Competition and Pass-Through: Evidence from the Greek Islands[1]

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Abstract

We measure how pass-through varies with competition in isolated oligopolistic markets. Using daily pricing data from gas stations, we study how unexpected and exogenous changes in excise duties (different across different petroleum products) is passed-through to retail prices on islands with different number of sellers. We find that pass-through increases from about 0.44 in monopoly markets to about 1 in markets with four or more competitors and remains constant thereafter. Moreover, the speed of price adjustment is about 60 percent higher in more competitive markets. Finally, we show that geographic market definitions based on arbitrary measures of distance across sellers, often used by researchers and policy makers, result in significantly overestimating the pass-through when there is a small number of competitors.

JEL: H22, L1

Keywords: Pass-through; Tax incidence; Gasoline; Market structure; Competition

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1. Introduction

A fundamental issue in economics is how firms pass cost shocks (taxes, exchange rates, input prices) through to prices. The incidence and pass-through of taxation are classic public policy issues (Fullerton and Metcalf, 2002). The pass-through of exchange rates and tariffs is important for its effects on firm productivity and international trade (De Loecker and Koujianou-Goldberg, 2014). Moreover, the pass-through of input prices is relevant in the analysis of oligopolistic markets, price discrimination (Aguirre, Cowan, and Vickers 2010), and merger analysis (Jaffe and Weil, 2013). Finally, the cost pass-through is also important for the policy debate in many industries, for example in the health (Cabral, Geruso, and Mahoney, 2015) and energy sectors (Fabra and Reguant, 2014).

Theoretical analysis shows that competition is a key determinant of pass-through (Weyl and Fabinger, 2013). With regard to the empirical analysis, there is a well-established line of research exploiting variability in costs to infer the magnitude of the pass-through.[4] In empirical studies, competition is generally measured by the number of competitors located within a given geographical area around each firm. Variability in the number of close competitors captures some important aspects of competition, but does not guarantee that there are no significant substitution effects beyond the selected geographical area (for example, some consumers may commute across geographical markets for work or family reasons, hence generating substitution effects across geographically distant markets). While market structure is recognized to be an endogenous outcome, this type of market definitions provide little in the way of an explanation for why some firms face more competition than others.

[4] Such variability may come from changes in sales taxes (Barzel 1976, Poterba 1996, Besley and Rosen 1998, Marion and Muehlegger 2011), exchange rate fluctuations (Campa and Goldberg 2005, Gopinath, Gourinchas, Hsieh, and Li 2011), or changes input prices (Borenstein, Cameron, and Gilbert 1997, Genesove and Mullin 1998, Nakamura and Zerom 2010, Miller, Osborne, Sheu 2017).

Following the literature started by Bresnahan and Reiss (1991), we measure how pass-through varies with competition in isolated oligopolistic markets of different size. Our data come from the retail market for petroleum products (gasoline, unleaded gasoline, diesel, heating diesel) on small Greek islands. Greece is characterized by a large number of small islands. Some of these islands are so small as to support only one gas station, while others support two, three, or more. The naturally occurring variability in the size of the island provides an exogenous source of variability in the level of competition. Islands clearly define local markets, as substitution effects across islands are zero.[5]

We take advantage of this unique setting and a significant policy change, whereby the Greek government – in the middle of a financial crisis - altered the excise duty for petroleum products three times during 2010. These changes were large and unexpected, providing an ideal exogenous shock to estimate the pass-through to retail prices. For political reasons, the Greek government completely excluded heating diesel from these changes, as it was considered a necessity good.

Using daily gas station data, we study how the pass-through of the excise duty tax varied across markets with a different number of competitors, while using heating diesel as a control group. Thus, we can account for unobserved heterogeneity across islands and gas stations, and control for the daily aggregate price fluctuations of petroleum products. We find four main results. First, pass-through significantly increases with the number of competitors. Moreover, the relation between competition and pass-through is nonlinear. On average, a 10c increase in excise duties implies a 4.4c increase in prices in monopolistic islands. The pass-through increases up to islands with 4 competitors, where the pass-through is about 1. We do not detect any effect of increases in competition on pass-through beyond markets with 4 competitors. Second, the response to cost

[5] Refueling a car by travelling to a different island is prohibitively expensive, and privately importing fuel in tanks or similar containers is dangerous and illegal.

shocks is fast and occurs within a 10 day period. Third, we find that the speed of price adjustments is much higher in more competitive markets. Ten days after an excise duty change, we still find that the cost pass-through is about 60 percent higher in more competitive (4-7 competitors) than in less competitive markets (1-3 competitors). Fourth, we find that using geographical market definitions based on distance across sellers (instead of the island market definition) leads to an overestimation of pass-through in highly concentrated markets.

Our results contribute to the literature on the transmission of cost shocks to prices, which has the ultimate objective of understanding the strength of nominal rigidities and the impact of fiscal, monetary, and exchange rate policy. Existing evidence on the impact of competition on pass-through is scarce. Miller et al. (2016) find that increasing competition reduces pass-through in a market in which the pass-through is above unity (more generally pass-through has been found to be incomplete), but they do not explore its potentially nonlinear effects. Cabral, Geruso and Mahoney (2018) study the pass-through of government subsidies to premiums of Medicare Advantage plans and find evidence of larger pass-through in more competitive markets, with pass-through estimates ranging between 13% and 74%. Alm, Sennoga and Skidmore (2009) find a somewhat lower pass-through in rural than in urban gasoline markets, which might be related to the different competitive environments.

Our quick estimated response to cost shocks is in line with the results of Bonadio, Fisher, and Sauré (2016), who show a two-week adjustment period after a large exchange rate shock. Our results imply a positive correlation between speed of adjustment and pass-through across markets with different levels of competition (Gopinath and Itskhoki, 2010). Our results are also related to the literature on the nonlinear effects of competition on firm behavior (Bresnahan and Reiss, 1991) by showing that pass-through quickly converges to competitive levels as the number of competitors grows. Finally, our results contribute to the empirical literature on the estimation of cost pass-through and the analysis of competition in geographical markets (Houde, 2012).

2. Theoretical background

Economic theory provides some general results on how competition and other variables interact in determining the level of pass-through. Following the conduct parameter approach of Genesove and Mullin (1998), Weyl and Fabinger (2013) obtain an equation for the pass-through in oligopolistic markets with n symmetrically differentiated firms. Denoting by $\epsilon_D = -\frac{p}{qp'}$ the elasticity of demand, they describe the solution to the firm maximization problem by a conduct parameter $\frac{p-mc(q)}{p}\epsilon_D = \theta$, where $mc(q)$ is the marginal cost. θ captures the intensity of the competition among firms ($\theta = 0$ in a competitive market and $\theta = 1$ in a monopolistic market). Independently of the specific model considered, the impact of an increase in marginal cost (i.e., the pass-through) on the equilibrium price is

$$\rho = \frac{1}{1+\frac{\theta}{\epsilon_\theta}+\frac{\epsilon_D-\theta}{\epsilon_S}+\frac{\theta}{\epsilon_{ms}}}. \quad (1)$$

The pass-through ρ depends on the conduct parameter θ and how it varies as the quantity produced changes ($\epsilon_\theta = \frac{\theta}{q\frac{d\theta}{dq}}$), but also on the determinants of the elasticity of demand ϵ_D, the elasticity of the inverse marginal cost curve ϵ_S (the elasticity of supply), and the curvature of the demand function ϵ_{ms}.[6] In general, the sign and magnitude of the pass-through is ambiguous. Also

[6] $\epsilon_{ms} = \frac{ms}{ms'q}$, where ms is the negative of the marginal consumer surplus ($ms = -p'q$). ϵ_{ms} measures the curvature of the log of demand (Fabinger and Weyl 2012). If demand is linear then $\epsilon_{ms} = 1$, if concave $\epsilon_{ms} < 1$, if convex $\epsilon_{ms} > 1$ (and the opposite is also true).

the sign and magnitude of the effect of an increase in the conduct parameter on the pass-through is ambiguous.

The expression for ρ greatly simplifies in some special cases, which highlight the role of the different elements in the denominator of equation (1). The ratio $\frac{\epsilon_D-\theta}{\epsilon_S}$ links demand heterogeneity and pass-through.[7] This ratio is equal to zero if the marginal cost is constant. As we will argue in Section 3, there is direct evidence in our data that marginal cost is constant at the firm level, at least in the short run, and for the range of quantities typically sold by gas stations in our sample. This suggests that demand heterogeneity is unlikely to play a big role in our application.

A second interesting special case is when θ is constant. If θ is constant, then the term $\frac{\theta}{\epsilon_\theta}$ is also equal to 0. The conduct parameter θ is a constant in a number of prominent models. For example, theta is equal to 1 in monopoly, equal to 0 in perfect competition and in the Bertrand model, equal to $\frac{1}{n}$ in the Cournot model.[8] Price competition with symmetrically differentiated products implies that $\theta = 1 - A$, where $A \equiv -\sum_{j\neq i}\frac{\partial q_j}{\partial p_i}/\frac{\partial q_i}{\partial p_i}$ is the aggregate diversion ratio, which is a constant if the demand is linear in prices. The conduct parameter is assumed to be a constant in most empirical applications based on the conduct parameter approach.

Finally, an important determinant of the pass-through is the demand curvature ϵ_{ms}. Most empirical studies are based on linear demand specifications, which directly imply that $\epsilon_{ms} = 1$. A few studies assume different demand specifications that imply different curvature, but there is little

[7] Note that if $\theta = 0$, then $\rho = \frac{1}{1+(\epsilon_D/\epsilon_S)}$, which is the classic formula for tax pass-through in perfect competition.
[8] The relation between the conduct parameter and the number of firms n illustrates the sense in which an increase in the number of firms leads to more competition. In empirical papers, which typically deal with specific industries, the number of firms is often used as a proxy for the intensity of competition.

empirical evidence on the sign and magnitude of ϵ_{ms}. Hence, it is difficult to put a priori restrictions on its sign and magnitude.

If the marginal cost were constant, θ were constant, and demand were linear, then $\rho = \frac{1}{1+\theta}$ and an increase in the conduct parameter would lead to lower pass-through. This is an interesting benchmark but is not a general theoretical prediction to be taken to the data. In fact, the first assumption is met in a number of industries and is realistic in our application. The second is often considered a reasonable simplification in empirical studies, not putting restrictions on the intensity of competition. However, the third is difficult to justify without specific evidence on the second derivative of the demand function. Hence, the impact of an increase in the conduct parameter on pass-through remains largely an empirical issue.

