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Competition and Pass-Through: Evidence from Isolated Markets

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Abstract
We measure how pass-through varies with competition in isolated oligopolistic markets with captive consumers. Using daily pricing data from gas stations, we study how unanticipated and exogenous changes in excise duties (which vary across different petroleum products) are passed through to consumers in markets with different numbers of retailers. We find that pass-through increases from 0.44 in monopoly markets to 1 in markets with four or more competitors and remains constant thereafter. Moreover, the speed of price adjustment is about 60% 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 significant overestimation of the pass-through when the number of competitors is small.

Key words: pass-through, tax incidence, gasoline, market structure, competition
JEL Codes: H22; L1

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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 concerns (Fullerton and Metcalf, 2002). The pass-through of exchange rates and tariffs has important repercussions on firm productivity and international trade (De Loecker and Koujianou-Goldberg, 2014). Moreover, the pass-through of input prices is relevant to 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 relevant to the policy debate in many industries, such as 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). As for the empirical analysis, there is a well-established line of research exploiting variability in costs to infer the magnitude of 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). However, while market structure is recognized as an endogenous outcome, this type of market definition does not explain why some firms face greater 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 in input prices (Borenstein, Cameron and Gilbert, 1997; Genesove and Mullin, 1998; Nakamura and Zerom, 2010; Miller, Osborne and Sheu, 2017).

Following the literature initiated by Bresnahan and Reiss (1991), we measure how pass-through varies with competition in isolated oligopolistic markets of different sizes. Our data come from the retail market for petroleum products (gasoline, unleaded gasoline, diesel, heating oil) on the many small islands Greece is known for (Figure 1). Some of these islands are so small that they have just a single gas station, while others have two, three, or more. The naturally occurring variability in island size provides an exogenous source of variability in the level of competition. Islands clearly define local markets, as substitution effects between islands are zero.[5]

Along with this unique setting, we take advantage of significant policy changes made by the Greek government when, at the beginning of the financial crisis, they increased the excise duty on petroleum products three times in 2010. The increments were large and unannounced and provide us with an ideal exogenous shock for estimating the pass-through to retail prices. For political reasons, heating oil was excluded from the rate hike, 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 different numbers of competitors, while using heating oil 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 using the control group. We find four main results. First, the response to cost shocks is rapid, with an average pass-through of 0.77 after 10 days from an excise duty change. Second, pass-through increases significantly with the number of competitors, and the relation between competition and pass-through is nonlinear. On average, the pass-through is 0.44 on monopolistic islands and grows to about 1 on islands with 4 competitors (measured 10 days from an excise duty change). We found no further effect on pass-

[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.

through in markets beyond 4 competitors. Third, we find that price adjustments are larger and occur more quickly in more competitive markets, which leads to faster pass-through in more competitive markets. Fourth, we find that using geographical market definitions based on distance across sellers (rather than the island market definition) results in overestimation of pass-through in highly concentrated markets.

Our results contribute to the literature on the transmission of cost shocks to prices, whose ultimate objective is to understand 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 and somewhat mixed. Miller, Osborne and Sheu (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. In contrast, Doyle and Samphantharak (2008) and Stopler (2017) find that greater brand concentration and market power are associated with larger pass-through rates in the gasoline market.

Our finding of quick 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 pass-through and frequency of price adjustments across markets with different levels of competition, which is in line with the results of 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 the 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. The sign and magnitude of the effect of an increase in the conduct parameter on the pass-through can be either positive or negative.

The expression for ρ greatly simplifies in some special cases, highlighting 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, it is realistic to assume 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, θ 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.

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[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).

[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 greater 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.

Finally, an important determinant of the pass-through is the demand curvature ϵ_{ms}. Many empirical studies are based on linear demand specifications, directly implying that $\epsilon_{ms} = 1$. However, it is not uncommon to assume different demand specifications that imply different curvature, although there is little guidance in the literature on the sign and magnitude of ϵ_{ms}.

