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Tacit collusion or parallel behaviour in oligopolistic markets? The two faces of Janus

Michael L. Polemis[a,b] and Aikaterina Oikonomou[c]

[a]Assistant Professor, Department of Economics, University of Piraeus, Piraeus, Greece; [b]Member of the Board, Hellenic Competition Commission, Athens, Greece; [c]Case Handler, Hellenic Single Public Procurement Authority, Athens, Greece

ABSTRACT
A fundamental step in the assessment of antitrust law cases examined by National Competition Authorities (NCAs) is to detect and penalize anti-competitive behaviour (e.g. cartel agreements, secret agreements and tacit agreements). However, this is not an easy task for NCAs since the boundaries between non-explicit (tacit) collusion and parallel behaviour in oligopolistic markets under Bertrand competition are often vague. The scope of this paper is twofold. On the one hand, it aims to cast light on the role of economic analysis in tacit collusion cases by introducing the main quantitative techniques used in antitrust policy. In this way, it contributes to the literature by highlighting the role of economic analysis blended by the use of modern econometric techniques in unveiling the tacit collusion mechanism. On the other hand, it delves into discussions of Greek competition law matters by analysing in depth a tacit collusion case from the petroleum industry.

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KEYWORDS Competition; tacit collusion; oligopoly; Bertrand; econometric techniques

I. Introduction

From an economic standpoint, collusion describes a situation where market prices are close to monopoly despite an oligopolistic market structure. In contrast to unilateral conduct – which may allow prices to rise significantly above the competitive price level in an oligopolistic environment as well – collusion rests on the dynamic interaction between firms.[1] This type of dynamic interaction allows firms to maintain prices at levels close to monopoly prices and significantly above what unilateral conduct alone would allow for.

CONTACT Michael L. Polemis mpolemis@unipi.gr

[1]P Versbach, JU Franck, 'Econometric Evidence to Target Tacit Collusion in Oligopolistic Markets' (2015) 11 (2) Journal of Competition Law and Economics 463.

After the successful implementation of leniency programmes throughout the world, international stakeholders – both, the scientific community and competition authorities – are shifting attention to the question of how to detect cartels based on economic analysis. During the last decades, the fight against hard-core cartels is ranked high on the agenda of competition authorities. To give but an example, it is noteworthy that the European Commission detected only ten cartel cases during the 1995–1999 period, but 30 in the period from 2000 to 2004 and 33 in the 2005–2009 period.[2] However, empirical evidence suggests that a large fraction of the existing hard-core cartels remain undetected. It is noteworthy that the average annual probability of cartel detection estimated lie between 12.9% and 15%.[3] As a consequence, a substantial fraction of customers of undetected cartels face elevated cost levels in the sourcing of their input goods.

During the last decade, increasing empirical literature on the detection of hard-core cartels focuses on the application of screening tools by competition authorities and firms with an elevated risk of cartelization. More specifically, competition authorities can apply reactive methods such as complaints (by, e.g. competitors or employees), or leniency applicants, and/or proactive methods (e.g. press monitoring or screening tools). Screening tools use " … data such as prices, costs, market shares, bids, transaction prices, spreads, volumes, and other data … [t]o identify patterns that are anomalous or highly improbable".[4] It is noteworthy that screening approaches can be subdivided into general industry-based structural screening approaches and more specific market-based behavioural screening approaches.

Different collusion markers can be applied to distinguish between collusive market behaviour and competitive market behaviour.[5] These include (a) price-related collusive markers (e.g. reduced variation in prices across customers) and (b) quantity-related collusive (e.g. highly stable market shares over time).

Most research concentrates on one specific price-related collusive marker. Price variance as marker is justified by the expectation that – price variance is reduced during a conspiracy, and that – the transition from a cartel state to a non-cartel state is characterized by an increase in price variance. In a seminal paper, Abrantes-Metz et al. (re)investigate price movements over time around the collapse of a bid-rigging

[2]R Abrantes-Metz and others, 'Libor Manipulation?' (2011) 36 Journal of Banking and Finance 136; K Hüschelrath, T Veith, 'Cartel Detection in Procurement Markets' (2014) 35(6) Managerial and Decision Economics 404.
[3]Hüschelrath and Veith (n 2).
[4]Abrantes-Metz and others (n 2).
[5]J Harrington, 'Detecting Cartels' in P Buccirossi (ed), *Handbook of Antitrust Economics* (Cambridge 2008).

conspiracy among seafood processors in the United States.[6] Further detection studies are provided by Esposito and Ferrero and Bolotova.[7] Recent contributions discuss to what extent screening tools can be included in antitrust compliance programmes of firms with an elevated risk of cartelization.[8]

Customers of cartelized industries can be interpreted as third group which typically has both possibilities and incentives to detect cartels proactively. Possibilities might be present as customers have a profound knowledge of their procurement markets, and have detailed transaction-based data in the form of invoices available in their (cost) accounting systems. The accuracy and effectiveness of such tools depend on factors such as the time of entry in the respective procurement market, the frequency and size of purchases of the cartelized good, and the behaviour of the cartel.

The scope of this paper is twofold. On the one hand, it aims to cast light on the role of economic analysis in tacit collusion cases by introducing the main quantitative techniques used in antitrust policy. On the other hand, it stimulates a debate from a theoretical and empirical standpoint around tacit collusion in practice by analysing in depth a Greek competition case study drawn from the petroleum industry.

The rest of this paper is organized as follows. Section II, critically discusses the competitive conditions prevailing in the Greek petroleum industry in each of the three distinct market segments while it provides a full presentation of the anti-competitive case. In Section III the theoretical model of oligopolistic price competition is developed, while Section IV presents the econometric framework and discusses the main empirical findings. Finally, Section V concludes the paper.

II. Industry structure and history of the case

A. Petroleum industry in Greece

Oil sector in Greece was deregulated in 1992 and consists of three distinct market segments such as refining, wholesaling and retailing (see Figure 1).

[6]RM Abrantes-Metz and others, 'A Variance Screen for Collusion' (2006) 24(3) International Journal of Industrial Organization 467.

[7]F Esposito, M Ferrero, 'Variance Screens for Detecting Collusion: An Application to Two Cartel Cases in Italy' Working Paper, Rome (2006); Y Bolotova, 'Cartel Overcharges: An Empirical Analysis' Working Paper, Purdue University, West Lafayette (2005).

[8]See for example Abrantes-Metz and others (n 2); P Versbach, JU Franck, 'Endogenous Price Commitment, Sticky and Leadership Pricing: Evidence from the Italian Petrol Market' (2015) 40(C) International Journal of Industrial Organization 32.

During the regulated period, the government retained the exclusive right to set the prices in all of the three market segments. The Greek government had the sole responsibility for the supply of crude oil and the provision of the domestic market with petroleum products. The government not only determined the logistic scheme of the oil companies (i.e. 70% of the domestic market was covered from the refineries of the Public Oil Corporation and the other 30% from the other two private refineries) but totally controlled the ex-refinery price, the profit margins of the oil companies and the petrol station owners and the wholesale and retail price of the petroleum products.

With the law 2008/1992, oil market was deregulated and petroleum product prices have been set freely in all of the market segments. Each oil company is free to set its prices and the profit margins, while petrol station owners set their retail prices and the profit margins according to local competition, the level of investment incurred by the wholesalers (invoice and quantity discounts, credit notes, price support scheme, etc.) and the level of their cost (see Figure 2). The Ministry of Development is responsible for the application of the oil law (3054/2002) while specific responsibilities were assigned to Regulatory Authority for Energy (RAE). RAE is by law (2773/1999) the independent national regulatory authority for the energy sectors.

The Greek fuel market appears isolated from abroad by restrictive measures and practices. Unlike in other EU countries, there are limited

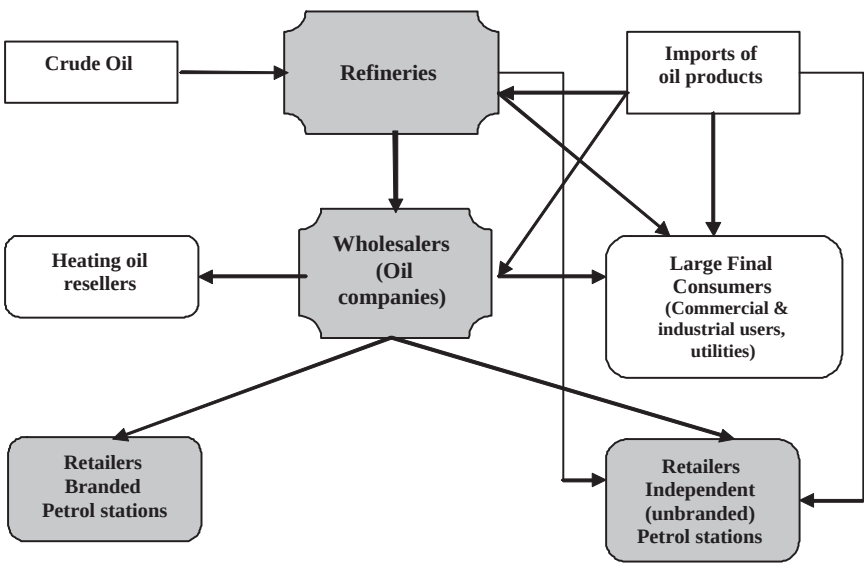

Figure 1. Structure of the Greek oil industry.

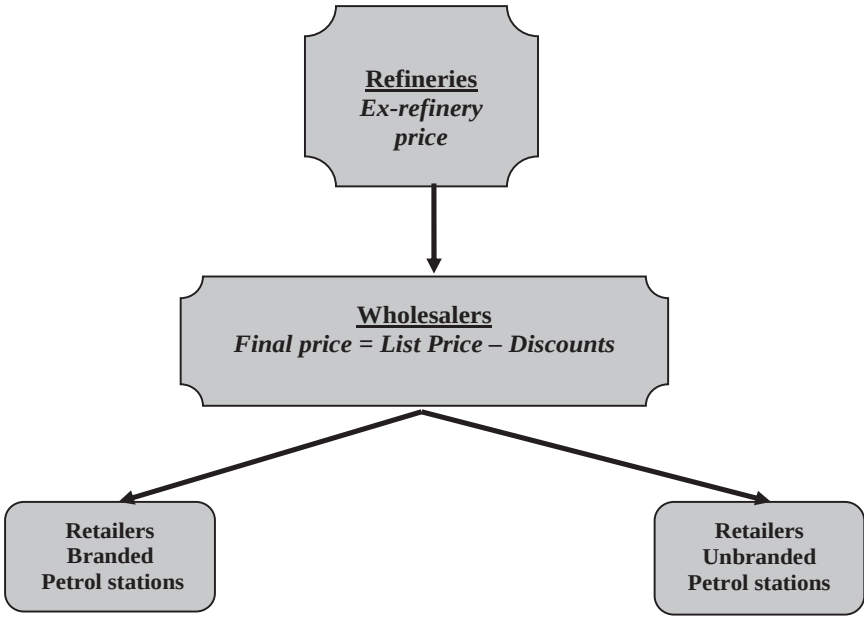

Figure 2. Pricing structure in the Greek gasoline industry.

imports of refined fuel (e.g. gasoline, diesel, LPG, etc.). Only crude oil is imported and refined by two Greek refinery companies.[9] The European Court of Justice and the European Commission have attempted to open the market with infringement cases, but these have had limited impact.[10] The Hellenic Competition Commission (HCC) investigated the fuel market in September 2006 and issued four reports and two decisions, but this too has had limited effect.[11] The Greek fuel market appears closed. Uncompetitive markets cause high costs for Greek consumers. Greece is among the most expensive EU countries before taxes (Figure 3). Average taxes are 55% of the final price for gasoline today, with 23% in heating oil, and 44% in diesel.