3. Industry background and data

Oil is the main energy source in Greece. In 2010 it accounted for 52% of the country's total primary energy supply, which is substantially higher than the average in most other advanced countries (36% in 2010).[9] Two companies operate in the Greek refining industry: Hellenic Petroleum has three refineries, while Motor Oil Hellas has one. Hellenic Petroleum controls 72% of the wholesale market.[10] There are ten oil terminals in Greece, seven of them are located in the Attica area (Athens) and three in the Salonica area (north). In 2010, there were 20 fuel trade companies operating in the retail market, the largest of which were EKO (a subsidiary of Hellenic Petroleum), Shell, BP, Avin Oil (100% subsidiary of Motor Oil), and Jet Oil.

[9] International Energy Agency, Energy Policies of IEA Countries, 2011 review.
[10] The Greek government owns 35.5% of Hellenic Petroleum, but no shares in Motor Oil Hellas.

In general, the unit price does not depend on the variability in sales at the individual gas station level. The marginal cost of petroleum products depends on long term contract between gas stations and trade companies. Within the observed range of quantities sold, the marginal cost of gas stations is reasonably constant. EU member states are obliged to impose a minimum set of energy taxes, but each member state has significant freedom in setting tax rates.[11] There are two main taxes that are imposed on energy products: excise duties, which is a unit tax rate (€-cents per liter), and the Value Added Tax (VAT), which is a percentage tax. In this paper, we only focus on changes in excise duties.[12]

In 2010 the inability of the Greek government to borrow new funds from the international markets, led to financial support from euro area Member States and the International Monetary Fund. One of the first measures of the Greek government to increase tax revenues was to increase excise duties on fuel. Excise duties on fuel were raised three times during 2010. Each of these three tax changes was announced and implemented the day after, as is typically the case in order to reduce any arbitrage opportunities. Table 1 shows that the increase was very different across products. Remarkably, excise duties remained unchanged for heating gasoline.[13]

3.1. Data and measurement of competition

We combined a number of datasets for our analysis. First, we obtained daily station-level retail prices during 2010. The data on prices was officially collected by the Ministry of Development and Competitiveness through a reporting system, which required managers of each petrol station

[11] EU guideline 2003/96/EU.
[12] The retail price is determined as $P_{retail} = (P_{refinery} + taxes\&fees + margins)(1 + VAT)$.
[13] Heating diesel is chemically identical to diesel (but colored differently) and it is sold by the same gasoline stations throughout the country. A lower excise duty applies as it is considered a necessity, since the vast majority of households use heating diesel instead of gas or electricity during the winter months.

to record retail prices on a daily basis (e-prices.gr). The purpose of this is to ease comparisons and reduce search costs for consumers. The data contains information on five different gasoline products: unleaded 95, unleaded 100, super (or leaded gasoline), diesel, and heating diesel. Second, we obtained socioeconomic (e.g., education, income, number of tourist arrivals) and geographic (size, distance from Piraeus[14], distance from mainland, number of ports and airports etc.) characteristics of each island from the Hellenic Statistical Authority (www.statistics.gr). Third, using company reports and Google Maps, we geo-located each gas station. Table 2 reports summary statistics. We measure competition using the number of stations on each island.[15] The logic behind this is that the number of competitors on a given island is the result of an entry game. In equilibrium, larger islands can sustain more competitors, each of them enjoying smaller markups (Bresnahan and Reiss, 1991).

We focus on small islands, with fewer than 8 stations. This is for two main reasons. First, small islands are little inhabited and physically small. The median island in our sample has about 2,500 inhabitants, and it is just 86 Km^2 (Table 2). Hence, consumers can reasonably have close to perfect information about each station' prices and can reach them quite easily. Second, Bresnahan and Reiss (1991) find that competitive conduct changes quickly as the number incumbents increases. They find most variation in conduct happens with the entry of the second or third firm. Hence, selecting islands with less than 8 firms provides a sufficiently large range to capture the main effects of competition.

[14] The primary distribution centre for gasoline products in Greece

[15] We also obtained independent information on the number of gas stations on each island from Yellow Pages data, which covers all stations in every island. Industry reports and Yellow Pages data for different years show that entry and exit was essentially zero in this period. Using data on number of reporting stations or a different period does not affect the results.

Different measures of competition are possible for islands with more than one gas station. Having geo-located each station, we also compute measures of competition based on the number of competitors within a 3 Km driving distance from each station, 3 Km radius, or alternatively 5 minute driving time. These are conventional methods of measuring competition when there is no natural boundary across markets. In Section 6.4, we compare the results obtained using these alternative measures.

4. Preliminary evidence

Islands vary in size and number of gas stations. Figure 2 shows that the larger the island, either in terms of size (Km^2) or population, – the larger the number of stations. On average, monopolies have about 1,100 inhabitants, while islands with 7 stations have about 9,800 (Figure 2). In terms of physical size, monopolies are on average 54 Km^2, while islands with 7 stations are about 110 Km^2. Prices significantly vary across islands. For example, Figure 3 describes the distribution of the average price for diesel and heating diesel across islands.[16] On average, prices tend to fall as the number of competitors increases. Taken together, Figures 2 and 3 show that larger islands tend to support more competitive markets, which lead to lower prices.

5. Identification and empirical methodology

We use a difference in difference approach and we start by estimating the following model:

$$P_{kist} = \beta_0 + \rho Tax_{kt} + \beta_{ks} + \beta_t + e_{kist} \quad (1)$$

$\{\tau - 1, \tau + \delta\}$, where τ is the date of each of the three excise duty changes and $\delta = 1, \ldots, 10$ is the length of the adjustment period considered. Tax_{kt} is the excise duty, and the coefficient

[16] The range of prices in Figure 3 is about 0.15€ for both diesel and heating diesel.

ρ captures the tax pass-through. Finally, the model includes product-gas station and day fixed effects. We then focus on the interaction between taxes and competition and estimate the model:

$$P_{kist} = \beta_0 + \rho(n_i, Z_i)Tax_{kt} + \beta_{ks} + \beta_t + e_{kist} \quad (2)$$

where the pass-through $\rho(n_i, Z_i)$ is a linear function $\rho(n_i, Z_i) = \rho_0 + \rho_1 n_i + \rho_2 Z_i$ of the number of competitors n_i and other island specific characteristics Z_i. Alternatively, the relation between pass-through ρ and number of stations j can be non-parametrically estimated replacing $\rho(n_i) = \sum_j \rho_j I(n_i = j)$, where I is an indicator variable for each observed number of gas stations.

The identifying assumption is $E(e_{kist}|X) = 0$, where X is the matrix of all covariates. This OLS condition is reasonably met in our difference in difference framework. In fact, the tax change was not anticipated and the price of the different petroleum products tended to follow the same trend before the policy changes (Figure 4). In summary, the differential changes in excise duties across products (Table 1) provide identification of the tax pass-through, while fixed effects capture island- and station-specific characteristics as well as macroeconomic shock that affect the whole economy, while the control group accounts for aggregate changes in the prices of petroleum products. Although variables in Z capture the potential effect of other observed island characteristics on pass-through, in Section 6.2 we will also report IV estimates of model (2), where exogenous variability in market size is used to estimate the impact of the number of competitors on pass-through. Following the literature on equilibrium entry in oligopoly markets (Bresnahan and Reiss 1991; Berry, 1992; Mazzeo, 2002; Toivanen and Waterson, 2005), the rationale for the IV approach is that market size is a crucial determinant of entry and competition, while it is arguably uncorrelated with unobservable determinants of the pass-through. Hence, the IV approach assumes that market size can be excluded from Z, while being correlated with measures of competition. This second assumption can be tested and it is verified in our data.

6. Empirical results

6.1. The estimated pass-through

Figure 5 shows the difference between the average price of diesel and heating diesel around the three changes in excise duties. The solid lines represent linear regressions separately estimated before and after the tax change. Similar results are obtained for the other products (see Figure A1 in the appendix). There is a significant jump corresponding to the event date. Moreover, prices tend to increase during the days following the tax changes as stations adjust their prices infrequently. On average, 59 percent of product-station specific prices are adjusted within three days, 88 percent within 7 days, 94 percent within 10 days from the tax change.

The average pass-through at a given date depends on two margins. The extensive margin is the number of station having adjusted their price by a given date. The intensive margin is the size of the price increase for stations actually changing their prices. Accordingly, we can use equations (1) and (2) to estimate the "average" pass-through or the "conditional" pass-through, using respectively all the data or only the data for firms that have changed their prices by a given date. For long enough adjustment periods the two definitions coincide as all stations have adjusted their prices. However, for shorter adjustment periods, the two definitions might substantially differ. We start by reporting results for the conditional pass through for a 10 day adjustment period[17] and, in Section 6.3, we will compare conditional and average pass through for shorter adjustment periods.

Table 3 reports the estimated coefficients of model (1). In column 1-3, we consider each policy change separately, in column 4 we pool all the data. The pass-through is about 0.77, with a standard

[17] The 10-day window was chosen so that it is close enough to the event of excise duty change and at the same time long enough so that even remote islands are refilled. Refilling is done by ships that leave from Piraeus (the main port near Athens) and follow a predetermined route across the Aegean sea. This process is independent of the excise duty changes and it is not related to the size of the island (or other observable characteristics) but to the geographical dispersion of islands in the Aegean sea.

error of 0.07. This pass-through is slightly smaller than the unit pass-through estimated by Marion and Muehlegger (2011), Chouinard and Perloff (2007), Doyle and Samphantharak (2008), Alm et al. (2009) for US state taxes on petroleum products and by Poterba (1996) for sales taxes on clothing.

6.2. Pass-through and competition

Table 4, column 1 reports the results of model (2) allowing for the interaction between tax changes and number of competitors. In column 2, we add controls for the interaction of excise duty changes and island characteristics such as income, education, number of ports and airports, distance from Piraeus and number of tourist arrivals. The pass-through significantly increases with competition. Column 4 shows that the relation between competition and pass-through is concave. This result is robust controlling for interactions of excise duty changes and covariates (column 5). Table 4, columns 3 and 6 report the IV estimates, where the instruments are the size of each island (measured by population) and its square. First stage results are highly significant, showing a strong correlation between market size and number of competitors. Overall, the impact of competition on pass-through is positive and decreasing as the number of competitors grows.