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. Moreover, in this special case, the relation between pass-through and theta can be inverted, so estimating the pass-through provides information about the conduct parameter. The first assumption is met in several industries and is realistic in our application. The second is often considered a reasonable simplification in empirical studies, in 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, in general, the impact of an increase in competition on pass-through remains largely an empirical issue.

However, if one could test and fail to reject the hypothesis of linear demand in a specific application, then one could take this theoretical prediction to the data. One such a test is possible for the market for petroleum products on monopoly islands, where simple monopoly pricing theory and linear demand implies that the pass-through should be equal to 0.5. Failing to reject this hypothesis would support the assumption of linear demand. In Section 6.2, we provide this evidence and estimate the pass-through (and hence the conduct parameter) in markets with different numbers of competitors.

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 which are 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. 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 contracts 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 required to impose a minimum array 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 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 taken by the Greek government to increase tax revenues was to increase excise duties on fuel. Excise duties on fuel were raised three times in 2010. Each of these

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[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.
[11] EU guideline 2003/96/EU.
[12] The retail price is determined as $P_{retail} = (P_{refinery} + taxes\&fees + margins)(1 + VAT)$.

three tax changes was announced and implemented the day after the decision was made, as typically happens in order to reduce opportunities for arbitrage. Table 1 shows that the increase was very different across products. Remarkably, excise duties for heating oil remained unchanged.[13]

3.1. Data and measurement of competition

We combined several datasets for our analysis. First, we obtained daily station-level retail prices during 2010. The data on prices was officially collected by the Greek Ministry of Development and Competitiveness through a reporting system, which required managers of each petrol station to record retail prices daily. The purpose of this system was to facilitate comparison 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 oil. 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 reasoning behind this is that the number of competitors on a given island is the result of an entry game. In equilibrium,

[13] Heating oil is chemically identical to diesel (although a different color) and is sold by the same gasoline stations throughout the country. A lower excise duty is applied to it, as it is considered a necessity, since the vast majority of households use heating oil rather than gas or electricity during the winter months.

[14] The primary distribution center 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 on 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.

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. There are two main reasons for this. First, small islands are sparsely 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 plausibly have close to perfect information about each station' prices and can reach all of them quite easily. Second, Bresnahan and Reiss (1991) find that competitive conduct changes quickly as the number of incumbents increases. They find that the most variation in conduct occurs with the entry of the second or third firm. Hence, selecting islands with fewer than 8 firms provides a sufficiently large range to capture the main effects of competition.

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, a 3 Km radius, or alternatively, a 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. Finally, there is very little to no brand concentration at the island level. In all islands in our sample, gas stations are either franchisees of different brands or independently owned. Hence, the number of gas stations on each island realistically captures the number of competitors on that island.

4. Preliminary evidence

Islands vary in size and number of gas stations. Figure 2 shows that the larger the island (either in terms of land area (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 vary significantly across islands. For example, Figure 3 shows the distribution of the average price for diesel and heating oil 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, thus leading to lower prices.

5. Identification and empirical methodology

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

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

where P_{kist} denotes the retail price of product k, on island i, in gas station s, on day $t \in \{\tau - 1, \tau + \delta\}$, where τ is the date of each of the three excise duty changes and $\delta = 1, \dots, 10$ is the length of the adjustment period considered. Tax_{kt} is the excise duty, and the coefficient ρ captures the tax pass-through. Finally, the model includes product-gas station and day fixed effects. This econometric approach follows a long literature on difference in difference estimators and is based

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

on the comparison of prices on two different dates (before and after the policy change) for a treatment (gasoline and diesel) and a control group (heating oil).[17]

We then focus on the interaction between taxes and competition and estimate the model:

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

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 increase 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 the macroeconomic shocks that affected 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

[17] Early applications of this methodology are found in Ashenfelter and Card (1985), Card (1992), and Card and Krueger (1994, 2000); more recent applications in industrial economics include, for example, Ashenfelter et al. (2013) and Genakos, Koutroumpis and Pagliero (2018).

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 (such as demand convexity). 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 results described in the next section.