There are excessive margins in the system. Even though taxes on heating oil and diesel are relatively lower, these benefits are not passed

[9]The refineries belong to Motor Oil (1) and HELPE (3).

[10]The respective cases are: ECJ in C-347/88 on restrictions on imports, and ECJ in C-398/98 on safety stocks and restrictions on imports, Letter by the EC to GR of 7 April 1993, and by commissioner Monti of 19 September 1995 on independent fuel providers, EC procedure for conditions to set up a gas station – safety distances, on opening hours, and on tank vehicles. Safety distances are being addressed in the MoU but not yet implemented.

[11]HCC on the right of independent gas stations to directly import fuel and to purchase directly from the refinery (rather than through a wholesaler). A Letter by Commissioner Monti of 19 September 1995 threatened an infringement case, and the judgment C-398/98 concerned safety stocks and restrictions to import.

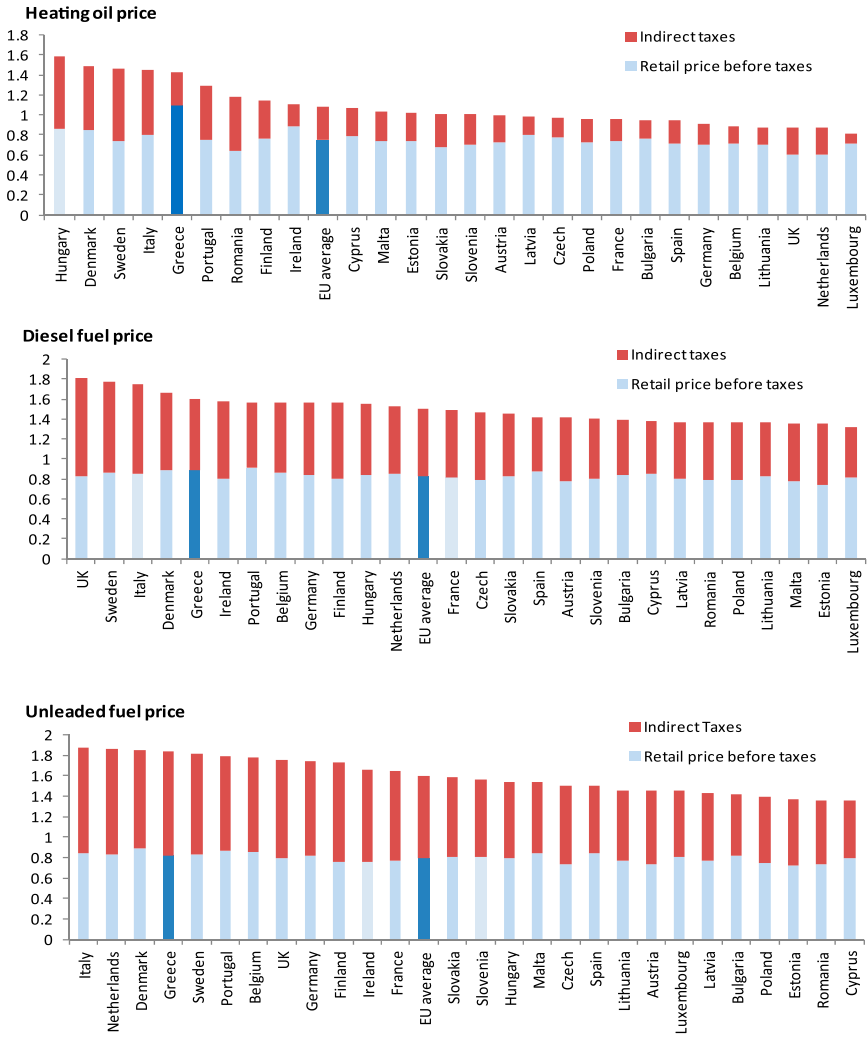

Figure 3. Retail prices and indirect taxes for different types of fuel (in Euros per litre). Source: www.energy.eu; September 05, 2012.

on to consumers; instead, these fuels have some of the highest margins in Europe (Figure 4).[12] If these margins were at the average of other EU countries, the costs to consumers for their fuel purchases would be lowered by 1.0€ billion a year. Moreover, direct fuel and heating oil products account for about 7% of the consumer price index (CPI). Hence, the direct effect of such downward adjustment in prices of fuel could lower the

[12]Margins are defined as the difference between the end-consumer price (excluding any taxes) and the price of crude oil, which is assumed to be the same for all EU countries. Hence, they cover refining, transportation, insurance, stockpiling, distribution and sale to consumers and profits.

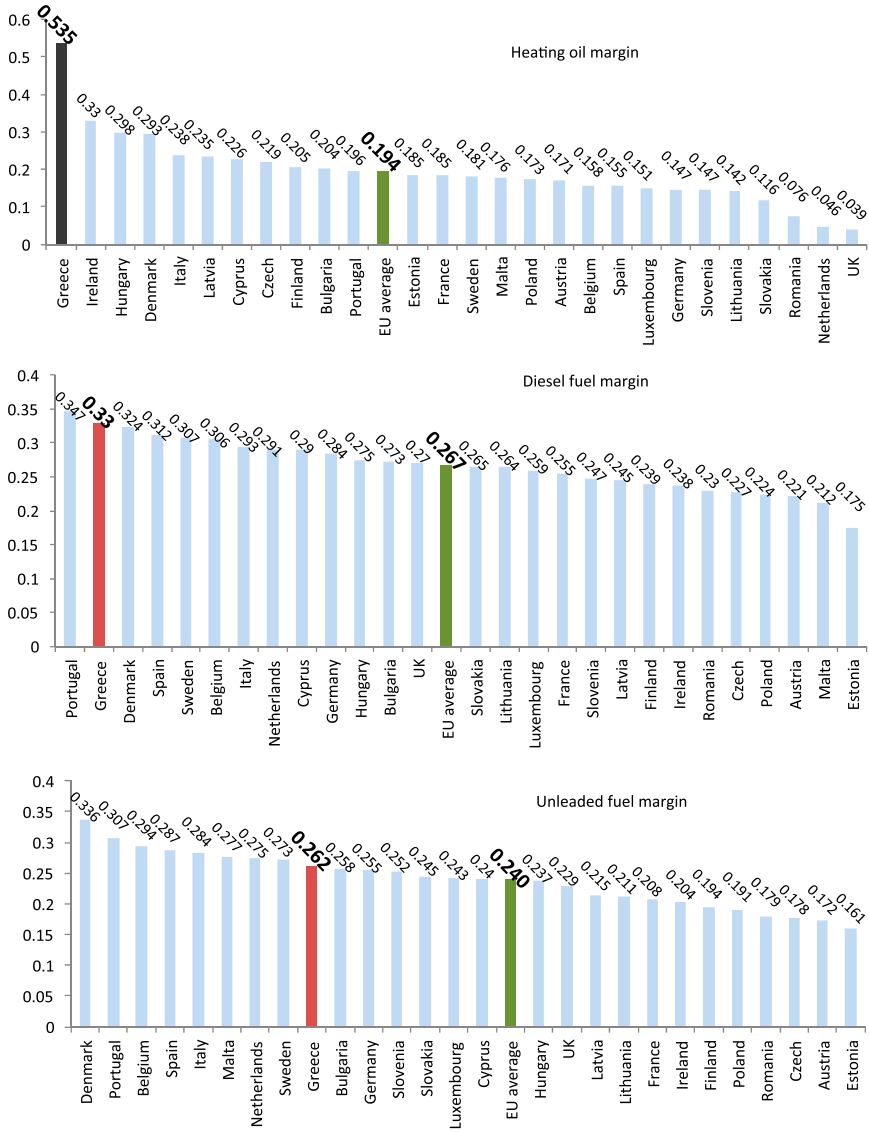

Figure 4. Margins for different types of fuels (in Euros per litre). Source: www.energy.eu; September 05, 2012.

CPI by 1.15%. Given how important energy is for the overall economy, better functioning fuel markets could help to boost competitiveness of Greece.

The Greek market is dominated by the two domestic refining companies and their wholesalers. Greece is the only EU country without a

foreign fuel operator.[13] In 2009–2010, Shell and BP left Greece and sold their operations to Motor Oil and HELPE, respectively. The two refineries and their distribution subsidiaries control over 70% of the wholesale market. There are less than 20 licenced wholesalers, but except for the 2 integrated refinery groups only 4–5 have a market share over 3%. The two refinery groups also control about 60% of the gas stations (they were obliged to dispose of some gas stations before the competition committee approved the takeovers). Independent retailers were about 10% of the gas stations in 2000; today they are below 5%. Independent gas stations are not bound by an exclusive purchase agreement with one wholesaler or franchisor.

In the retail segment, there are approximately 6,500 petrol filling station operators (nearly 600 are unbranded) that cover the increasing demand for oil products. The majority of them are Company Owned Dealer Operated (CODO) or Dealer Owned Dealer Operated (DODO). Most of the petrol stations is situated close to the Attica region and represents half of the total turnover of the retail market. Apart from filling station operators, there are a small number of traders (so called "resellers") that usually sell directly to the final consumers heating oil and kerosene.