The non-linear relation between competition and pass-through is more clearly described in Figure 6, which shows the results of a non-parametric specification (reported in Table 5, column 1). The pass-through is about 44% in monopoly islands and increases up to 100% in islands with four competitors. The relation between pass-through and number of competitors is flat thereafter. The quick convergence to a unit pass-through is in line with the results of Bresnahan and Reiss (1991) that show that entry thresholds converge quite fast, in other words, once we get to three or four firms, an additional entrant does not much affect competition.

Note that the estimated pass-through for monopoly islands is not significantly different from the 50% pass-through predicted by a monopoly model with linear demand.[18] Moreover, if demand were linear also in markets with more than one firm, then the conduct parameter θ that measures the intensity of competition could be recovered from the estimated pass-through for different market configurations, since $\theta = \frac{1-\rho}{\rho}$. Figure 7 shows the implied θ as the number of competitors increase. It sharply decreases (faster than in the Cournot model) as the number of competitors increase and it converges to zero at about four competitors.

6.3. Pass-through and speed of adjustment

Results in Tables 3 and 4 are obtained with a 10 day adjustment period. Table 6, column 1 reports the estimated average pass-through for different day windows. Shorter adjustment periods imply a lower average pass-through, as stations progressively adjust their prices. Figure 7 shows that the average pass-through converges to the conditional pass-through. The conditional pass-through does not significantly depend on the length of the adjustment period (Table 6, column 2). The speed of convergence of the average and the conditional pass-through is in line with the relatively fast exchange rate pass-through measured by Bonadio, Fischer and Sauré (2016). Still, the speed of adjustment in our data is slower than that observed in other studies on the gasoline market (for example, Knittel, Meiselman, and Stock, 2016, or Doyle and Samphantharak, 2008). This can be partly explained by some specificities of our sample. In particular, the average pass-through in our sample can be affected by the delays in refilling gas stations on relatively remote islands.[19]

[18] The pass-through estimated for monopoly islands can be used to test the null of linear demand. In fact, in monopoly markets, $\rho = 1/(1 + \frac{1}{\varepsilon_{ms}})$, where $\varepsilon_{ms} = 1$ for linear demand.

[19] Using a probit model, we find that the probability of a price change is not systematically related to any island characteristic such as size, population, distance from Piraeus etc.

Does the speed of adjustment depend on competition? This is an important question as it relates to understanding how quickly prices adjust to cost shocks in the economy. In imperfectly competitive markets, we cannot expect an equal speed of adjustment in markets with different level of competition (Gopinath and Itskhoki, 2010). We split islands into two groups. We group as "Low competition intensity" islands with 1 to 3 competitors and "High competition intensity" those with 4 competitors or more. Table 7 and Figure 9 report the average and the conditional pass-through for the two groups for different adjustment periods. The average pass-through is significantly higher for islands with more competitors. At $t + 1$, the pass-through in more competitive markets is about 0.16 higher (about double) than in less competitive markets. At $t + 10$, the pass-through in more competitive markets is about 0.3 (or 60 percent) higher. The conditional pass-through is stable over time and significantly larger in more competitive markets. Finally, Figure A3 in the appendix describes the cumulative frequency of price changes for the two groups. Stations in the two groups do not show large differences in the timing of price changes. Overall, more competitive markets adjust faster to cost shocks because price adjustments are larger, rather than more frequent.

6.4. Alternative market definitions

Without a clear definition of market boundaries or detailed traffic data (Houde, 2012), the literature has typically defined markets based on distance across gas stations (Shepard, 1991; Barron, Taylor, and Umbeck, 2004; Eckert and West 2005; Hosken, McMillan and Taylor, 2008). For each station, we followed standard market definitions and computed for each station the number of competitors within a 3-kilometer radius, 3 and 5-kilometer driving distance, and 10-minute drive (using Google maps). While these three procedures do not obviously affect monopoly islands, they may reduce the number of competitors for stations on larger islands. We then estimate the pass-through using model (2) and the new market definitions. Table 5, columns 2-4 report the estimated coefficients and Figure 10 show the estimated relation between pass-through and number of competitors. Overall, monopolies, duopolies, and triopolies according to the new definitions show a significantly higher pass-through than those previously estimated (also reported in the blue line in Figure 10 for comparison). For example, the 3Km driving distance definition implies that the pass-through is 70, 64, and 36 percent higher for markets with one, two, and three firms respectively. The most likely explanation for this overestimation is the existence of substitution effects across sellers at the boundary of the market. This bias seems to become negligible in markets with at least four sellers. Similar results are obtained with the other market definitions.

7. Concluding Remarks

The paper provides new empirical evidence on the effects of competition on pass-through in oligopolistic markets with few firms. We contribute to the growing literature on pass-through by showing that pass-through increases with competition in a nonlinear fashion, going from 0.44 for monopoly markets to about 1 for markets with four competitors or more. Moreover, the speed of price adjustment is much faster in more competitive markets. We also find that conventional definitions of markets, based on distance between sellers, imply overestimating the pass-through for markets with up to four competitors. Since these definitions are often used in policy analysis, care should be taken when studying oligopolistic markets.

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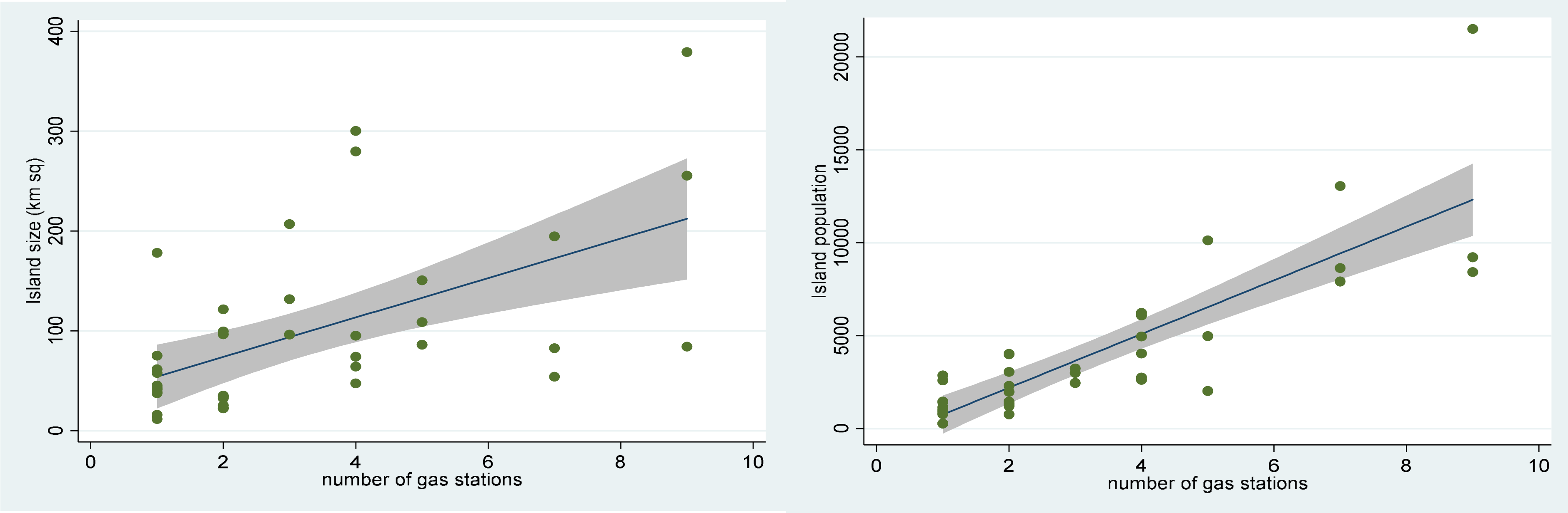
FIGURE 1: GREEK ISLANDS

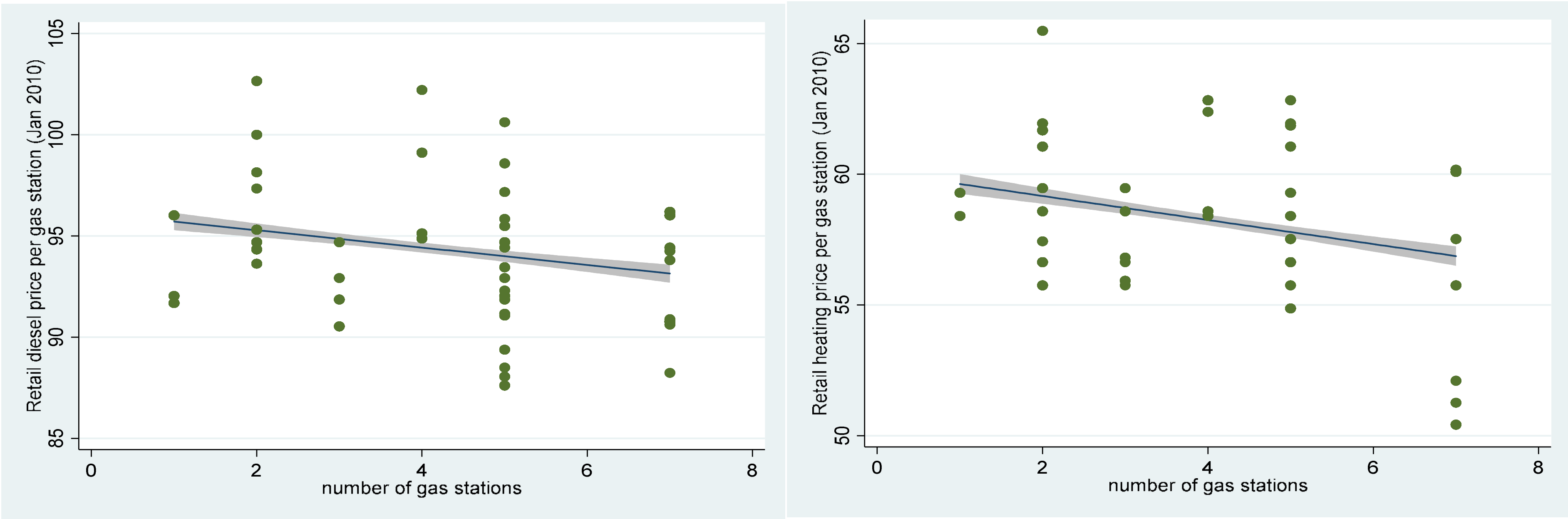
Notes: The main figure shows the map of Greece, with the two smaller figures showing more detail maps of Cyclades and Dodecanese islands.