6. Empirical results

6.1. The estimated pass-through

Figure 5 shows the difference between the average price of diesel and heating oil 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 progressively adjust their prices during this period.[18] On average, 59% of product-station specific prices are adjusted within three days, 88% within 7 days, and 94% within 10 days of the tax change.

The average pass-through on a given date depends on two margins. The extensive margin is the number of stations 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

[18] There are no significant changes in the price of heating oil around the changes in excise duties (see Figure A2 in the appendix).

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 and, in Section 6.3, we will compare the conditional and average pass-throughs for shorter adjustment periods. The 10-day adjustment period is chosen so that it is close enough to the change in excise duty, but is also long enough for almost all of the gas station to have changed their prices.[19]

Table 3 reports the estimated coefficients of model (1). In column 1-3, we consider each policy change separately, and in column 4 we pool all the data. The pass-through is 0.77, with a standard error of 0.07. This pass-through is slightly smaller but within the range of the unit pass-through estimated by Marion and Muehlegger (2011), Chouinard and Perloff (2007), Doyle and Samphantharak (2008), Alm, Sennoga and Skidmore (2009) for US state taxes on petroleum products and by Poterba (1996) for sales taxes on clothing. This suggests that the market for petroleum products in our sample of islands does not operate very differently from other markets studied in the literature, which is important for the external validity of our results. The lower value of pass-through in our case is likely related to the fact that many gas stations in our data have a significant degree of market power. It is this topic that we explore next.

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,

[19] The likely cause of delayed price adjustments is the slow process of refilling gas stations in relatively remote areas. 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 determined by the geographical dispersion of islands in the Aegean Sea and is independent of the excise duty changes and the size of the island (or other observable characteristics).

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).[20] 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 (reported in Table A3 in the appendix) 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 0.44 in monopoly islands and increases up to about 1 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 quickly; in other words, after three or four firms, an additional entrant does not affect competition much.

Note that the estimated pass-through for monopoly islands is not significantly different from the 0.5 pass-through predicted by a monopoly model with linear demand.[21] This provides direct evidence that demand convexity is not significant in monopoly islands and supports the assumption that demand convexity is also not relevant in markets with more competitors. Under this assumption, as we argued in Section 2, the conduct parameter θ can be recovered from the

[20] Table A1 and A2 in the appendix provide results introducing interactions one by one.

[21] 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.

estimated pass-through for different market configurations, since $\theta = \frac{1-\rho}{\rho}$. Figure 7 shows the θ implied by our pass-through estimates as the number of competitors increases: it sharply decreases as the number of competitors increases and is close to zero from about four competitors on.

More precisely, the average point estimate of the conduct parameter beyond four competitors is 0.05. Assuming a demand elasticity between -1 and -0.5, this implies a profit margin between 5 and 10%.[22] While we do not have direct evidence on retail profit margins in our sample of small islands, interviews with industry professionals suggest that profit margins throughout Greece (including the more competitive markets on the mainland) are about 5%. Hence, our estimates seem to be broadly in line with the market reality.

6.3. Pass-through and speed of adjustment

The results shown 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 adjustment periods. Shorter adjustment periods imply a lower average pass-through, as stations progressively adjust their prices. Figure 8 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 of the gasoline market (for example, Knittel, Meiselman and Stock, 2016). This can be partly

[22] Although estimates of the elasticity of demand for gasoline vary, there is evidence suggesting that aggregate demand at the country level is rigid (Brons, Nijkamp, Pels, and Rietveld, 2008).

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.[23]

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 the islands into two groups: those with 1 to 3 competitors ("low competition") and those with 4 or more competitors ("high competition"). Table 7 and Figure 9 report the average and the conditional pass-throughs 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%) higher. The conditional pass-through is stable over time and significantly larger in more competitive markets. Finally, Figure 10 shows the cumulative frequency of price changes for the two groups and provides direct evidence that stations in more competitive markets react more quickly to changes in excise duties. Hence, more competitive markets adjust faster to cost shocks, partly because the conditional pass-through is larger and partly because price changes are faster.