Importing is only permitted by those owning or renting storage facilities that can hold at least 90 days of inventory which is costly for small operators. Independent gas stations are allowed to import, but often do not have or cannot rent adequate storage facilities, and there are further restrictions in tanker truck transportation (more below).[14] Branded gas stations (e.g. Shell, BP stations) are contractually prohibited to import. Wholesalers can import and have storage facilities, but the refineries do not like import competition (more below). Refineries import crude oil and other oil products since they have storage facilities. While wholesalers have the option to import, they are not exercising it. When this option opened up, refineries adopted aggressive rebate programmes and credit schemes to dissuade wholesalers from importing fuels. Then after the acquisition of the Shell and BP facilities to the two large domestic refiners, the refiners gained market power and imposed stricter credit policy on wholesalers. Effectively, the two refineries appear to dominate the wholesale market. Independent retailers can form consortia to import fuels. In order to import they need to comply with the 90-day storage regulation, and also have their own

[13]Malta also lacks a foreign fuel operator, but the Maltese market is tiny compared to Greece.
[14]Laws 3054/2002 and 3335/2005.

tanker vehicles, for which they encounter further restrictions. At the end, the cumulative set of nested restrictions makes it impossible for independent gas stations to import their own fuel.

Wholesalers have tanker trucks big enough to import fuels but they can only transport fuel from the refineries to their customers. In other words, they cannot directly transport fuels from abroad to independent retailers or their customers, thereby bypassing the refineries, because the refineries are custom zones where custom duties must be paid and they function as import facilities. In conclusion, if a consortium of independent gas stations, or wholesalers, imports fuels, effectively this fuel gets first sold to a Greek refinery, then it is sold by the refinery to a wholesaler, and then the wholesaler resells this fuel to the independent gas stations (possibly the original importer) or its own customers.[15] Thus, through regulation, it seems that smaller operators cannot bypass refineries for importing fuels – this resembles market capture.

In the refinery segment, the major problem is connected to the existing strategic stockholding obligation system. Due to this and other specific restrictions (i.e. lack of storage, strict environmental legislation, bureaucracy, system of compulsory oil reserves in the Greek territory) a marketer (oil company, end-user) cannot easily import oil products.

Specifically, the basic obligation – according to EU law – is for all member states to stock a reserve corresponding to 90 days of consumption or under the new directive 61 days of consumption days of net imports of crude oil, whatever is the higher quantity.[16] The problem is how Greece implements this obligation combined with the lack of storage facilities. This implementation has been brought before the European Court of Justice twice for their restrictive effects. First, even though refineries and big wholesalers can rent storage facilities to third parties, reality shows that no independent oil company or independent retailer has so far managed to rent storage facilities from refineries (despite the new

[15]This situation is described by the Greek Competition Authority in its Report dated 27 May 2008. The authority concluded that independent retailers cannot import fuel or purchase directly from the refineries because they cannot have their own private tankers to transport the fuel from the custom zones or the refineries installations to their gas stations.

[16]This is based on EU Directive 2006/67/EC. It asks the member states to guarantee emergency fuel reserves of the equivalent of 90 days crude oil equivalents of consumption. The new, revised Directive 2009/119/EC, to be transposed into national legislation by 31 December 2012, changes the obligation to 90 days of net imports or 61 days of domestic consumption, whichever is higher (for Greece, most probably the 90 days of net imports will apply). Member States are free to decide on their stockholding regime: they can set up specific entities to hold emergency stocks; they can impose an obligation on economic operators (typically oil companies) or can have a mixed system. Greece is one of the few countries in the EU which imposes the whole obligation on economic operators.

Licence Regulation 12565/2007 that prohibits discrimination).[17] Second, regulations prescribe that importing refined fuels requires a commitment to import for a year and a contract with a storage facility for a year (law 3054/2002). It is virtually impossible for small independent retailers to comply with these obligations. The blocking restrictions on transportation (tanker trucks), and on storage restrain competition in the fuels market.

Refineries have rendered ineffective the right for independent gas stations to buy fuel directly from them (law 3054/2002), despite the HCC decision 2466/2008 stipulated that refineries are supposed to price independent retailers who wish to buy directly from them, at a price which would make such possibility applied. Motor Oil refuses to sell, and HELPE imposed a special premium for direct sales to independent retailers. The premium makes it more expensive to buy fuel directly from refineries than from wholesalers, and it is designed to stop independent retailers from purchasing fuel directly from refineries.

At the wholesale market segment significant competition restrictions apply. More specifically, only wholesalers can transport fuel in Greece. Transport of fuel cannot be provided as an independent service, nor can it be carried out by the gas stations themselves (contrary to practices in other EU countries). The regulation of tanker trucks is an obstacle. For an independent retailer to contract a "public use" vehicle (rent a tanker from a trucking company), this independent retailer first needs a licence for a "private use" vehicle (have a licence for its own tanker).[18] However, independent gas stations are not allowed to operate private tankers above 8 tons (slightly bigger than a pickup truck).[19] But such small tankers are not allowed access to refineries or import installations like custom zones.[20] Moreover, article 320 of law 4072/2012[21] dictates that it is forbidden to drive a tank vehicle and transport fuel into Greece unless the truck bears the trademark and commercial sign of a Greek wholesale company. This makes it impossible for independent gas stations to transport fuel into Greece. Further, any public transport

[17]In Italy, seven franchisors/wholesalers offer 20% of their capacity in refineries and storage to independent retailers.

[18]Ministerial circular Γ5/29829/2313 dated 14 June 2006. The Joint Ministerial Decision 63771/6239/2011 does not remove restrictions for independent retailers.

[19]Article 7, paragraph 10 of law 3054/2002.

[20]Law 3054/2002, Ministerial Circular G5/29829/2313 of 14-6-2006, Legislative Decree 49/1968, art 4 and Law 1959/1991 art 4, and Presidential Decree 91/1988.

[21]Article 320 introduces some additional requirements on private and public use tank vehicles, including the need to exhibit on a well-seen part of the truck, the trademark and commercial sign of the (Wholesale) Trade License holder or of the Refinery License, in case the vehicle gets its oil supply directly from a refinery; and (ii) they need to introduce a GPS system on their vehicle.

company that gets an order from an independent gas station cannot use its own trademark, but needs to paint the vehicle in the colours of the Greek wholesale company under whose name it transports (article 320 of law 4072/2012). On top of this, there are minimum tariffs set by Ministerial Decision for the use of public use tankers.

In the retail segment, competition is relatively strong. However, some problems may occur and are the outcome of the existing legal framework. Although gasoline and oil prices have been set freely, the government retains the right to set price ceiling if it considers that the market is not functioning well. Moreover, as a consequence of the existing legislation, hypermarkets are not an active player in petrol retailing. Therefore the competition in the retail market is hindered.

More analytically, gas stations are forbidden by law to sell to each other, including within their own network (law 3054/2002).[22] Gas stations do not have access to prices that wholesalers charge every day (the "price list"). Wholesalers do not disclose their prices to other gas stations.[23] Moreover, they do not want their own franchisees to know the prices they charge to independent gas stations or other franchisees. As a result, they price discriminate in their own network.[24] Franchised gas stations are subject to tight restrictions. It is worth mentioning that more than 20% have an oral but not a written contract. Oral arrangements allow wholesalers to apply more pressures, such as an obligation to sell minimum quantities, subject to penalties. Also, with an oral contract, the stations can be forced to stay in an exclusive purchase agreement up to 15 years, whereas the maximum legal period for a written contract in Greece is 3–5 years. Such oral contracts are enforced through up-front payments or credit lines.

Lastly, independent gas stations are obliged to use a specific sign called "AP" (independent stations). This "AP" sign is three times taller than any other sign including the trademark of the company operating the gas station (Ministerial Decision A3/5262/2004). Article 320 of law 4072/2012 made APs and their providers (refineries or wholesalers) equally responsible for the quantity and quality of the fuel dispensed in the gas station. This is in contrast to other EU countries where full responsibility rests with the owner of the gas station. Since the wholesaler is now legally co-responsible for the quantity and quality of fuel sold in an AP station,

[22]The contract with a wholesaler could exclude this, but in Greece it is imposed by law.
[23]Since 2011, this information is provided to RAE.
[24]The German Competition Authority has forbidden the six big franchisors/refineries to impose discriminatory prices on independent retailers.

this means that sooner or later, the wholesaler will demand to equip the dispenser with its own control mechanism. This is a way to tie independents into a franchise or an exclusive wholesaler.

B. Background of the case

In 2008 the HCC issued the Decision No. 421/V/2008 following the General Directorate for Competition's (GDC) ex officio investigation with the aim to identify possible infringements of law 703/1977 by petroleum products trading companies. The investigation in question indicated that during the period from 1 January 2003 through 31 December 2003 BP HELLAS S.A. (henceforth "BP") and Shell HELLAS S.A. (henceforth "Shell") proceeded in coordinating their discount policies. In particular, BP and Shell – both multinational corporations active in Greece, whose joint market-share in unleaded gasoline (95 RON) reaches approximately 40% – applied different discounts in the various regions of Greece but of the same ratio. That is to say, if BP applies discount *A* in prefecture *F* and Shell applies discount *B* (of a different amount) in the same prefecture (*F*), then BP would apply a discount *A* + 50% in prefecture *G*, while Shell would also apply a discount *B* + 50% in prefecture *G*.

The GDC after a request of the Minister of Development launched an ex-officio investigation in the wholesale gasoline market in Greece in order to examine possible anti-competitive practices by oil companies (wholesalers). After a thorough investigation of the data (prices, rebates, quantities, transportation cost, concentration, etc.) focusing on the implementation of the discount policy of the oil companies in Greece, GDC has issued two reports (initial and complementary).

In the relevant reports, GDC claims that two of the major oil companies (BP and Shell) implemented a common discount policy in order to fix total gasoline prices in certain regions of Greece. By implementing this anti-competitive practice, the companies seem to have "divided" Greece into three main groups or clusters. The GDC claims that the only possible explanation for this common discount policy by the two oil companies is a concerted practice.

It should be noted that the above are the average discounts for all retailers in each prefecture, as BP and Shell offer different discounts to each of their retailers. It should also be mentioned that "transparency" is not a feature of the discount policy applied, that is to say, a company does not know and is not in a position to become informed of the discounts of its competitor. The common discount policy pattern cannot be

attributed to reasonable economic factors, as the relevant analysis has indicated (e.g. transportation costs, economic geography across the regions, demand conditions, etc.), since the two oil companies: (a) have different cost structure, (b) have different logistic schemes across the Greek regions, and (c) differ in the number of branded petrol stations. As a consequence no other plausible explanation exists for the parallel conduct of the two companies than that of a concerted practice. In particular, the HCC, taking into consideration the objections of both parties to the infringement decided by majority that the concerted practice of the two trading companies with respect to their discount policy applied in regions of Greece amounted to a price-fixing agreement, which constitutes a manifest infringement under article 1 of law 703/1977 and article 81 of the EC Treaty. The HCC, sustaining the objections of the DGC's complementary Report, firstly ascertained the special role enjoyed by the aforementioned oil products trading companies in comparison to the rest of the undertakings active in the sector in question, mainly due to their strong brand names, and secondly established inter alia their intention not to compete with one another, but instead to converge their net wholesale prices by means of a common discount ratio policy. By way of its decision, the HCC orders the undertakings in question to bring the infringement to an end and refrain from committing in the future. For this purpose, within 90 days from the notification of the decision, the above undertakings shall separately and independently of each other calculate and grant discounts (on invoices and annually) to the retail outlets, with which they each deal in the Greek unleaded gasoline market.