FIGURE 2: COMPETITION AND MARKET SIZE



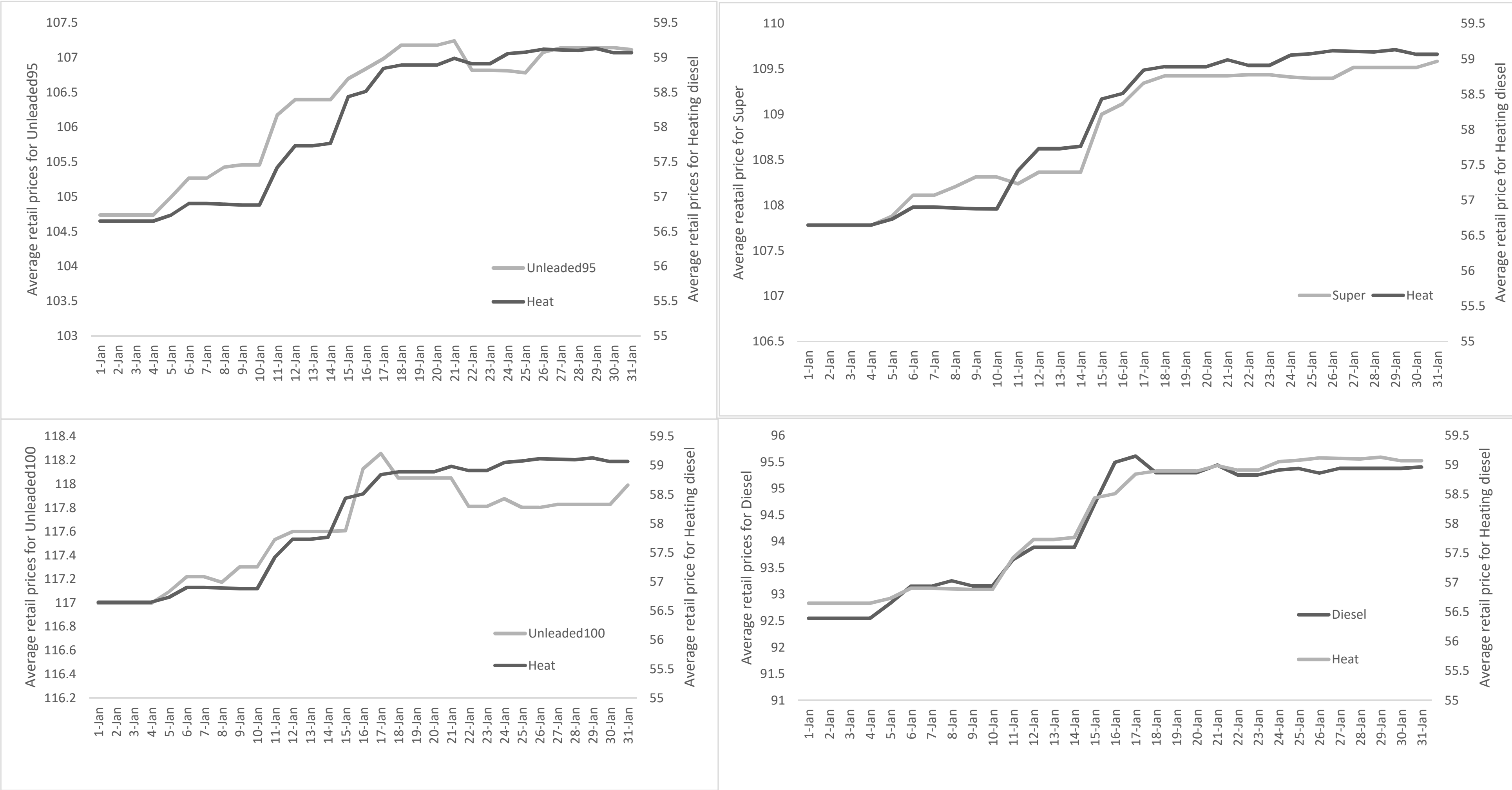
Notes: The figure on the left plots the number of gas stations and island size (measured in squared km), whereas the figure on the right plots the number of gas stations and island population.
Source: Authors' calculations based on data from the Greek Ministry of Development and the Hellenic Statistical Authority.

FIGURE 3: COMPETITION AND PRICES



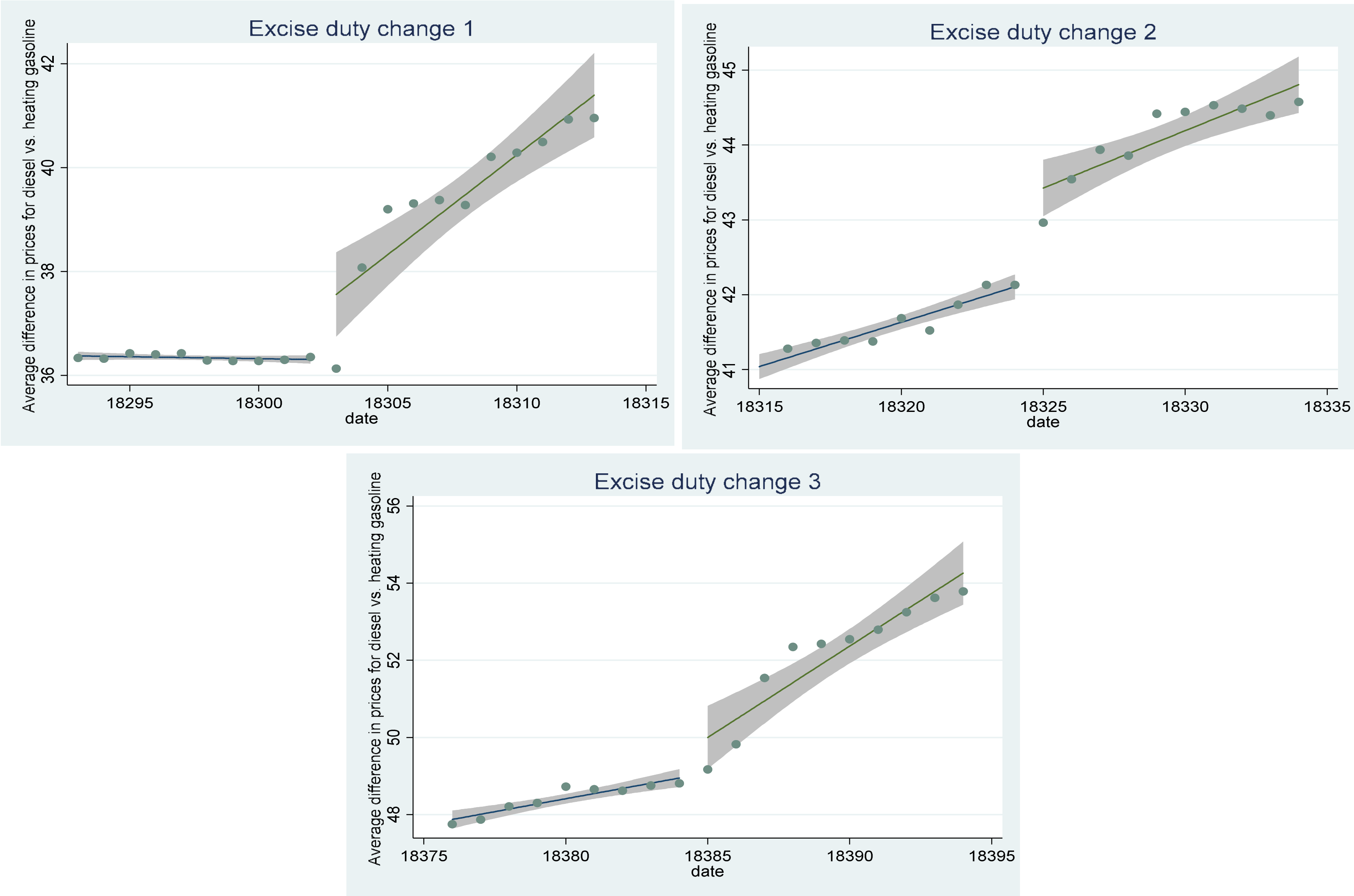
Notes: The figure on the left plots the retail diesel price per gas station, whereas the figure on the right plots the retail heating gasoline price per gas station across different islands for January 2010.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 4: PARALLEL TRENDS OF DIFFERENT GASOLINE PRODUCTS



