in accordance with the players' preferences. We assume, as above, that the players seek to maximize revenues (3). It implies that a higher value of revenue is strongly preferred to a smaller one. After necessary calculations (details of that phase upon request),we may rank the outcomes by preferences for player 1:

$$R^3{}_1(°) \} R^1{}_1(°)\sim R^2{}_1(°) \} R^6{}_1(°)\} R^4{}_1(°)\sim R^5{}_1(°) \} R^7{}_1(°)\sim R^8{}_1(°)\sim R^9{}_1(°).$$

Similar preference ranking is valid for player 2 with one vital difference. Due to the capacity distribution, we calculate:

$$R^6{}_2(°) \} R^1{}_2(°)\sim R^2{}_2(°) \text{ } if \text{ } p^f - p_1/p_2 - p^f > 2/3,$$

in other words, for any fixed p^f small undercut of price, ($p^f - p_2 < 1.5$) is profitable for player 2, as player 2 represents a smaller company. So if player 2 expects that the player's 1 price will be higher than the focal price, it is rational to determine the price level slightly below the focal price.

The rank of outcomes by preferences for player 2 is:

$$R^3{}_2(°) \} R^6{}_2(°)\} R^1{}_2(°)\sim R^2{}_2(°) \} R^4{}_2(°)\sim R^5{}_2(°) \} R^7{}_2(°)\sim R^8{}_2(°)\sim R^9{}_2(°).$$

4. Analysis of equilibria

In the next step, we constructed a simple game of (down – focal – up) actions and payoffs normalized to integers from 1 to 5. The extensive and strategic forms of the game are then:[14]

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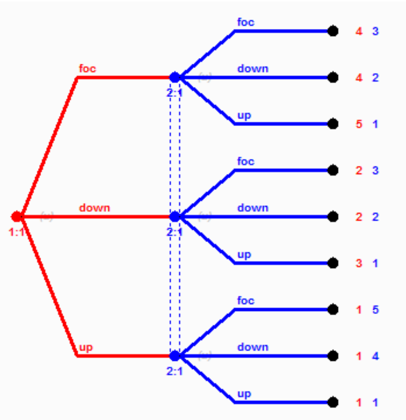
[14] We use Gambit: Software Tools for Game Theory version 14.0.2 by Richard McKelvey, Andrew McLennan, and Theodore Turocy.



Player1\Player2	Focal	Down	Up
Focal	(4; 3)	(4; 2)	(5; 1)
Down	(2; 3)	(2; 2)	(3; 1)
Up	(1; 5)	(1; 4)	(1; 1)

Figure 1. Extensive and Normal forms of a game

Source: own elaboration.

If we look for equilibria of this game, we may work with a strategic (normal) form because the game is static (we may observe one information set for player 2).

Clearly, the only pair of pure actions in Nash equilibrium[15] (best responses to each other) is a pair {Focal; Focal}. Moreover, that pair of action may be indicated as possible strategic results of this game by a strong dominance criterion.

As we seek to discover the strategic interaction's patterns in price paths, it becomes necessary to impose some dynamics to the game. From our research of the market and pricing mechanism we conclude that a repeated game structure is both a sufficient and the most adequate model.

If the game is repeated infinite horizon *n*-times, the {Focal, Focal} profile repeated n-times would become an equilibrium strategy (backward induction property). If we repeat the game with infinite horizon and with a common discount factor,[16] assuming perfect monitoring (from previous remarks regarding the price announcements, we have no reason to impose other informational assumptions),the repeated game's pure strategy:

$$S_i^t : H^t \to P_i ; \quad P_i = \{pd, pf, pu\}$$

of the form:

$$S_i = p_i^t = p_i^f \text{ for } \tau = 0, ..., t-1,$$

[15] In fact, there are no other Nash equilibria, even in mixed strategies.

[16] For a general theory of supergames see: Fudenberg and Tirole (1996) or Mailath and Samuelson (2006).

for $i = 1, 2$ forms a strategy profile S, which is subgame perfect, as there are no profitable one-shot deviations from this profile.[17] The result is obvious, as any deviation from a strategy profile S for any player, and any discount factor after any history h^t would be unprofitable for a player due to payoffs of a unique static Nash equilibrium of the stage game that are Pareto efficient.

Conclusions and directions of further research

In this study, we focused on the construction of a simple price game model consistent with market characteristics and an implied price creation mechanism, which would explain an observable strategic behavior of players.

First, we analyzed the basic descriptive statistics. We investigated the wholesale price creation mechanism, and concluded that the pricing mechanism of the players corresponds to the well-known IPP formula.

Based on the extracted industry/market characteristics, we restricted the set of possible models of adequate games by specifying the essential elements of a game model. We constructed a basic 'focal pricing game' model from the scratch, as we were unable to find in a literature a structure which would be well-suited for the specifics of the Polish wholesale market. The primary conclusion from our theoretical model is as follows:

– it is strategically possible to use the same (or very close) price levels for both players in daily interactions, which reassembles parallel pricing phenomenon; and
– the common price level for both players should remain very close to the IPP price level if one assumes the ability of the players to properly calculate the price level on the basis of commonly known factors.

The conclusions from this theoretical model may be used as the markers of consistency of the strategic behavior of players predicted by the model and tested against empirical data. The first implications has been empirically tested in Bejger (2015b), the second one is in the process of research.

At least two paths for further research on the current model can be pointed: improving the game theoretical model by introducing some stochastic errors in the focal price calculation, and determining precisely a dependency of the equilibrium profiles on the capacities and elasticity of demand, and modifying the informational assumption and the structure of the model to study the role of public information provided by the players on their strategic behavior.

[17] It is a well known one shot deviation principle for repeated games, see for example: Mailath and Samuelson (2006), p. 25.

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