Lastly, the HCC decided to impose a fine of €30,066,585.00 on "BP HELLAS S.A." and a fine of €19,664,888.00 on "SHELL HELLAS S.A." for infringing article 1 of law 703/1977 and article 81 of the EC Treaty. The fines imposed do not exceed the maximum limit set out in article 9 paragraph 2 of law 703/1977 (i.e. 15% of the turnover of the financial year, during which the infringement was committed, namely 2003). In case of failure to comply with the abovementioned obligations within the time limit specified above, each undertaking involved in the infringement shall be liable to a fine of €10,000 for each day of non-compliance. This decision is considered one of the most important decisions the HCC has ever issued, not only due to the nature of the infringement (cartel case), but also because it has been the first time that HCC succeeded in finding the necessary economic and legal data to substantiate such a case in this particularly sensitive market.

III. The theoretical model

Consider that we have two firms ($i = 1, 2$) competing each other under Bertrand competition. The product is homogenous and the two rivals face the same (linear) total cost equal to $\mathrm{TC} = C(qi) = cqi$, with $c \geq 0$. The marginal cost for each firm i is given as $\mathrm{MC} = c$.

The two firms choose their prices (p_1 and p_2) simultaneously and separately with its clients for each period $t = 1, 2, 3, \ldots$ (with unknown infinite time horizon). The two firms discount their future profits by using the discount factor δ, with $0 < \delta < 1$.[25] This means that the smaller (larger) the value of δ the smaller (larger) the value of the future profits.

Firms play a repeated game. In stage one, firm i maximizes its total profits in period $t = 1$ by setting its price equal to monopoly ($p = p_m$). In stage two, firm i continues to charge the monopoly price within the next periods $t = 2, \ldots$ provided that its rival will do the same. In this stage, the firms are in a cooperation/collusion phase. The profits for each firm in this period are equal to $\pi^c = \pi^m/2$.

However, the rival might deviate in one period by charging a lower price satisfying the market demand. This period is called deviation period. During this period the profits of the firm who deviates are equal to $\pi^d = \pi^m$, while the profits of firm i take zero values. From the next period and for the rest of the game, firm i "punishes" the rival by charging a low price equal to its marginal cost $P = \mathrm{MC}$. In other words, if the discount factor is significantly high, then there exists a subgame perfect Nash equilibrium of the repeated game whereby firms set monopoly price in every period under the "threat" that if any firm ever deviates from this price level, then both firms revert to, pricing at marginal cost level indefinitely ("trigger" strategy).[26] According to the latter, a firm starts by cooperating in the first period (setting the price that a monopolist would set) and continues to cooperate in the next periods as long as there was no aggressive act from the rival. Otherwise, it punishes the rival by choosing to play aggressively forever. In such a case, the firm sets its price equal to MC ($p = \mathrm{MC}$).

During the punishment period, the total profits of the firms are given by $\pi_p = 0$. In this period it holds that $\pi^d > \pi^c > \pi^p$. As a consequence, each firm faces the trade-off between the larger profits should it deviates and the future profit losses as a result of the punishment. The trade-off

[25]The discount factor is given by $\delta = 1/(1+r)$, where r is the interest rate per period.
[26]For more details on the mechanism of tacit collusion in oligopolistic markets see Cabral Luis, *Introduction to Industrial Organization* (2nd edn, 2017) 218.

depends on the profit magnitude during the deviation and collusion periods and the discount factor (δ).

The model can be solved algebraically as follows: the present value of the total profits when collusion is present in each time period is given by the following equation:

$$V^C = \pi^c + \delta\pi^c + \delta^2\pi^c + \ldots = \frac{1}{1-\delta}\pi^c, \tag{1}$$

where V denotes discounted (net present value) equilibrium payoff or value and δ is the discount factor described above. The present value of the total profits of a firm when it deviates from the collusive agreement is given as:

$$V^D = \pi^d + \delta\pi^n + \delta^2\pi^n + \ldots = \pi^d\frac{1}{1-\delta}\pi^n, \tag{2}$$

where π^n are the competitive profits (i.e. zero in the long-run) earned when one of the two firms acts aggressively (i.e. deviates from cooperation/collusion). Combing the two equations, it is evident that none of the two companies has the incentive to deviate when the following inequalities are met:

$$\begin{aligned} V^C \geq V^D &\Leftrightarrow \frac{1}{1-\delta}\pi^c \geq \pi^d + \frac{1}{1-\delta}\pi^n \\ &\Leftrightarrow \frac{1}{1-\delta}(\pi^c - \pi^n) \geq \pi^d - \pi^c. \end{aligned} \tag{3}$$

Therefore, the condition that must be satisfied in order to trigger the tacit collusion mechanism is the following:

$$\Leftrightarrow \delta \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^n} \equiv \delta_{\min}. \tag{4}$$

The above condition leads to the following stylized facts:

(a) in order to achieve tacit collusion, the oligopolistic firms must place significant weight on their future profits;
(b) the larger the profits in the collusion period π^c the more likely the tacit collusion;
(c) the larger the profits in the deviation period π^d the less likely the tacit collusion.

IV. Empirical framework

A. Data and formulation of research hypotheses

Our sample used in this analysis, constitutes of 46 regions of the Greek territory and includes several dependent and control variables (averages) for the year 2003 (cross-section data). More specifically, the reduced form equation is the following:

$$Y_i = a_0 + a_1 X_i + u_i, \tag{5}$$

where $i = \{\text{BP, SHELL}\}$. $Y = \begin{bmatrix} \text{R}_i \\ \text{PN}_i \\ \text{PF}_i \end{bmatrix}$ denotes the vector of the three main dependent variables of the model accounting for the retail final price of BP and SHELL (RBP, RSHELL), the nominal wholesale prices (PNBP, PNSHELL) net of discounts and the final wholesale prices of the two companies (PFBP, PFSHELL) in the gasoline relevant market respectively. $X = \begin{bmatrix} \text{APOL}_i \\ \text{TIMOL}_i \\ \text{Q}_i \end{bmatrix}$ represents the vector of the independent (control) variables of the model accounting for the quantity discounts (APOLBP, APOLSHELL) given at the end of the reference period (i.e. year, month, semester, etc.), the invoice discounts (TIMOLBP, TIMOLSHELL) and the gasoline quantity supplied from each of the two firms. Table 1 reports a complete set of summary statistics for all the variables used in the econometric analysis.

From the relevant table, it is evident that the sample data are well behaved showing limited variability in relation to the mean of the population, since the values of the coefficient of variation measure are close to zero. By contrast, the majority of the variables are not normally distributed, since the relative values of the skewness and kurtosis measures are not zero and three respectively. However, the final wholesale prices of the two companies do follow the normal distribution since the null hypothesis of the Kolmogorov–Smirnov test cannot be statistically rejected (see relevant table in Appendix C). This implies that the relevant variables do not violate the hypothesis of normality, which constitutes one of the most basic prerequisite in order to perform sound econometric analysis. Moreover, as it is evident from Table 1, there are strong and statistically significant correlations between the sample variables of each oil company (BP and SHELL). More specifically, the real (final) price of the two companies is strongly and statistically significant correlated with a high correlation

Table 1. Sample variables correlations.

		RBP	RSHELL	ApolBP	ApolShell	TimolBP	TimolShell	QBP	QSHELL	PNSHELL	PNBP	PFSHELL	PFBP
RBP	Pearson correlation	1											
	Sig. (2-tailed)												
RSHELL	Pearson correlation	0.853 (**)	1										
	Sig. (2-tailed)	[0.000]											
ApolBP	Pearson correlation	0.414 (**)	0.261	1									
	Sig. (2-tailed)	[0.004]	[0.079]										
ApolShell	Pearson correlation	0.289	0.442 (**)	−0.079	1								
	Sig. (2-tailed)	[0.051]	[0.002]	[0.603]									
TimolBP	Pearson correlation	0.939 (**)	0.836 (**)	0.077	0.347 (*)	1							
	Sig. (2-tailed)	[0.000]	[0.000]	[0.612]	[0.018]								
TimolShell	Pearson correlation	0.845 (**)	0.958 (**)	0.312 (*)	0.168	0.808 (**)	1						
	Sig. (2-tailed)	[0.000]	[0.000]	[0.035]	[0.265]	[0.000]							
QBP	Pearson correlation	0.096	0.121	−0.010	0.144	0.109	0.088	1					
	Sig. (2-tailed)	[0.526]	[0.421]	[0.946]	[0.340]	[0.471]	[0.562]						
QSHELL	Pearson correlation	0.107	0.137	0.007	0.148	0.115	0.104	0.992 (**)	1				
	Sig. (2-tailed)	[0.479]	[0.363]	[0.966]	[0.327]	[0.448]	[0.492]	[0.000]					
PNSHELL	Pearson correlation	0.432 (**)	0.466 (**)	0.041	0.210	0.458 (**)	0.445 (**)	−0.106	−0.127	1			
	Sig. (2-tailed)	[0.003]	[0.001]	[0.789]	[0.161]	[0.001]	[0.002]	[0.483]	[0.399]				
PNBP	Pearson correlation	−0.075	−0.079	−0.181	0.090	−0.014	−0.116	−0.091	−0.093	−0.033	1		
	Sig. (2-tailed)	[0.619]	[0.600]	[0.229]	[0.552]	[0.926]	[0.443]	[0.550]	[0.538]	[0.830]			

(*Continued*)

Table 1. Continued.

		RBP	RSHELL	ApolBP	ApolShell	TimolBP	TimolShell	QBP	QSHELL	PNSHELL	PNBP	PFSHELL	PFBP
PFSHELL	Pearson correlation	−0.831 (**)	−0.983 (**)	−0.274	−0.434 (**)	−0.807 (**)	−0.942 (**)	−0.153	−0.175	−0.295 (*)	0.079	1	
	Sig. (2-tailed)	[0.000]	[0.000]	[0.066]	[0.003]	[0.000]	[0.000]	[0.309]	[0.245]	[0.047]	[0.602]		
PFBP	Pearson correlation	−0.982 (**)	−0.840 (**)	−0.436 (**)	−0.263	−0.911 (**)	−0.840 (**)	−0.110	−0.121	−0.424 (**)	0.264	0.819 (**)	1
	Sig. (2-tailed)	[0.000]	[0.000]	[0.002]	[0.078]	[0.000]	[0.000]	[0.466]	[0.422]	[0.003]	[0.076]	[0.000]	

Note: ** (*P*-value) 0.01 (2-tailed). * (*P*-value) 0.05 (2-tailed). (+) The numbers in braces denote the *P*-values.

coefficient equal to 0.853. The same outcome applies to other sample variables of the two companies such as invoice discounts (0.808). In the next sections, we attempt to apply proper econometric techniques to ensure that these correlations trigger a tacit collusion mechanism focusing on the evolution of nominal and real prices.