These results imply a positive correlation between pass-through and frequency of price adjustments across islands (with different levels of competition). This is consistent with the results of Gopinath and Itskhoki (2010), who find a positive correlation between frequency of price adjustments and magnitude of exchange rate pass-throughs across sectors. Our results are also in

[23] 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, or distance from Piraeus.

line with their theoretical model, in which firms in more competitive markets (i.e., with higher residual demand elasticity) are those with higher frequency of price adjustments and higher pass-throughs.

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 the distance between gas stations (Shepard, 1991; Barron, Taylor and Umbeck, 2004; Eckert and West, 2005; Hosken, McMillan and Taylor, 2008). While realistic, this approach cannot guarantee the absence of substitution effects with firms outside the geographical area considered. In our application, the definition of markets is simpler. Monopoly islands are unambiguously classified as such. In islands with more stations, there can only be substitution effects among firms on the same island. Given the small scale of these islands, some substitution is likely to exist among all stations on the same island.

However, 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 obviously do not 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 our new market definitions. Table 5, columns 2-4, reports the estimated coefficients, and Figure 11 shows 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 indicated by the black line in Figure 11 for comparison). For example, the 3Km driving distance definition implies that the pass-through is 70, 64, and 36% 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 a small number of firms. We contribute to the growing literature on pass-through by showing that pass-through increases with competition in a nonlinear fashion, growing from 0.44 for monopoly markets to 1 for markets with four competitors or more. Moreover, the pass-through and the frequency of price adjustments are higher in more competitive markets. We also find that conventional definitions of markets that are based on distance between sellers lead to overestimation of 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. The relation between competition and pass-through generally depends on the second derivative of the demand function, which is difficult to estimate in practice. Still, the evidence from monopoly islands suggests that demand curvature does not play a big role in our data. Hence, we can use estimates of the pass-through to provide novel evidence on the relation between the conduct parameter and competition.

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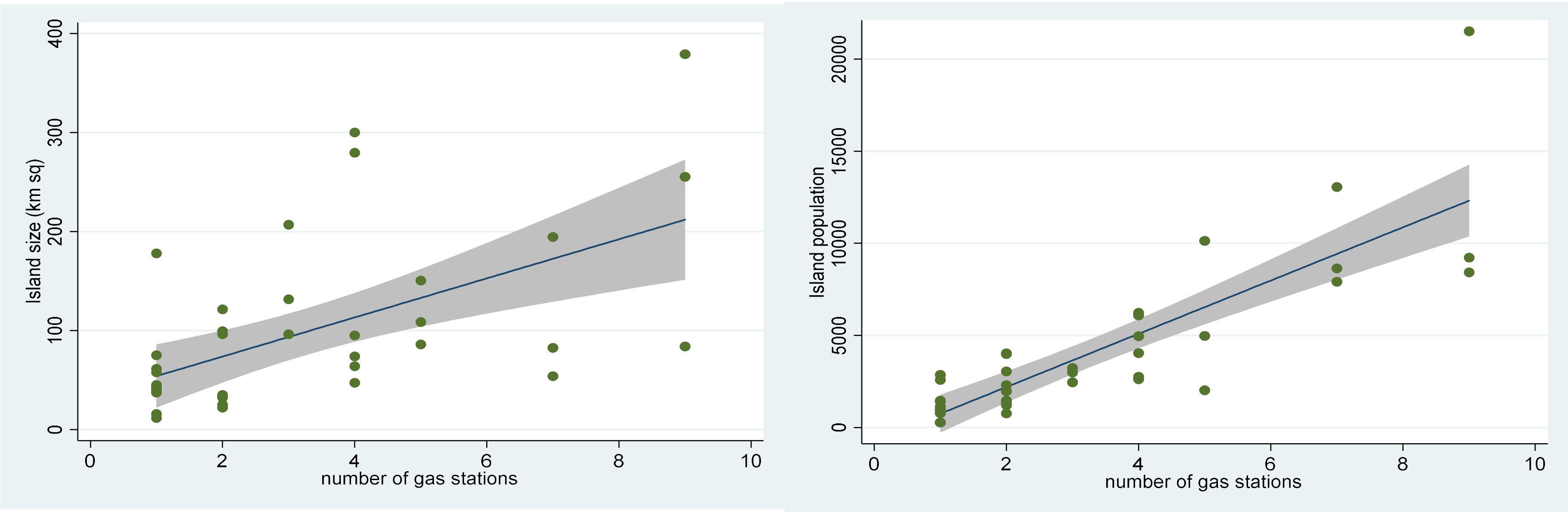
FIGURE 1: GREEK ISLANDS