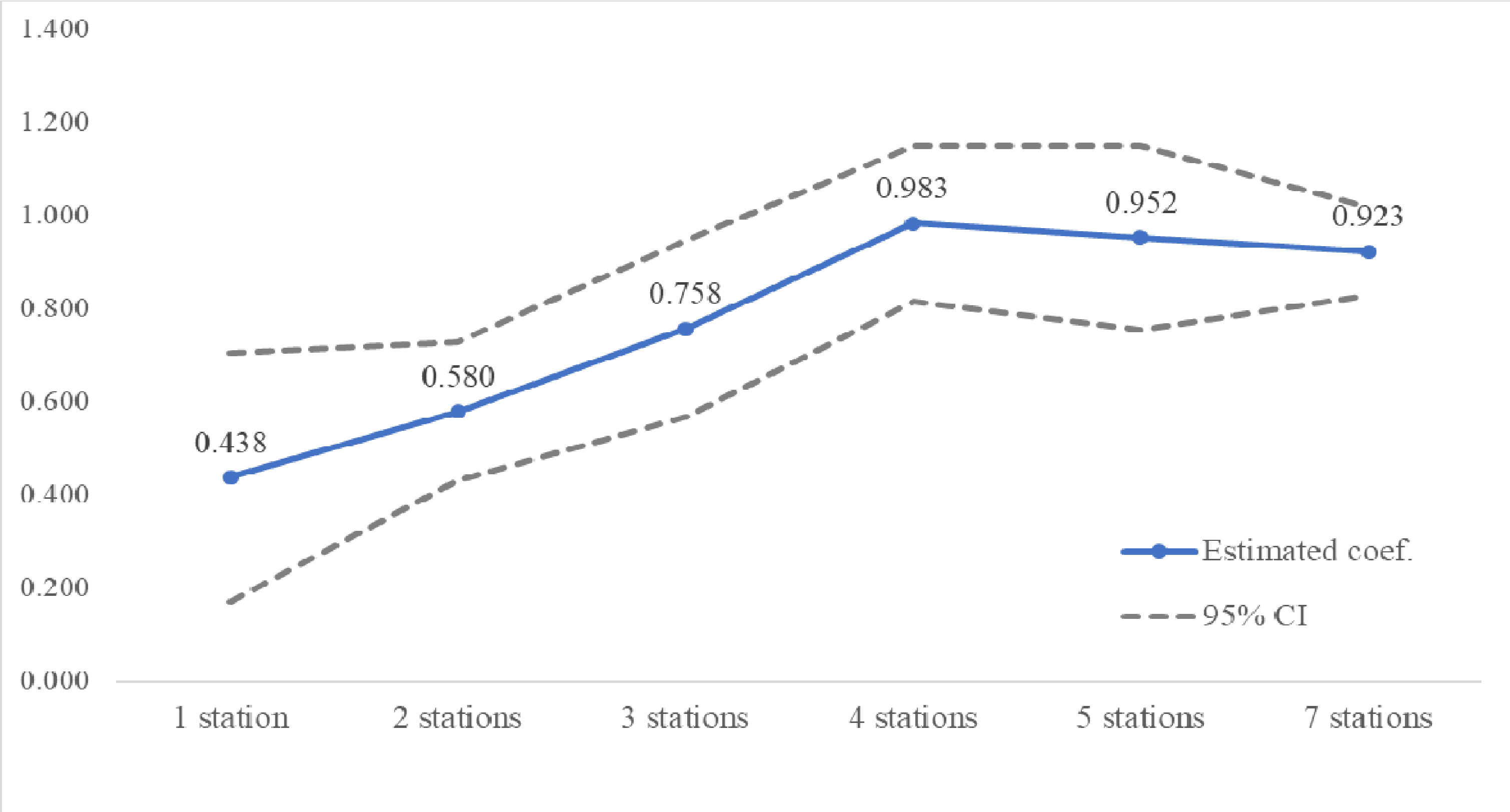
Notes: The four figures plot average retail prices for the different petroleum products (clockwise from left: Unleaded95, Super, Unleaded100, Diesel) sold at the gas stations and the heating gasoline during January 2010.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 5: BEFORE AND AFTER THE EXCISE DUTIES CHANGES (DIESEL vs HEATING GAS)



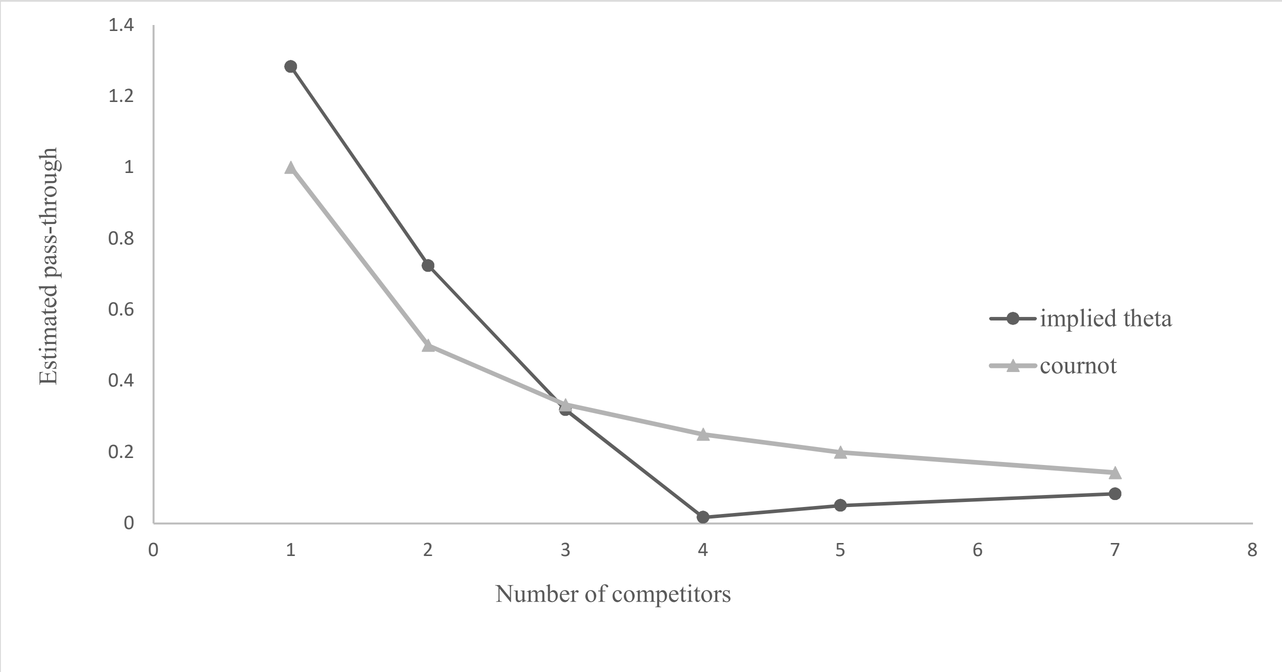
Notes: The three figures plot the average difference between diesel and heating gasoline ten days before and after the changes in excise duties for each of the three incidents as detailed in Table 1. Figure 1 in the Appendix plots the same differences for the three other gasoline products (Unleaded95, Unleaded100, Super) for each of the three tax changes demonstrating that they follow very similar patterns. Also, Figure 2 in the Appendix plots the average prices for diesel and heating gasoline separately.

FIGURE 6: PASS-THROUGH AND COMPETITION



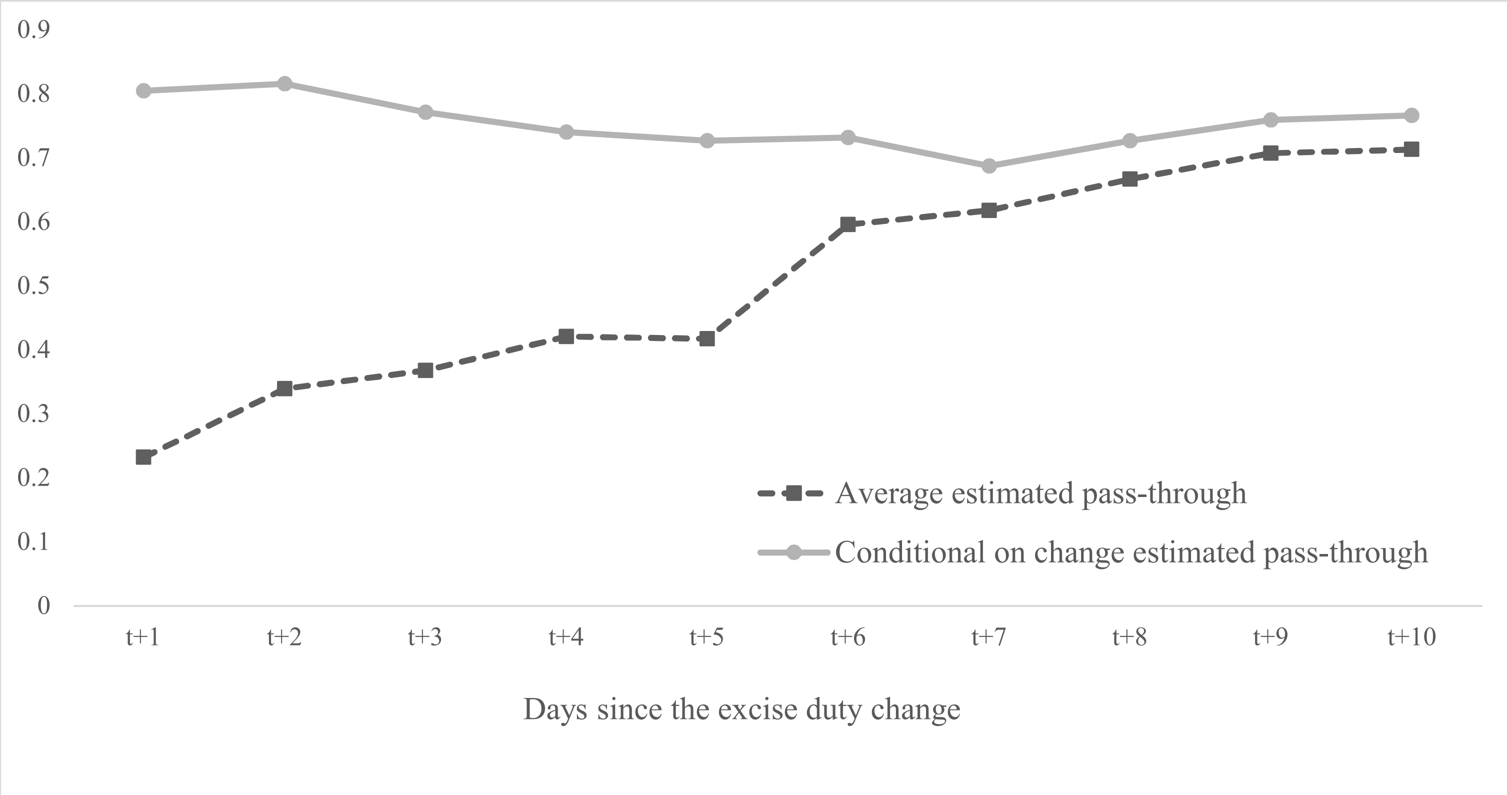
Notes: The figure plots the estimated coefficients from Table 5, column 1, together with the 95% confidence interval.
Source: Authors’ calculations based on data from the Greek Ministry of Development.