We proceed our empirical analysis with the imposition of the main research hypotheses and the assumptions underlined regarding the tacit collusion model. These research questions are then tested empirically. In order to be more concise and informative, we group them into two relevant subsections.

1. Discount policy

The two oil companies offer discounts to their retail stations when competitors temporarily reduce prices to increase sales, "requiring" that the discount is passed on to the consumer ("price support" scheme). However, support is not given when a retail station itself initiates a price reduction. Therefore filling station operators have no incentive to cut prices. Not only they do not receive a discount, but also the operators know that their competitors are able to follow any price reduction immediately. This raises competition concerns since this type of policy might trigger collusive behaviour on the gasoline industry by the wholesales.[27] However, we must mention that the HCC did not include in the analysis all the elements of a pricing policy of an oil company (i.e. investments, credit terms, marketing schemes, etc.), because only discounts can affect the prices at the pump. Discounts are easily observable and have an immediate effect on the pricing structure of the petrol station owner.

According to the business practice, invoice and periodic (ad hoc) discounts are not usual transparent to third parties. Temporary rebates (i.e. available for a few weeks or more) are granted on an ad-hoc basis in order to enhance the level of local competition. Moreover, volume rebates are given for reaching set thresholds at a specific period of time (e.g. month, semester or year). As a consequence, discounts must be short-lived and variable across the various regions of the country responding to the local competition.

Therefore, we can summarize the above considerations in the following research hypotheses that will be empirically tested:

[27] L Bettendorf, SA Van der Geest and M Varkevisser, 'Price Asymmetry in the Dutch Retail Gasoline Market' (2003) 25(6) Energy Economics 669.

Hypothesis one. Is the common discount policy scheme between the two alleged firms the outcome of a parallel behaviour?

Hypothesis two. Does the level of discounts vary across the two alleged firms and systematically correlate with the volume of their gasoline sales?

Hypothesis three. Can the common discount policy pattern between the two alleged firms be explained by reasonable economic factors (transportation cost, economic geography across regions, demand conditions, etc.)?

2. Pricing policy

As it was clearly examined in the theoretical model, the pricing mechanism constitutes the basic market strategy followed by the oligopolistic firms in order to increase their market shares and hence the level of their profits. Regarding the Greek gasoline industry, wholesale prices are not transparent and are linked to a significant extent with the level of discounts levied on the petrol stations by the wholesalers.

However, we must bear in mind that finding a strong correlation and parallelism in wholesale final prices driven by similar discount policies would probably be the outcome of an oligopolistic behaviour by two firms competing with the same (unobserved) costs and demand. In such a case we have to distinguish between the two fundamental hypotheses (competition vs. collusion) since price harmonization cannot be illegal "per se". Therefore, we hypothesize the following:

Hypothesis four. Is there a strong and positive causality existing between the nominal (list) wholesale prices of the two alleged firms?

Hypothesis five. Is the equality of the final wholesale prices of the two alleged firms the outcome of an oligopolistic à la Bertrand competition or a concerted practice?

B. Nominal wholesale prices and discounts

The assumption of a tacit collusion mechanism of net wholesale prices for each service station i and region j can be tested in an econometric formulation as:

$$P_{ji}^{\text{Final wholesale price Shell}} = P_{ji}^{\text{Final wholesale price BP}} + e_{ji}, \tag{6}$$

where $P_{ji}^{\text{Final wholesale price Shell}} = P_{ji}^{\text{Nominal price Shell}} - E_{ji}^{\text{Shell}}$ and $P_{ji}^{\text{Final wholesale price BP}} = P_{ji}^{\text{Nominal price BP}} - E_{ji}^{\text{BP}}$ are the net wholesale prices of

gasoline per petrol station, as they are formed after the discounts have been granted to each petrol station per region. Finally, e_{ji} is the disturbance term which is i.i.d. Under the assumption of wholesale price harmonization, the random variable e_{ji} should have a mean equal to zero. In other words, the following assumption must hold:

$$\mathrm{H}_0{:}\mu_{\mathrm{e}} \overset{\text{defines}}{\equiv} E(e_{ji}) = 0. \tag{7}$$

The above hypothesis denotes that the average final prices of BP and Shell ($P_{ji}^{\text{Final price, Shell}}$ and $P_{ji}^{\text{Final price, BP}}$) should be equal. In other words, the following hypothesis must hold:

$$\mathrm{H}_0{:}\mu^{\text{Shell}} \equiv E(P_{ji}^{\text{Final wholesale price,Shell}}) = \mu^{\text{BP}} \equiv E(P_{ji}^{\text{Final wholesale price, BP}}). \tag{8}$$

On the basis of the above analysis, it is clear that conducting the control of the difference of the means μ^{Shell} and μ^{BP} (or the average difference of their values from zero), for a certain subgroup of regions separately is not a problem for the interpretation of basic results of the GDC statement of objection. Even the average of a smaller county team can give an accurate measurement of the average price (or discounts) per service station if each prefecture is made up of a significant number of service stations. If we take into account that these averages represent average values for the year 2003, then the accuracy on which the harmonization assumption $\mathrm{H}_0{:}\mu_{\mathrm{e}} \equiv E(e_{ji}) = 0$ is controlled should be considered as fairly large, even if the group of prefectures is too small (e.g. four regions). To find this, empirically, in the reported tables of the Appendix A we present the estimates for the total of all the separate groups of 46 regions of the country. Out of this total, only the five regions in which both companies do not operate are excluded.

The figures in Table A2 show clearly that the differences in the final prices of the two companies (when discounts are taken into account) are statistically insignificant and therefore the zero-case hypothesis can not be rejected. The same conclusion does not hold to the level of discounts and nominal prices. The former have a mean of 0.0064 which is different from zero (as it has a t-statistic of 3.92), while the latter has a mean of 0.0072 which is also zero in significance of 5% (as has t-statistic 9.04). This means that the final (net) prices of the BP and SHELL companies are equal to the Greek regions, as

opposed to the nominal prices (price list) and the discounts that differ from each other.

The elements of the discounts and nominal prices based on the above tests are presented in the relevant tables of the Appendix A and B. From the examination of the reported tables, we argue that there is a small fluctuation of the nominal prices compared to the discounts while the net wholesale prices of the two companies show some volatility across the Greek regions. This is also evident in the following figure which illustrates the differences between the nominal values (dif_*n*), the net values (dif_*pf*) and the discounts, minus (−) because they are subtracted from the nominal values (−dif_*r*), between the two companies, for each county in the country. As can be seen from this representation, the differences in net discounts correspond to those of the net, final prices almost one-to-one. Both of these series show similar variability across the county. By contrast, with the exception of a relatively small number of regions, the variability of nominal price differences is very small, almost zero (Figure 5).

It is worth mentioning that the empirical analysis revealed that the level of the discounts of the two oil companies are not systematically correlated with the sales volume of unleaded petrol. Specifically, BP and Shell have the lowest correlation index which does not exceed the level of 0.15 and it is not statistically significant.

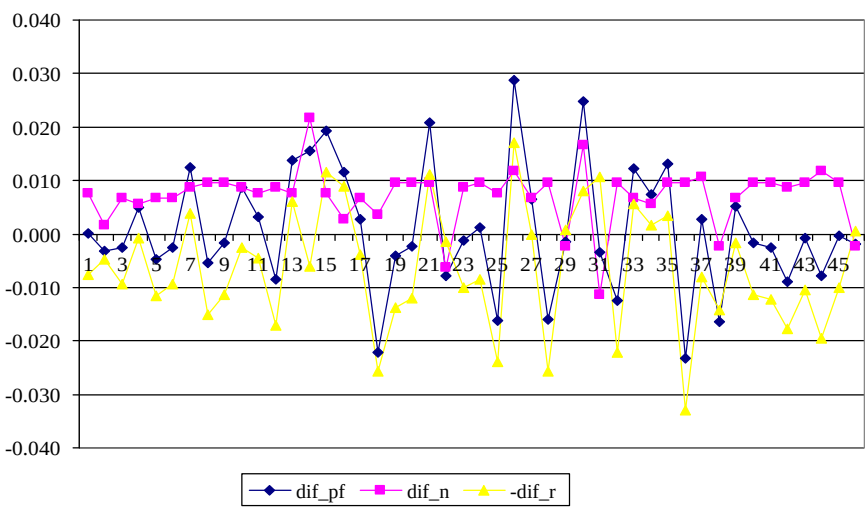

Figure 5. Absolute differences in nominal prices, final wholesale prices and discounts, between the two firms.

The above arguments can be statistically tested by the estimation of the following regression:

$$(P_{ji}^{\text{Final price Shell}} - P_{ji}^{\text{Final price BP}}) = a + b(E_{ji}^{\text{BP}} - E_{ji}^{\text{Shell}}) + e_{ji}. \qquad (9)$$

Based on the concerted practice model presented above, if the discounts determine the final wholesale prices then the slope parameter b of the above regression should equal unity and the coefficient of determination R^2, will be quite high. If the latter is true, then discounts will essentially determine the net wholesale gasoline prices. The estimates of the above regression are presented in Table 2 (see also Appendices A and B for a detailed representation). As the results of Table 2 show, both of the above assumptions are confirmed. Based on the standard error of the estimator of b, this coefficient is not different from unity, while the coefficient of determination (R^2) is very high (78%), especially for cross-section data.

C. Final wholesale prices

One of the key assumptions is whether final gasoline prices (adjusted for the presence of discounts) between the two companies do not differ significantly. Based on this finding, it is possible to compare the pre-tax average prices of the two companies and test statistically whether the average values of the difference is zero. If the assumption of harmonization of net gasoline prices is valid then their values will not differ systematically each other across the country. A consequence of this assumption is that the average levels of the final gasoline prices will be the same for both companies. For a better understanding of this argument, we present the following simple example, using imprecise averages.

Let $P_{ji}^{\text{Final price Shell}} = P_{ji}^{\text{Nominal price Shell}} - E_{ji}^{\text{Shell}}$ and $P_{ji}^{\text{Final price BP}} = P_{ji}^{\text{Nominal price BP}} - E_{ji}^{\text{BP}}$ represent Shell's and BP's wholesale prices respectively for each i and prefecture j. If there are no systematic differences between these prices, possibly due to local competition, or economic geography between the regions, then, under a concerted practice final

Table 2. Regression results.