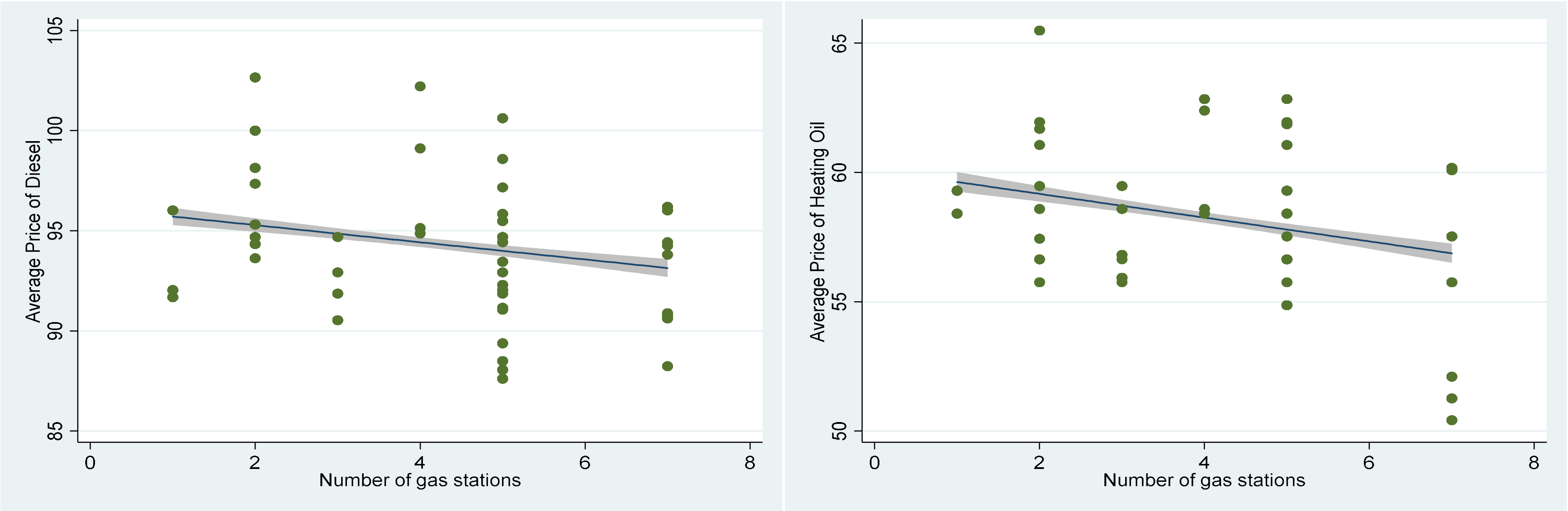
Notes: The main figure shows the map of Greece, with the two smaller figures showing more detailed maps of the Cyclades and Dodecanese islands.