FIGURE 7: IMPLIED DEGREE OF COMPETITION



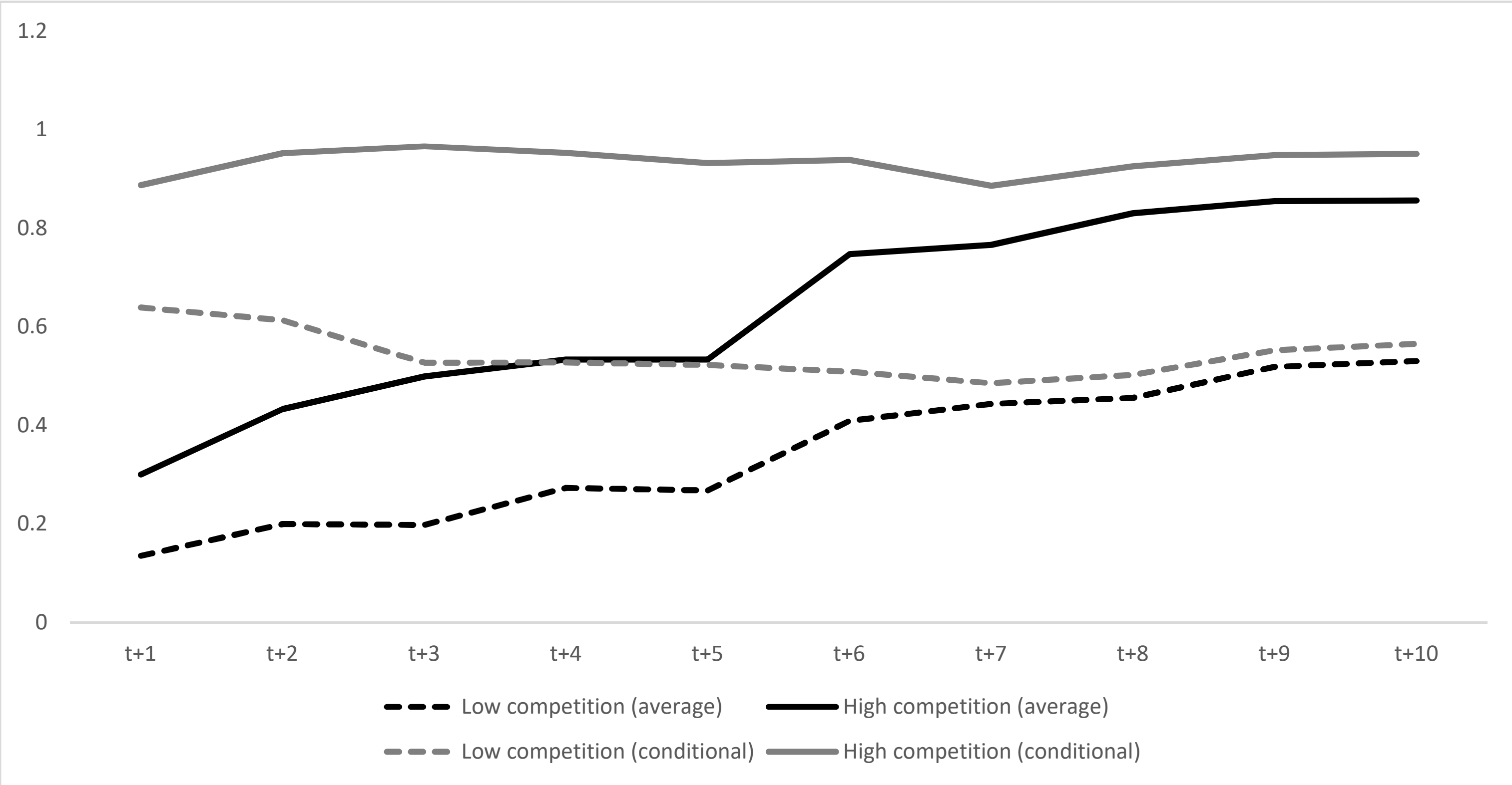
Notes: The figure plots the behavioral parameter theta implied by our estimates (assuming constant marginal cost and linear demand) and that obtained in the Cournot model.
Source: Authors' calculations based on estimated results.

FIGURE 8: AVERAGE vs. CONDITIONAL PASS-THROUGH



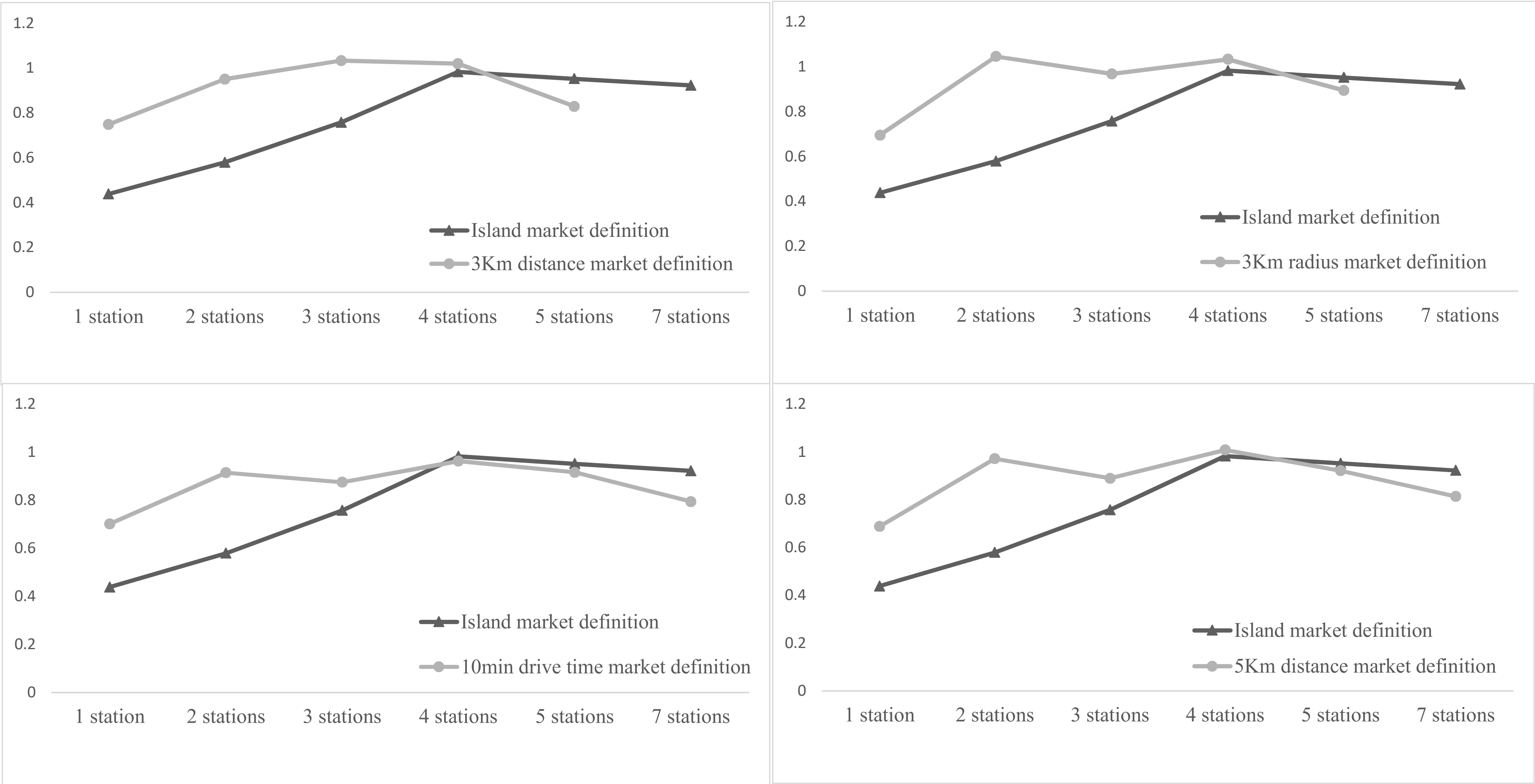
Notes: The figure plots the estimated coefficients from Table 6.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 9: SPEED OF PASS-THROUGH ADJUSTMENT



Notes: The figure plots the estimated coefficients from Table 7.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 10: ALTERNATIVE MARKET DEFINITIONS



Notes: The figure plots the estimated coefficients from Table 5 (column 1 vs columns 2-5).
Source: Authors' calculations based on data from the Greek Ministry of Development, Eurostat and Google Maps.

TABLE 1 - EXCISE DUTY TAX CHANGES (%Δ)

Type of energy product	(1) Unleaded 95	(2) Unleaded 100	(3) Diesel	(4) Super (leaded)	(5) Heating diesel
10-Feb-10	29%	29%	17%	29%	0%
04-Mar-10	15%	15%	9%	15%	0%
03-May-10	10%	10%	8%	10%	0%

Notes: The table reports the changes in excise duties by gasoline product.
Source: Authors' calculations based on data from the Eurostat (rates and structure of excise duties for energy products).

TABLE 2 - SUMMARY STATISTICS

Variable	Mean	Standard Deviation	Median	10th percentile	90th percentile
Unleaded 95	126	12.4	125	107	142
Unleaded 100	136	12.7	136	119	152
Super	127	12.5	125	110	143
Diesel	107	8.5	106	96	118
Heating diesel	62	4.1	62	57	67
Size	103	60	86	35	195
Population	3,222	2,939	2,523	765	7,917
Ports	2	1	1	1	3
Airports	0.2	0.4	0.0	0.0	1.0
Arrivals	112,046	168,061	58,748	13,188	296,016
Distance from Piraeus	123	61	111	45	210
Income	17,522	2,336	17,219	15,462	20,471
Education (tertiary)	11%	2%	10%	9%	13%

Notes: The above table provides summary statistics on the key variables used.
Source: Authors' calculations based on data from the Greek Ministry of Development, the Hellenic Statistical Authority and Eurostat.

TABLE 3 - EXCISE DUTY PASS-THROUGH

	(1)	(2)	(3)	(4)
Estimation method	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	Excise 1	Excise 2	Excise 3	All excise episodes
Tax_{it}	0.690***	1.076***	0.661***	0.767***
	(0.087)	(0.111)	(0.097)	(0.069)
Observations	283	267	365	915
Within R^2	0.743	0.757	0.662	0.931
Clusters	37	41	55	57
Time FE	yes	yes	yes	yes
Product × Station FE	yes	yes	yes	yes
Excise incident × Product type FE				yes
Excise incident × Station FE				yes

Notes: The dependent variable is the retail price of product *i,* in gas station *s,* and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.