	Magnitude	Standard deviation	t-Statistic $a = 0$, $b = 0$	$R^2 = 0.78$
Intercept (a)	0.0065	0.0011	5.77	$t_{a=0} = 5.77$
Slope coefficient (b)	0.9085	0.0768	11.82	$t_{b=1} = 1.19$

prices and discounts will not differ. A simple economic model linking the above prices is given by the following equation:

$$P_{ji}^{\text{Final price Shell}} = P_{ji}^{\text{Final price BP}} + e_{ji} \text{ or } P_{ji}^{\text{Final price Shell}} - P_{ji}^{\text{Final price BP}} = e_{ji}$$

where e_{ji} is a random variable where under the hypothesis of price alignment will characterized by expected price equal to zero. In other words, the following statistical hypothesis will hold

$$\text{H}_0{:}\mu_e \equiv \text{E}(e_{ji}) = 0. \tag{10}$$

But what should be the case for gasoline discounts and prices under competitive conditions in the wholesale gasoline market? Such an investigation is desirable in terms of statistical theory, since type II error is minimized, (i.e. accepting the case of a harmonized policy even if it is wrong). Under competitive market conditions, economic theory and practice predicts that discount differences should depend heavily on differences in sales volume between the two companies and economic geography.

However, this correlation is very small (0.10–0.15) for Shell and BP, and companies' discounts per region tend to be more closely related rather than the sales of the two companies. For this reason we estimate the following equation:

$$E_{ji}^{\text{BP}} = a + bE_{ji}^{\text{Shell}} + u_{ji}. \tag{11}$$

More specifically, the correlation of the discounts between the two firms within the Greek regions is high. In other words, the coefficient of determination is high enough ($R^2 = 72\%$) revealing that the level of correlation of the discounts per region is large and has a systematic pattern. On average for the 46 regions, the discount ratio $E_{ji}^{\text{Shell}}/E_{ji}^{\text{BP}}$ is equal to 1.25 (with a standard deviation of 0.12). The level of this magnitude is larger than unity and falls within the discount limits. Alternatively, we can estimate the following regression:

$$(P_{ji}^{\text{Final price Shell}} - P_{ji}^{\text{Final price BP}}) = a + b(E_{ji}^{\text{BP}} - E_{ji}^{\text{Shell}}) + c(Q_{ji}^{\text{Shell}} - Q_{ji}^{\text{BP}}) + e_{ji}, \tag{12}$$

where Q_{ji}^{Shell} and Q_{ji}^{BP} are the sales of the two companies. The regression results for the whole sample regions are given in Table 3.

The results as depicted in Table 3 explicitly show that any turnover differences between the two firms ($Q_{ji}^{\text{Shell}} - Q_{ji}^{\text{BP}}$) do not affect the differences in their final (real) wholesale prices ($P_{ji}^{\text{Final price Shell}} - P_{ji}^{\text{Final price BP}}$).

Table 3. Regression results.

	Magnitude	Standard deviation	t-Statistic $a = 0$, $b = 0$, $c = 0$	$R^2 = 0{,}78$
Intercept (a)	0.0065	0.0011	5.62	
Slope coefficient (b)	0.9086	0.0774	11.73	
Slope coefficient (c)	−2.29E−12	1.74E−11	−0.13	

The slope coefficient of difference c, is not found to be statistically significant, where the coefficient of determination (R^2) is almost the same with the previous regression (78%).

All in all, according to the Decision during the period from 1 January 2003 through 31 December 2003 BP and Shell proceeded in coordinating their discount policies. Specifically the two oil companies offered in such a way the level of their discounts dispersed among the Greek regions in order to fix their final (wholesale) prices. That is to say, if BP applies discount A in prefecture F and Shell applies discount B (of a different amount) in the same prefecture (F), then BP would apply a discount $A + 50\%$ in prefecture G, while Shell would also apply a discount $B + 50\%$ in prefecture G. As mentioned above, the two oil companies harmonized their discount policy across the majority of Greek regions in order to fix the level of their final prices (indirect price fixing). This was achieved by adjusting the level of their discounts (i.e. invoice and quantity rebates) in a systematic way that acted a "focal" point despite the existence of many dissimilarities among them (i.e. cost structure, logistic scheme, number of branded petrol stations, etc.).

The econometric analysis provides strong evidence that there are systematic relationships among the discounts which tend to equalize the final prices of unleaded petrol given that the locally list prices differ substantially. This common discount policy is stable across the regions of Greece and cannot be explained by relevant economic factors (i.e. differences in transportation cost, economic geography, gasoline volume, etc.).

It was surprising the finding that the strongest relationship exists between the invoice discounts which are not transparent to third parties (i.e. other oil companies, petrol retailers of the own or other brand) and must be variable across Greece. In contrast to a competitive pricing policy in which discounts are used in order to enhance the level of local competition between the petrol retailers (intra-brand and inter-brand competition), discounts of the two companies are not systematically correlated with the volume of unleaded petrol. According to the empirical analysis, the only plausible explanation for the systematically and stable relationship between the discounts and final prices of unleaded petrol

across the Greek regions is connected with the existence of a concerted practice carried by the two oil companies.

V. Conclusion

The red line between tacit collusion and parallel behaviour in oligopolistic markets, where in some instances competition is fierce since firms do not face severe capacity constraints (Bertrand model) is often extremely thin. In such cases, where no hard evidence is collected by National Competition Authorities (i.e. cartel agreements), economic analysis enforced by the use of quantitative techniques constitute the most important indicators in examining an antitrust case.

In order to set the boundaries between market competition (oligopolistic parallel behaviour) and anti-competitive behaviour (i.e. tacit collusion), we tried to analyse the tacit collusion mechanism and its facilitating factors either from a theoretical and empirical standpoint. For this reason, we critically present in depth a tacit collusion case examined by the HCC.

As it was presented, the scrutinized decision does not claim that the two companies built up a common policy on discounts based on the average rebate. What the analysis does is to clearly study the data and provide strong evidence that there are systematic relationships among the discounts which tend to equalize the final prices of unleaded petrol given that the locally list prices differ substantially. This common discount policy is stable across the regions of Greece and cannot be explained by relevant economic factors (i.e. differences in transportation cost, economic geography, gasoline volume, etc.).

The concerted practice by the two undertakings refers to the implementation of a common discount ratio policy in order to equalize the level of final (wholesale) petrol prices. The most surprising finding from the relevant estimates was the fact that the invoice discounts of the two undertakings reported a positive and statistically significant correlation despite the fact that this type of rebates is not transparent to the competitors.

In contrast, in a competitive environment, (invoice) discounts must be short-lived and variable across the various regions of the country responding to the local competition. Besides, any variations in wholesale price levels paid by petrol station owners (i.e. branded or unbranded gasoline retailers) must be explained largely by varying volumes purchased and its supplier, the level of volume discounts and the differences in the terms of agreement negotiated between each company and its supplier.

Alternatively, rebates may take the form of lump-sum payments or volume discounts with no direct influence on the marginal benefit of an extra unit of sales by the retailer, and which are less likely therefore to influence the pricing strategy of the retailer. However the above findings which are consistent with a competitive industry (oligopoly a la Bertrand) were not evident to this case.

The econometric results clearly show that the final prices and discounts between the two companies depend systematically on each county and show a very strong correlation, as is the case with a harmonized pricing policy. Although the final prices are based on the nominal values (price list values), the empirical analysis clearly shows that the latter do not define the final prices and are not related to them. The final prices are shaped by discounts. From the two categories of discounts (invoice and report), invoice discounts, which directly shape the final price, are the ones with the highest systematically correlation. It is worth noting that these are not published (they are completely opaque). Unlike a competitive pricing policy, which uses discounts to stimulate local competition, discounts are not systematically associated with sales. Based on the above, the only well-founded explanation for the correspondence between discounts and prices is the existence of a concerted practice between the two oil companies.

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Disclosure statement

No potential conflict of interest was reported by the authors.

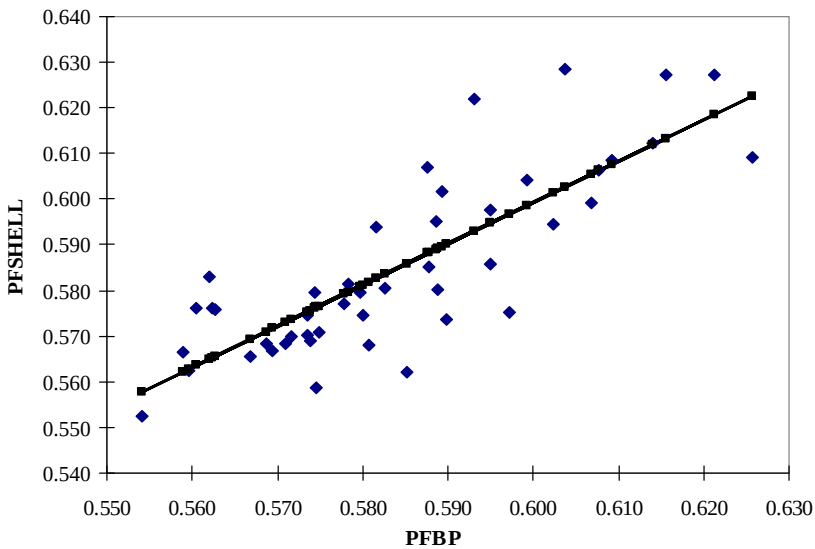
Appendices

Appendix A

$$\bar{P}_j^{\text{Final price Shell}} = a + b\bar{P}_j^{\text{Final price BP}} + e_j. \tag{A1}$$

Dependent variable: PFSHELL				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.055434	0.051890	1.068308	0.2912
PFBP	0.906356	0.089586	10.11719	0.0000
R-squared	0.670335	Mean dependent var.		0.585022
Adjusted *R*-squared	0.662843	SD dependent var.		0.019608
SE of regression	0.011385	Akaike info criterion		−6.070479
Sum squared resid.	0.005704	Schwarz criterion		−5.990973
Log likelihood	141.6210	*F*-statistic		89.46888
Durbin–Watson stat.	2.157906	Prob. (*F*-statistic)		0.000000