FIGURE 2: COMPETITION AND MARKET SIZE



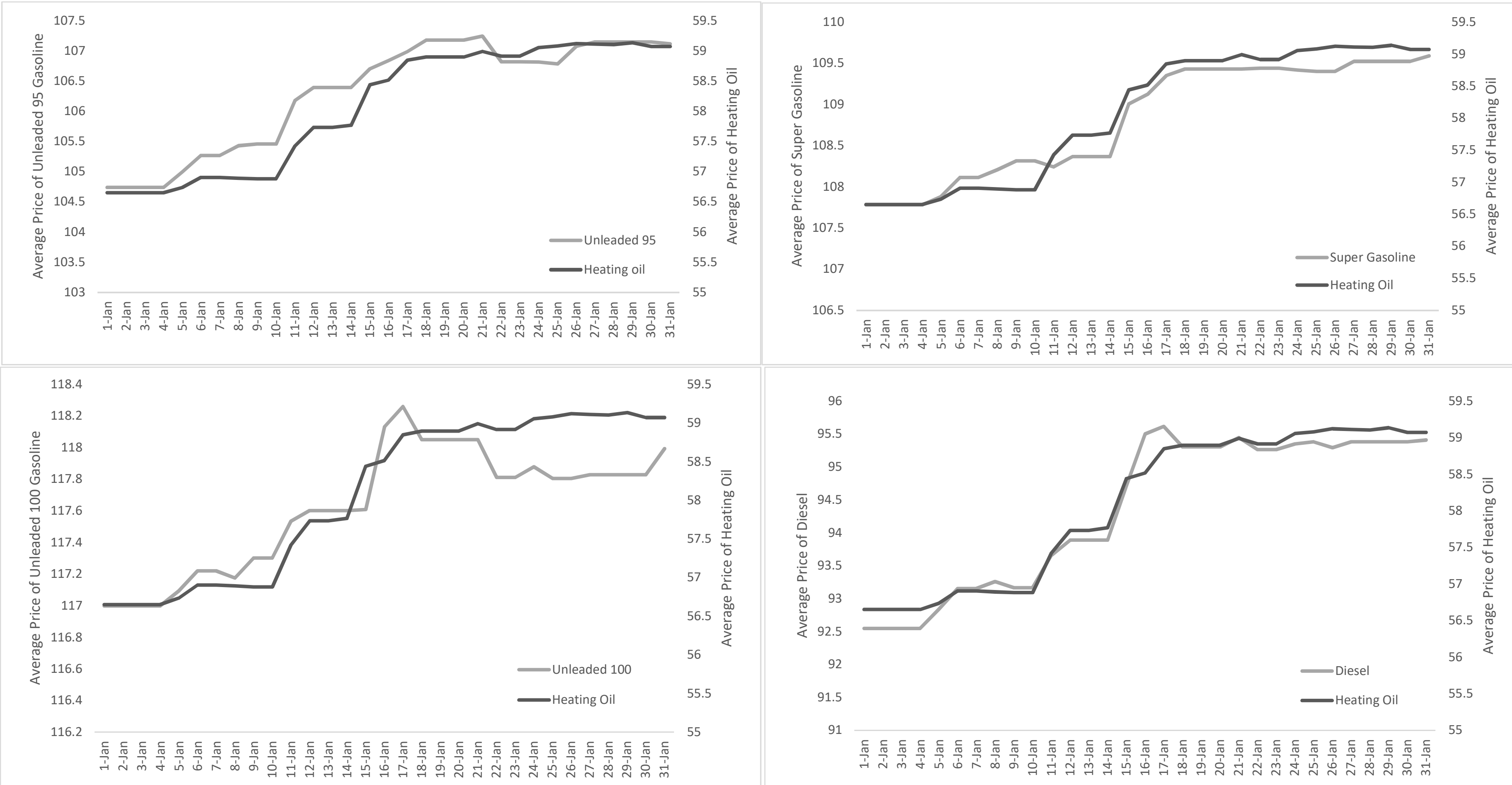
Notes: The figure on the left plots the number of gas stations and island size (measured in square km), whereas the figure on the right plots the number of gas stations and island population.
Source: Authors' calculations based on data from the Greek Ministry of Development and the Hellenic Statistical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