TABLE 4 - PASS-THROUGH AND COMPETITION

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	FE	FE	IV	FE	FE	IV
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes
Tax_{it}	0.449***	-0.833	0.464***	0.139	-0.601	-0.702
	(0.091)	(0.689)	(0.104)	(0.186)	(0.897)	(0.466)
Tax_{it} × Number of $competitors_s$	0.086***	0.083**	0.082***	0.289***	0.265	0.821***
	(0.020)	(0.031)	(0.020)	(0.100)	(0.172)	(0.294)
Tax_{it} × Number of $competitors_s^2$				-0.025**	-0.023	-0.090**
				(0.011)	(0.018)	(0.037)
		Additional controls include interactions with income, education, number of ports, and airports, distance from Piraeus and tourist arrivals.			Additional controls include interactions with income, education, number of ports, and airports, distance from Piraeus and tourist arrivals.	
Instruments						
1st Stage Coef. Population			0.513***			8.246***
			(0.069)			(1.131)
1st Stage Coef. $Population^2$						-0.358***
						(0.100)
1st Stage F-test			54.63***			42.01***
			[0.000]			*[0.000]*
Observations	915	915	915	915	915	915
Within R^2	0.937	0.939		0.939	0.939	
Clusters	57	57	57	57	57	57

Notes: The dependent variable is the retail price of product *i,* in gas station *s,* and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development, the Hellenic Statistical Authority and Eurostat.

TABLE 5 - PASS-THOURGH AND COMPETITION: ALTERNATIVE MARKET DEFINITIONS

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	Market definition: Island	Market definition: 3 Km driving distance	Market definition: 3 Km radius	Market definition: 10 min driving distance	Market definition: 5 Km driving distance
Tax_{it} × One competitor	0.438***	0.748***	0.695***	0.701***	0.688***
	(0.133)	(0.082)	(0.067)	(0.073)	(0.071)
Tax_{it} × Two competitors	0.580***	0.951***	1.046***	0.915***	0.972***
	(0.074)	(0.053)	(0.042)	(0.098)	(0.100)
Tax_{it} × Three competitors	0.758***	1.034***	0.968***	0.875***	0.890***
	(0.095)	(0.086)	(0.079)	(0.076)	(0.071)
Tax_{it} × Four competitors	0.983***	1.020***	1.034***	0.963***	1.009***
	(0.083)	(0.107)	(0.086)	(0.138)	(0.106)
Tax_{it} × Five competitors	0.952***	0.829***	0.895***	0.916***	0.922***
	(0.098)	(0.127)	(0.071)	(0.053)	(0.050)
Tax_{it} × Seven competitors	0.923***			0.794***	0.814***
	(0.048)			(0.119)	(0.127)
Observations	915	609	609	499	537
Within R^2	0.939	0.966	0.967	0.966	0.966
Clusters	57	39	39	39	39
Time FE	yes	yes	yes	yes	yes
Product × Station FE	yes	yes	yes	yes	yes
Excise incident × Product type FE	yes	yes	yes	yes	yes
Excise incident × Station FE	yes	yes	yes	yes	yes

Notes: The dependent variable is the retail price of product *i,* in gas station *s,* and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development, the Hellenic Statistical Authority, Eurostat and Google Maps.

TABLE 6 - SPEED OF ADJUSTMENT

	(1)	(2)
Estimation method	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes
	Average	Conditional
Tax_{it}	0.232***	0.805***
(T-1, T+1)	(0.074)	(0.097)
Tax_{it}	0.339***	0.816***
(T-1, T+2)	(0.087)	(0.127)
Tax_{it}	0.368***	0.771***
(T-1, T+3)	(0.088)	(0.116)
Tax_{it}	0.421***	0.741***
(T-1, T+4)	(0.088)	(0.106)
Tax_{it}	0.417***	0.727***
(T-1, T+5)	(0.088)	(0.105)
Tax_{it}	0.596***	0.732***
(T-1, T+6)	(0.083)	(0.080)
Tax_{it}	0.618***	0.687***
(T-1, T+7)	(0.081)	(0.077)
Tax_{it}	0.667***	0.727***
(T-1, T+8)	(0.080)	(0.076)
Tax_{it}	0.707***	0.759***
(T-1, T+9)	(0.075)	(0.071)
Tax_{it}	0.713***	0.767***
(T-1, T+10)	(0.073)	(0.069)

Notes: The dependent variable is the retail price of product *i,* in gas station *s,* and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.

TABLE 7A - SPEED OF ADJUSTMENT AND COMPETITION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Estimation method	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
	(T-1,T+1)	(T-1,T+2)	(T-1,T+3)	(T-1,T+4)	(T-1,T+5)	(T-1,T+6)	(T-1,T+7)	(T-1,T+8)	(T-1,T+9)	(T-1,T+10)
Tax_{it} × Low competition	0.136*	0.200**	0.198**	0.273***	0.268***	0.410***	0.443***	0.456***	0.519***	0.531***
(1-3 competitors)	(0.070)	(0.091)	(0.087)	(0.082)	(0.082)	(0.086)	(0.082)	(0.083)	(0.076)	(0.076)
Tax_{it} × High competition	0.301***	0.433***	0.500***	0.534***	0.534***	0.747***	0.766***	0.831***	0.855***	0.856***
(4-7 competitors)	(0.094)	(0.104)	(0.105)	(0.108)	(0.108)	(0.097)	(0.095)	(0.085)	(0.083)	(0.083)

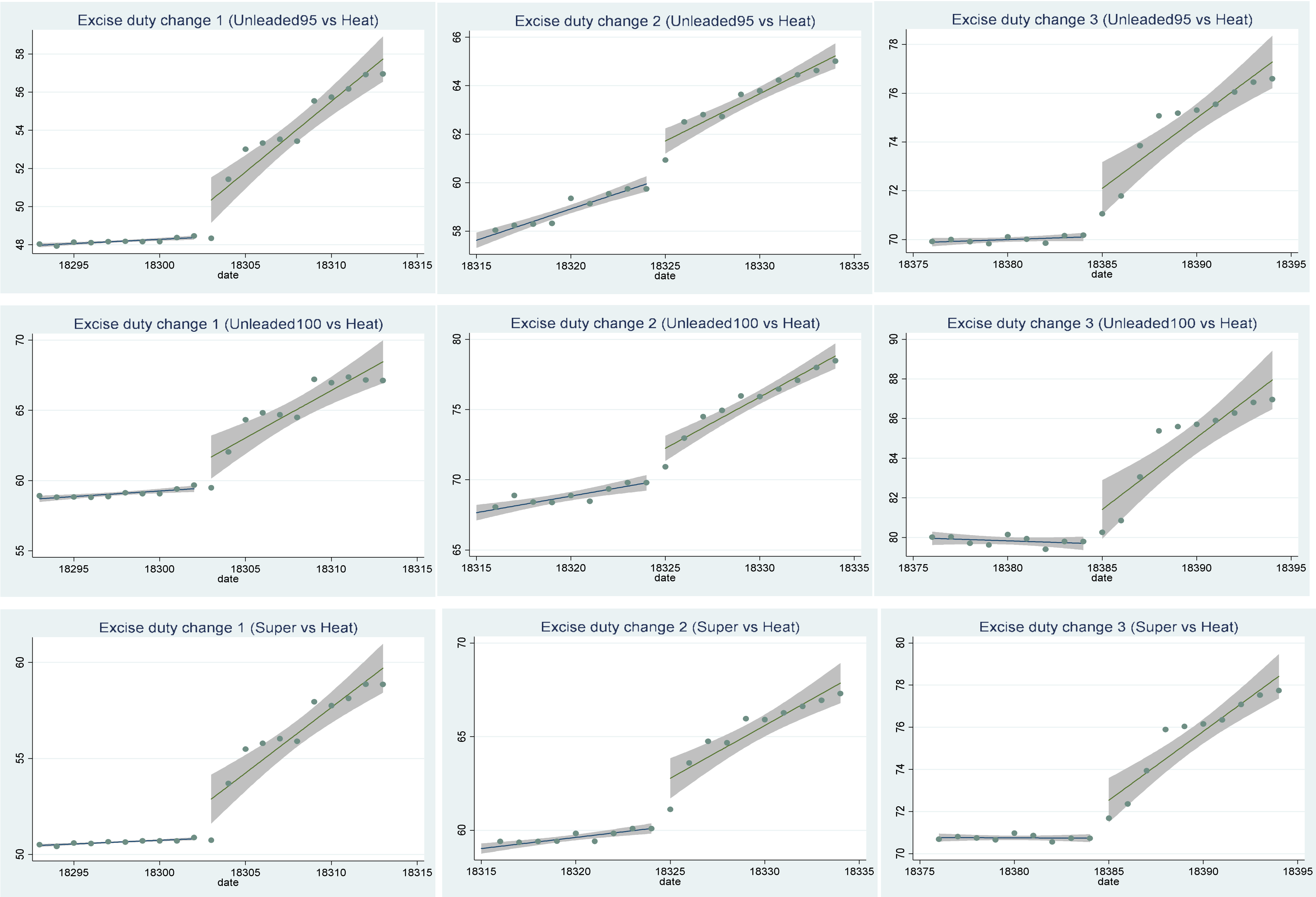
Notes: The dependent variable is the retail price of product *i*, in gas station *s*, and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.

TABLE 7B - SPEED OF ADJUSTMENT AND COMPETITION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Estimation method	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes
	Conditional	Conditional	Conditional	Conditional	Conditional	Conditional	Conditional	Conditional	Conditional	Conditional
	(T-1,T+1)	(T-1,T+2)	(T-1,T+3)	(T-1,T+4)	(T-1,T+5)	(T-1,T+6)	(T-1,T+7)	(T-1,T+8)	(T-1,T+9)	(T-1,T+10)
Tax_{it} × Low competition	0.639***	0.614***	0.528***	0.528***	0.523***	0.509***	0.486***	0.502***	0.552***	0.565***
(1-3 competitors)	(0.138)	(0.164)	(0.142)	(0.119)	(0.117)	(0.092)	(0.078)	(0.078)	(0.071)	(0.069)
Tax_{it} × High competition	0.888***	0.952***	0.966***	0.953***	0.932***	0.939***	0.886***	0.926***	0.948***	0.951***
(4-7 competitors)	(0.083)	(0.087)	(0.067)	(0.065)	(0.067)	(0.073)	(0.080)	(0.068)	(0.065)	(0.064)