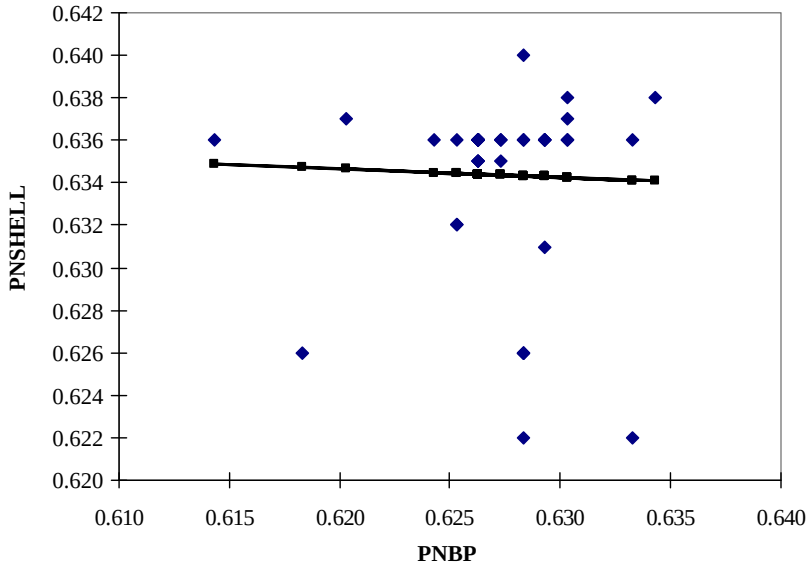
$P_j^{\text{Final price Shell}} = \text{PFSHELL and } P_j^{\text{Final price BP}} = \text{PFBP}.$



$$\bar{P}_j^{\text{Nominal price Shell}} = a + b\bar{P}_j^{\text{Nominal price BP}} + e_j. \qquad (A2)$$

Dependent variable: PNSHELL				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.658980	0.145204	4.538315	0.0000
PNBP	−0.039261	0.231892	−0.169306	0.8663
R-squared	0.001059	Mean dependent var.		0.634370
Adjusted *R*-squared	−0.021644	SD dependent var.		0.004101
SE of regression	0.004145	Akaike info criterion		−8.091388
Sum squared resid.	0.000756	Schwarz criterion		−8.011882
Log likelihood	188.1019	*F*-statistic		0.046649
Durbin–Watson stat.	2.263448	Prob. (*F*-statistic)		0.829998

$\bar{P}_j^{\text{Nominal price Shell}} = \text{PNSHELL}$ and $\bar{P}_j^{\text{Nominal price BP}} = \text{PNBP}$.



$$\bar{E}_j^{\text{Shell}} = a + b\bar{E}_j^{\text{BP}} + v_j. \tag{A3}$$

Dependent variable: RSHELL				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.004180	0.004286	0.975349	0.3347
RBP	1.053073	0.084846	12.41165	0.0000
R-squared	0.726650	Mean dependent var.		0.049348
Adjusted *R*-squared	0.720438	SD dependent var.		0.021184
SE of regression	0.011201	Akaike info criterion		−6.103160
Sum squared resid.	0.005520	Schwarz criterion		−6.023654
Log likelihood	142.3727	*F*-statistic		116.9660
Durbin–Watson stat.	2.137567	Prob. (*F*-statistic)		0.000000

$\bar{E}_j^{\text{Shell}} = \text{RSHELL}$, $\bar{E}_j^{\text{BP}} = \text{RBP}$,

$$\text{Timol}\bar{E}_j^{\text{Shell}} = a + b\text{Timol}\bar{E}_j^{\text{BP}} + v_j. \tag{A3A}$$

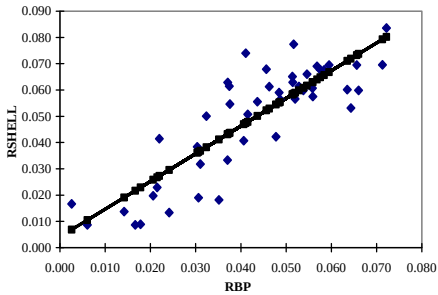
Dependent variable: TIMOLSHELL				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.004814	0.003792	1.269534	0.2109
TIMOLBP	0.995061	0.116782	8.520636	0.0000
R-squared	0.655698	Mean dependent var.		0.037348
Adjusted *R*-squared	0.647873	SD dependent var.		0.019308
SE of regression	0.011458	Akaike info criterion		−6.057823
Sum squared resid.	0.005776	Schwarz criterion		−5.978317
Log likelihood	141.3299	*F*-statistic		83.79470
Durbin–Watson stat.	1.776909	Prob. (*F*-statistic)		0.000000

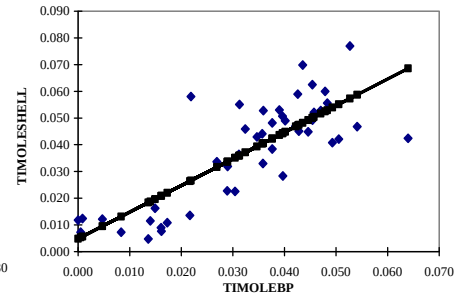
$$Apol\bar{E}_j^{\text{Shell}} = a + bApol\bar{E}_j^{\text{BP}} + v_j \qquad (A3B)$$

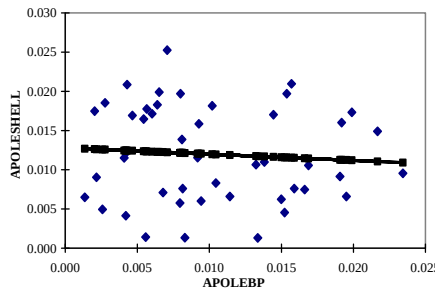
Dependent variable: APOLSHELL				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.012668	0.001807	7.008960	0.0000
APOLBP	−0.065631	0.134216	−0.488998	0.6273
R-squared	0.003996	Mean dependent var.		0.012000
Adjusted *R*-squared	−0.018640	SD dependent var.		0.006161
SE of regression	0.006218	Akaike info criterion		−7.280244
Sum squared resid.	0.001701	Schwarz criterion		−7.200738
Log likelihood	169.4456	*F*-statistic		0.176542
Durbin–Watson stat.	1.738084	Prob. (*F*-statistic)		0.676407

$$Timol\bar{E}_j^{\text{Shell}} = \text{TIMOLSHELL},\ Timol\bar{E}_j^{\text{BP}} = \text{TIMOLBP}$$

$$Apol\bar{E}_j^{Shell} = APOLSHELL,\ Apol\bar{E}_j^{BP} = APOLBP$$







Appendix B

$$(\bar{E}_j^{\text{Shell}} - \bar{E}_j^{\text{BP}}) = a + b(\bar{Q}_j^{\text{Shell}} - \bar{Q}_j^{\text{BP}}) + u_j \qquad (A4A)$$

Dependent variable: RSHELL–RBP
Method: Least squares
Included observations: 46
White heteroskedasticity-consistent standard errors and covariance

Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.006349	0.001729	3.671552	0.0006
QSHELL–QBP	−4.37E−11	5.18E−11	−0.843750	0.4034
R-squared	0.003067	Mean dependent var.		0.006457
Adjusted *R*-squared	−0.019590	SD dependent var.		0.011113
SE of regression	0.011221	Akaike info criterion		−6.099502
Sum squared resid.	0.005540	Schwarz criterion		−6.019996
Log likelihood	142.2886	*F*-statistic		0.135382
Durbin–Watson stat.	2.103565	Prob. (*F*-statistic)		0.714680

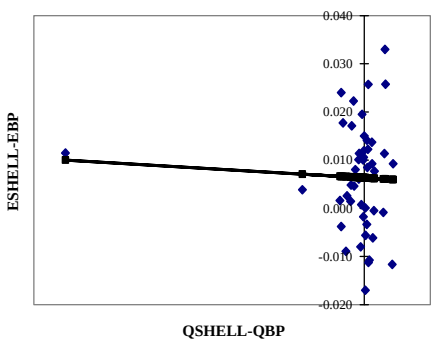
$$\bar{Q}_j^{\text{Shell}} = \text{QSHELL},\ \bar{Q}_j^{\text{BP}} = \text{QBP and } \bar{Q}_j^{\text{Shell}} - \bar{Q}_j^{\text{BP}}) = \text{QSHELL} - \text{QBP}$$

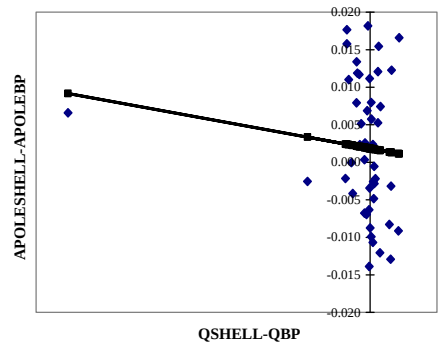
$$(Apol\bar{E}_j^{\text{Shell}} - Apol\bar{E}_j^{\text{BP}}) = a + b(\bar{Q}_j^{\text{Shell}} - \bar{Q}_j^{\text{BP}}) + u_j \qquad (A4B)$$

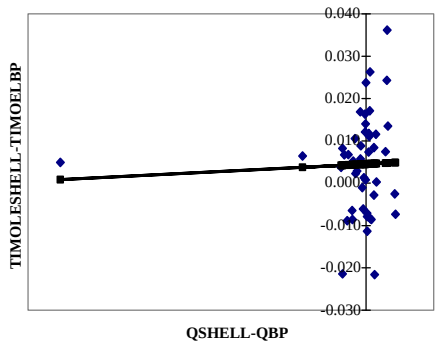
Dependent variable: APOLSHELL–APOLBP				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.001636	0.001360	1.202386	0.2356
QSHELL–QBP	−7.72E−11	4.23E−11	−1.826175	0.0746
R-squared	0.015212	Mean dependent var.		0.001826
Adjusted *R*-squared	−0.007169	SD dependent var.		0.008820
SE of regression	0.008851	Akaike info criterion		−6.573955
Sum squared resid.	0.003447	Schwarz criterion		−6.494449
Log likelihood	153.2010	*F*-statistic		0.679671
Durbin–Watson stat.	1.738129	Prob. (*F*-statistic)		0.414147

$$(Timol\bar{E}_j^{\text{Shell}} - Timol\bar{E}_j^{\text{BP}}) = a + b(\bar{Q}_j^{\text{Shell}} - \bar{Q}_j^{\text{BP}}) + u_j \qquad (A4C)$$

Dependent variable: TIMOLSHELL–TIMOLBP				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.004730	0.001779	2.658549	0.0109
QSHELL–QBP	3.16E−11	5.84E−11	0.541926	0.5906
R-squared	0.001548	Mean dependent var.		0.004652
Adjusted *R*-squared	−0.021144	SD dependent var.		0.011330
SE of regression	0.011449	Akaike info criterion		−6.059325
Sum squared resid.	0.005767	Schwarz criterion		−5.979819
Log likelihood	141.3645	*F*-statistic		0.068211
Durbin–Watson stat.	1.795692	Prob. (*F*-statistic)		0.795178