FIGURE 3: COMPETITION AND PRICES



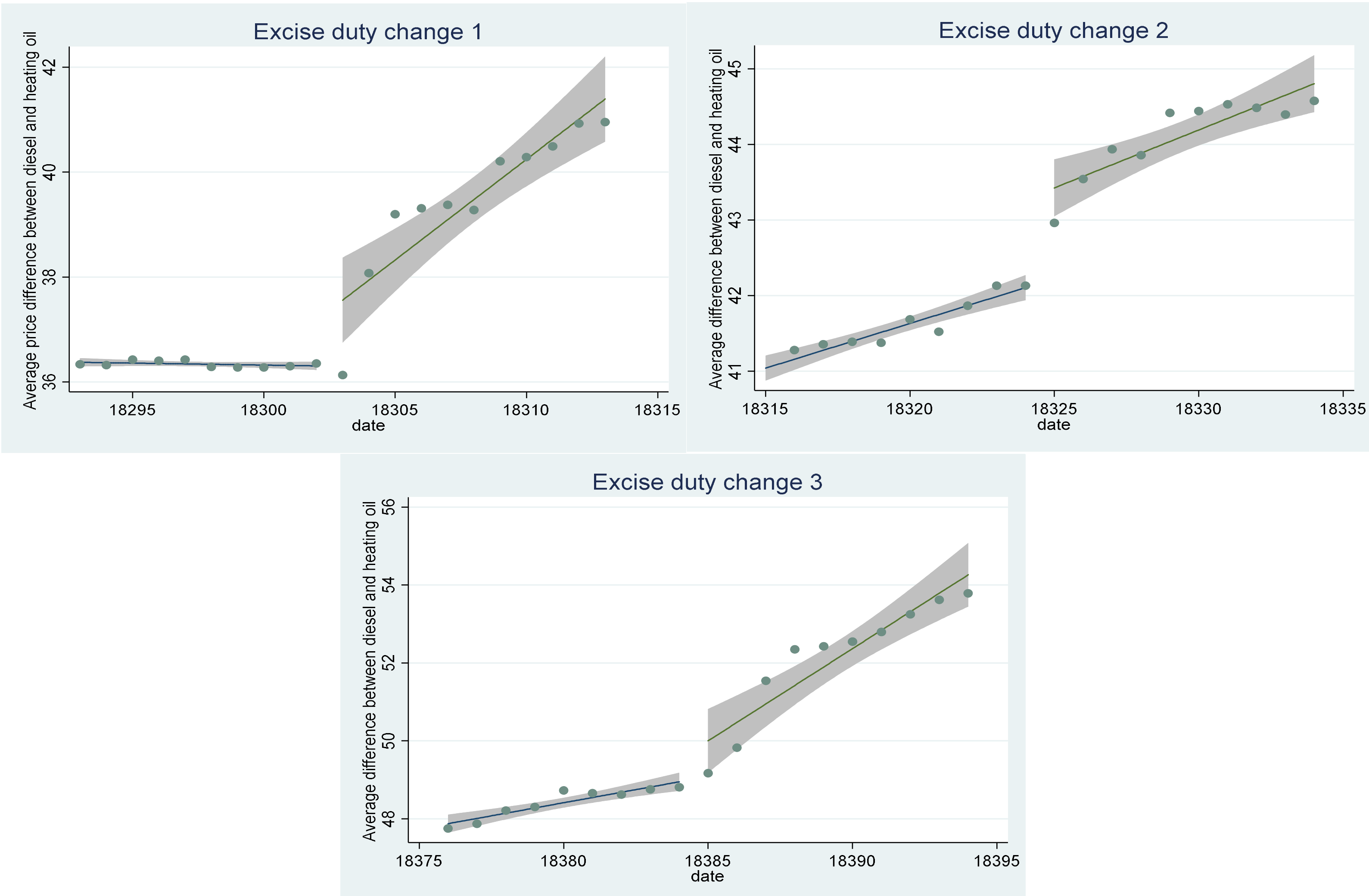
Notes: The figure on the left plots the average price of diesel, the figure on the right plots the average price of heating oil for islands with different number of competitors (January 2010).
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 4: AVERGE PRICES OF PETROLEUM PRODUCTS BEFORE THE EXCISE DUTY CHANGES.