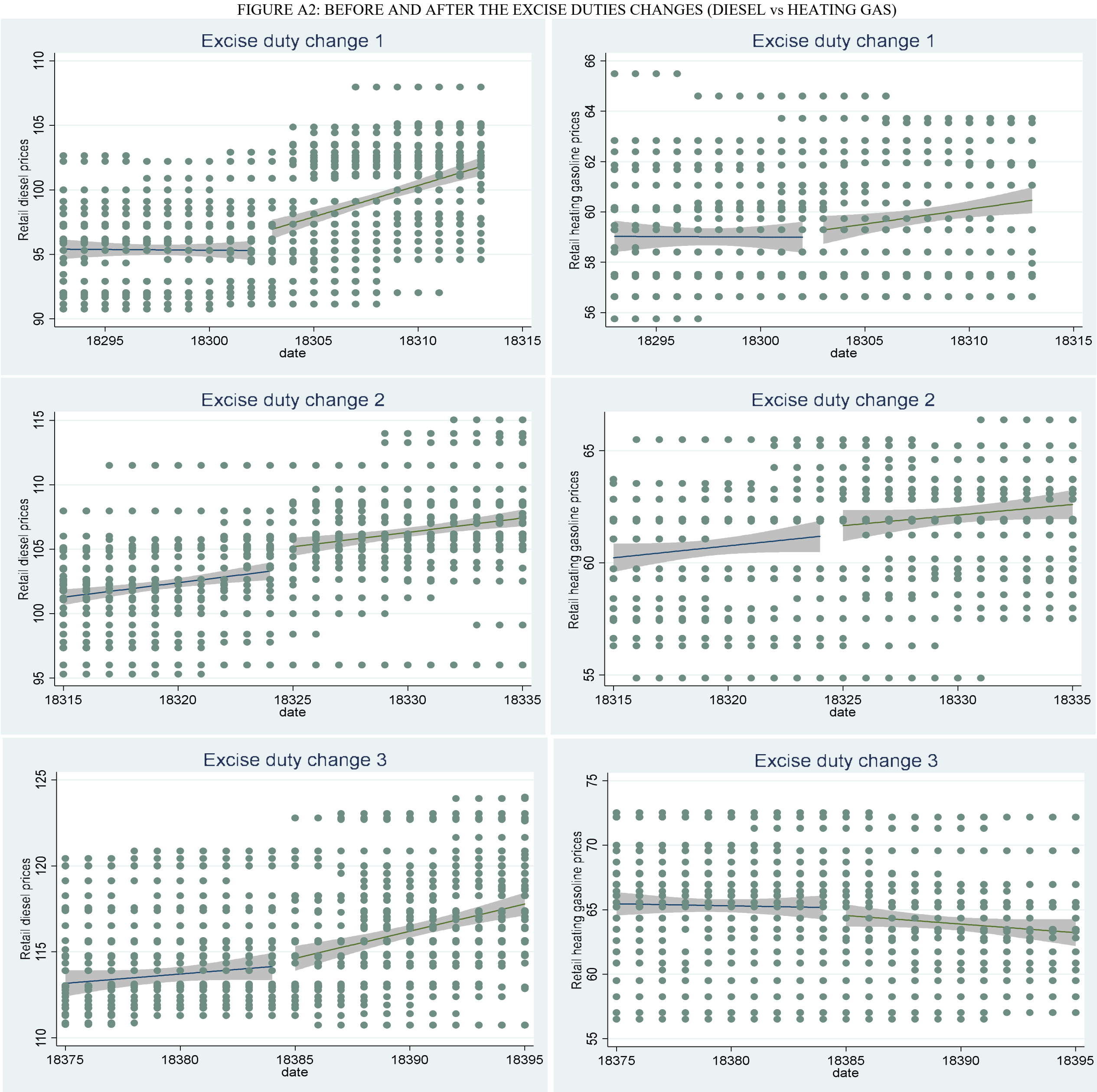
Notes: The dependent variable is the retail price of product *i*, in gas station *s*, and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.

FIGURE A1: BEFORE AND AFTER THE EXCISE DUTIES CHANGES



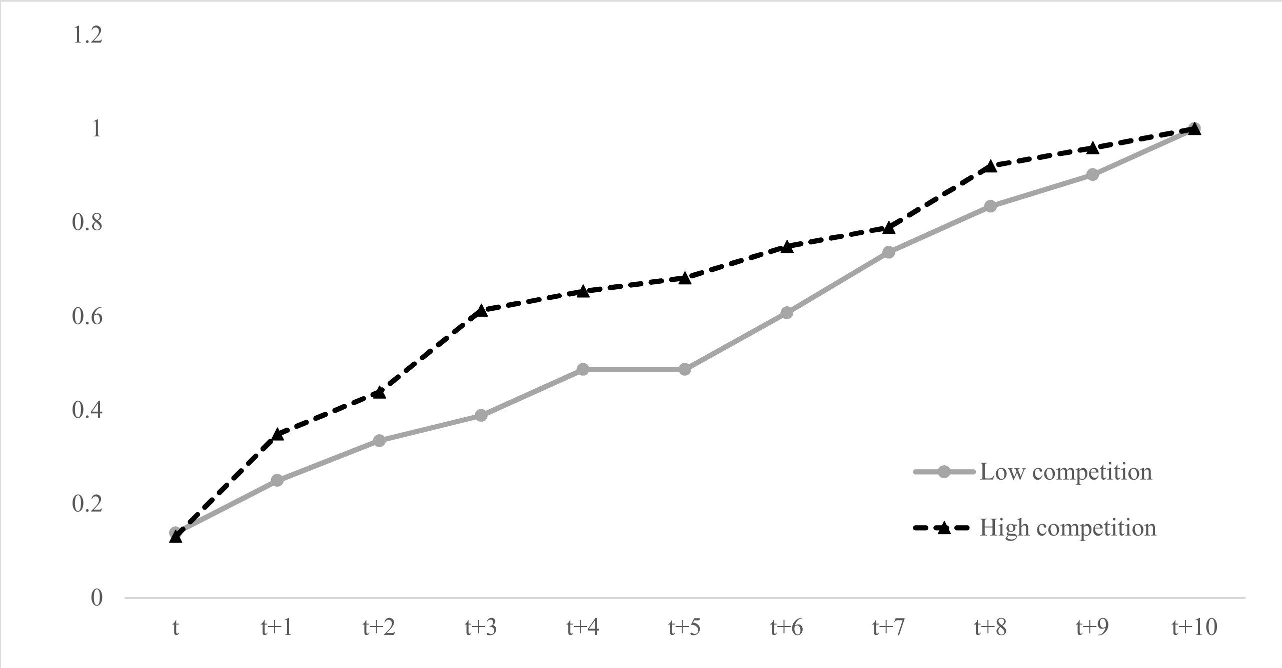
Notes: The figures plot the average difference between unleaded95, unleaded100, super and heating gasoline ten days before and after the changes in excise duties for each of the three incidents as detailed in Table 1.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE A2: BEFORE AND AFTER THE EXCISE DUTIES CHANGES (DIESEL vs HEATING GAS)



Notes: The figures plot the evolution of average prices for diesel and heating gasoline separately ten days before and after the changes in excise duties for each of the three incidents as detailed in Table 1.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE A3: SPEED OF ADJUSTMENT - FREQUENCY OF CHANGES



Notes: The figure plots the cumulative percentage of station-products that changed their prices at different days after the excise duty changes.
Source: Authors' calculations based on data from the Greek Ministry of Development.

TABLE A1 - PASS-THROUGH AND COMPETITION - ROBUSTNESS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation method	FE	FE	FE	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes
Tax_{it}	0.449***	-0.424	0.258	0.447***	0.470***	0.398***	0.475***	-0.736
	(0.091)	(0.391)	(0.262)	(0.092)	(0.126)	(0.134)	(0.093)	(1.040)
Tax_{it} × Number of $competitors_s$	0.086***	0.075***	0.087***	0.090***	0.086***	0.079***	0.058**	0.082**
	(0.020)	(0.018)	(0.019)	(0.021)	(0.020)	(0.019)	(0.027)	(0.034)
Tax_{it} × $Income_s$		0.048**						0.042
(*1000)		(0.019)						(0.044)
Tax_{it} × $Education_s$			1.876					4.223
			(1.870)					(3.062)
Tax_{it} × $Tourists_s$				-0.092				-0.379*
(*1000000)				(0.138)				(0.162)
Tax_{it} × Distance from $Peiraeus_s$					-0.092			-0.242
(*1000)					(0.138)			(1.223)
Tax_{it} × Number of $ports_s$						0.045		0.009
						(0.059)		(0.069)
Tax_{it} × Number of $airports_s$							0.183*	0.054
							(0.106)	(0.208)
Observations	915	915	915	915	915	915	915	915
Within R^2	0.937	0.939	0.937	0.937	0.937	0.937	0.938	0.939
Clusters	57	57	57	57	57	57	57	57

Notes: The dependent variable is the retail price of product *i*, in gas station *s*, and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.

TABLE A2 - PASS-THROUGH AND COMPETITION - ROBUSTNESS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation method	FE	FE	FE	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes	All excise episodes
Tax_{it}	0.139	-0.237	-0.016	0.122	-0.086	0.059	0.190	-0.601
	(0.186)	(0.474)	(0.290)	(0.194)	(0.285)	(0.194)	(0.197)	(0.897)
Tax_{it} × Number of $competitors_s$	0.289***	0.214	0.286***	0.305***	0.351***	0.289***	0.247**	0.265
	(0.100)	(0.157)	(0.098)	(0.108)	(0.122)	(0.096)	(0.114)	(0.172)
Tax_{it} × Number of $competitors_s^2$	-0.025**	-0.017	-0.025**	-0.026**	-0.033**	-0.026**	-0.023**	-0.023
	(0.011)	(0.017)	(0.011)	(0.011)	(0.014)	(0.010)	(0.011)	(0.018)
Tax_{it} × $Income_s$		0.026						0.022
(*1000)		(0.033)						(0.038)
Tax_{it} × $Education_s$			1.574					2.719
			(1.921)					(3.260)
Tax_{it} × $Tourists_s$				-0.163				-0.315*
(*1000000)				(0.133)				(0.180)
Tax_{it} × Distance from $Peiraeus_s$					1.144			0.453
(*1000)					(0.784)			(1.459)
Tax_{it} × Number of $ports_s$						0.060		0.034
						(0.054)		(0.067)
Tax_{it} × Number of $airports_s$							0.143	2.719
							(0.113)	(3.260)
Observations	915	915	915	915	915	915	915	915
Within R^2	0.937	0.939	0.939	0.939	0.939	0.939	0.939	0.939
Clusters	57	57	57	57	57	57	57	57

Notes: The dependent variable is the retail price of product *i*, in gas station *s*, and day *t*. Standard errors clustered at the gas station level are reported in parenthesis below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.
Source: Authors' calculations based on data from the Greek Ministry of Development and Eurostat.