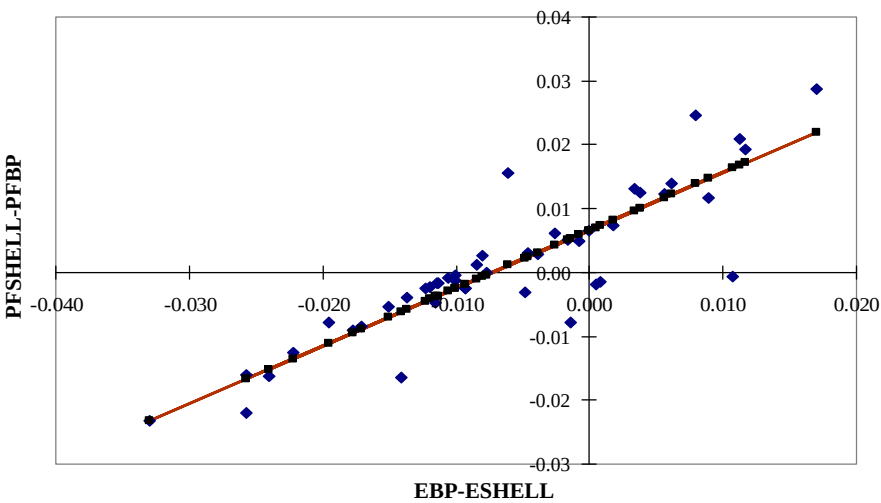
$$(P_j^{\text{Final price Shell}} - P_j^{\text{Final price BP}}) = a + b(E_j^{\text{BP}} - E_j^{\text{Shell}}) + e_j \qquad (A5A)$$

Dependent variable: PFSHELL–PFBP				
Method: Least squares				
Included observations: 46				
White heteroskedasticity-consistent standard errors and covariance				
Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.006583	0.001140	5.772567	0.0000
RBP–RSHELL	0.908528	0.076810	11.82828	0.0000
R-squared	0.787191	Mean dependent var.		0.000717
Adjusted *R*-squared	0.782354	SD dependent var.		0.011380
SE of regression	0.005309	Akaike info criterion		−7.596364
Sum squared resid.	0.001240	Schwarz criterion		−7.516858
Log likelihood	176.7164	*F*-statistic		162.7579
Durbin–Watson stat	2.455328	Prob. (*F*-statistic)		0.000000

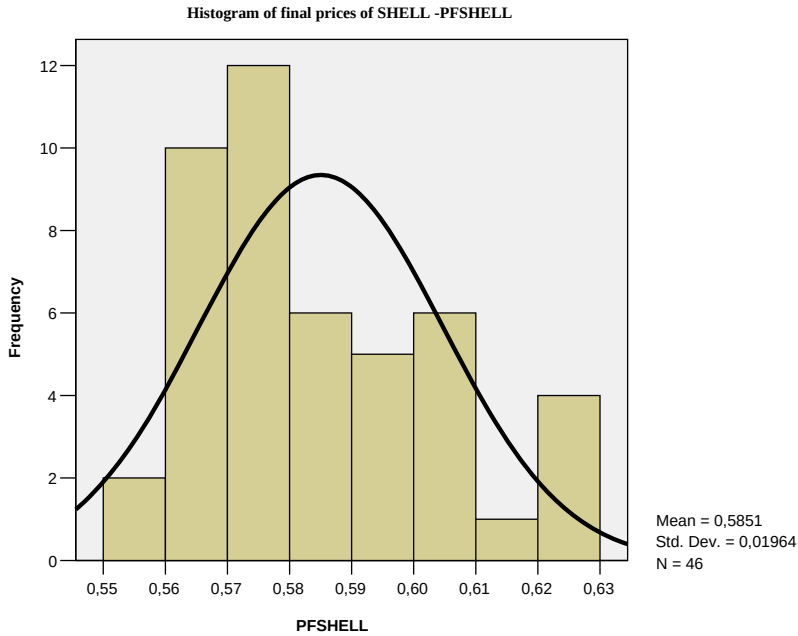
$$(P_j^{\text{Final price Shell}} - P_j^{\text{Final price BP}}) = a + b(E_j^{\text{BP}} - E_j^{\text{Shell}}) + c(Q_j^{\text{Shell}} - Q_j^{\text{BP}}) + e_j \quad (A5B)$$

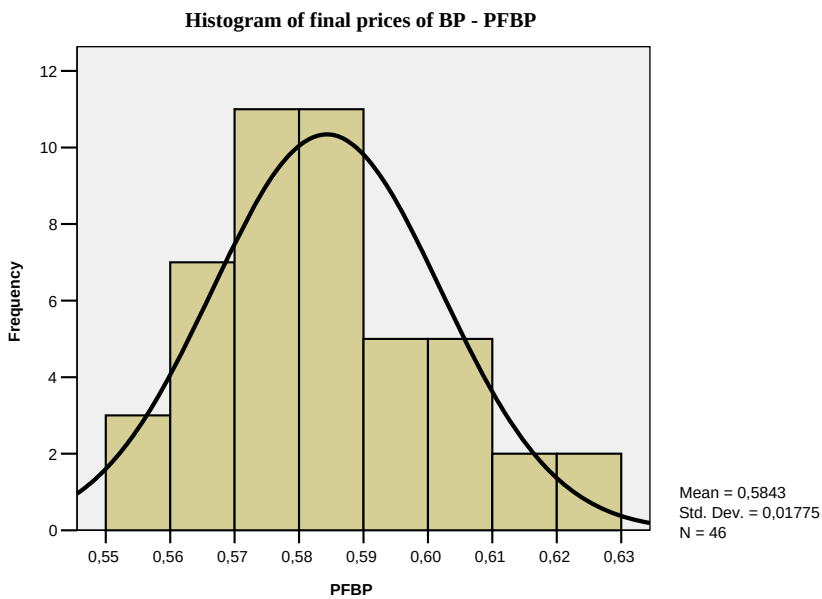
Dependent variable: PFSHELL–PFBP
Method: Least squares
Included observations: 46
White heteroskedasticity-consistent standard errors and covariance

Variable	Coefficient	Std. error	*t*-Statistic	Prob.
C	0.006579	0.001169	5.629217	0.0000
RBP–RSHELL	0.908688	0.077443	11.73360	0.0000
QSHELL–QBP	−2.29E−12	1.74E−11	−0.131080	0.8963
R-squared	0.787199	Mean dependent var.		0.000717
Adjusted *R*-squared	0.777301	SD dependent var.		0.011380
SE of regression	0.005370	Akaike info criterion		−7.552923
Sum squared resid.	0.001240	Schwarz criterion		−7.433664
Log likelihood	176.7172	*F*-statistic		79.53321
Durbin-Watson stat.	2.453556	Prob. (*F*-statistic)		0.000000

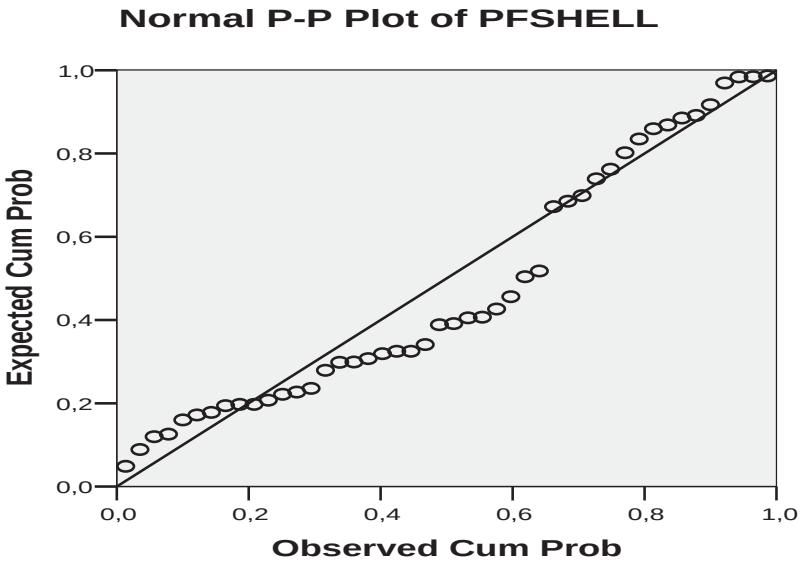


Appendix C


Histogram of final prices of SHELL -PFSHELL
Frequency
12
10
8
6
4
2
0
0,55
0,56
0,57
0,58
0,59
0,60
0,61
0,62
0,63
PFSHELL
Mean = 0,5851
Std. Dev. = 0,01964
N = 46


Histogram of final prices of BP - PFBP
Frequency
12
10
8
6
4
2
0
0,55
0,56
0,57
0,58
0,59
0,60
0,61
0,62
0,63
PFBP
Mean = 0,5843
Std. Dev. = 0,01775
N = 46

Cumulative distribution of PFSHELL



Cumulative distribution of PFBP

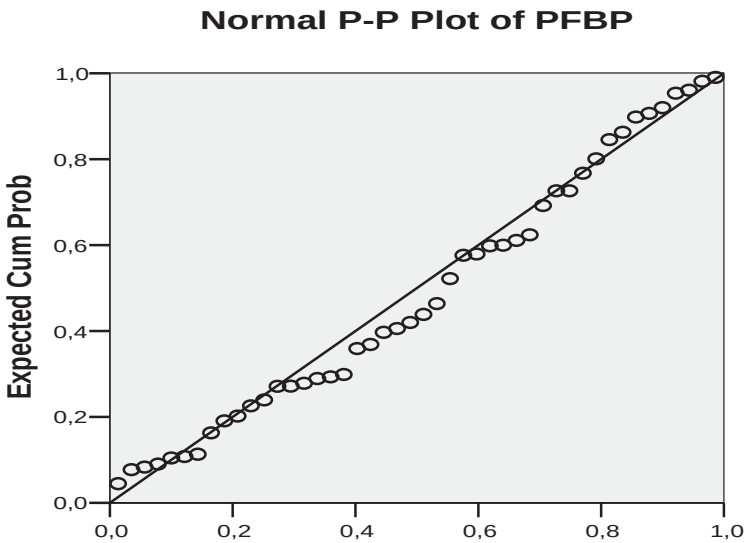


Table C1. Kolmogorov–Smirnov test for the final prices of Shell and BP.

		PFSHELL	PFBP
N		46	46
Normal parameters	Mean	0.5851	0.5843
	Std. deviation	0.01964	0.01775
Kolmogorov–Smirnov *Z*		1.089	0.628
Asymp. sig. (2-tailed)*		[0.186]	[0.825]

* The number in brackets represents *P*-values. The null hypothesis denotes normal distribution.