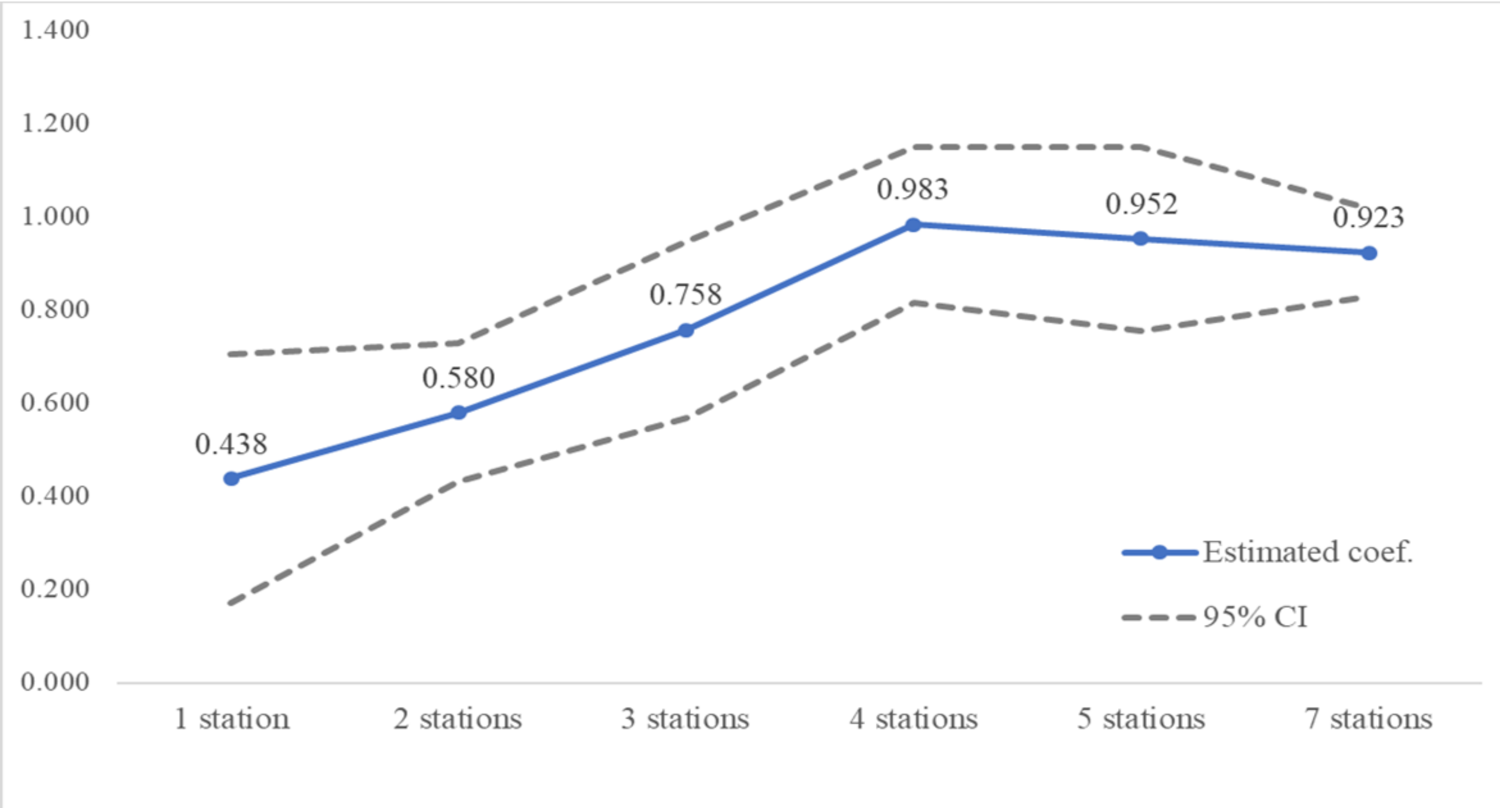
Notes: The four figures plot average retail prices of the different petroleum products (clockwise from left: Unleaded95, Super, Unleaded100, Diesel) and of heating oil during January 2010.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 5: AVERAGE PRICE DIFFERENCES BETWEEN DIESEL AND HEATING OIL.



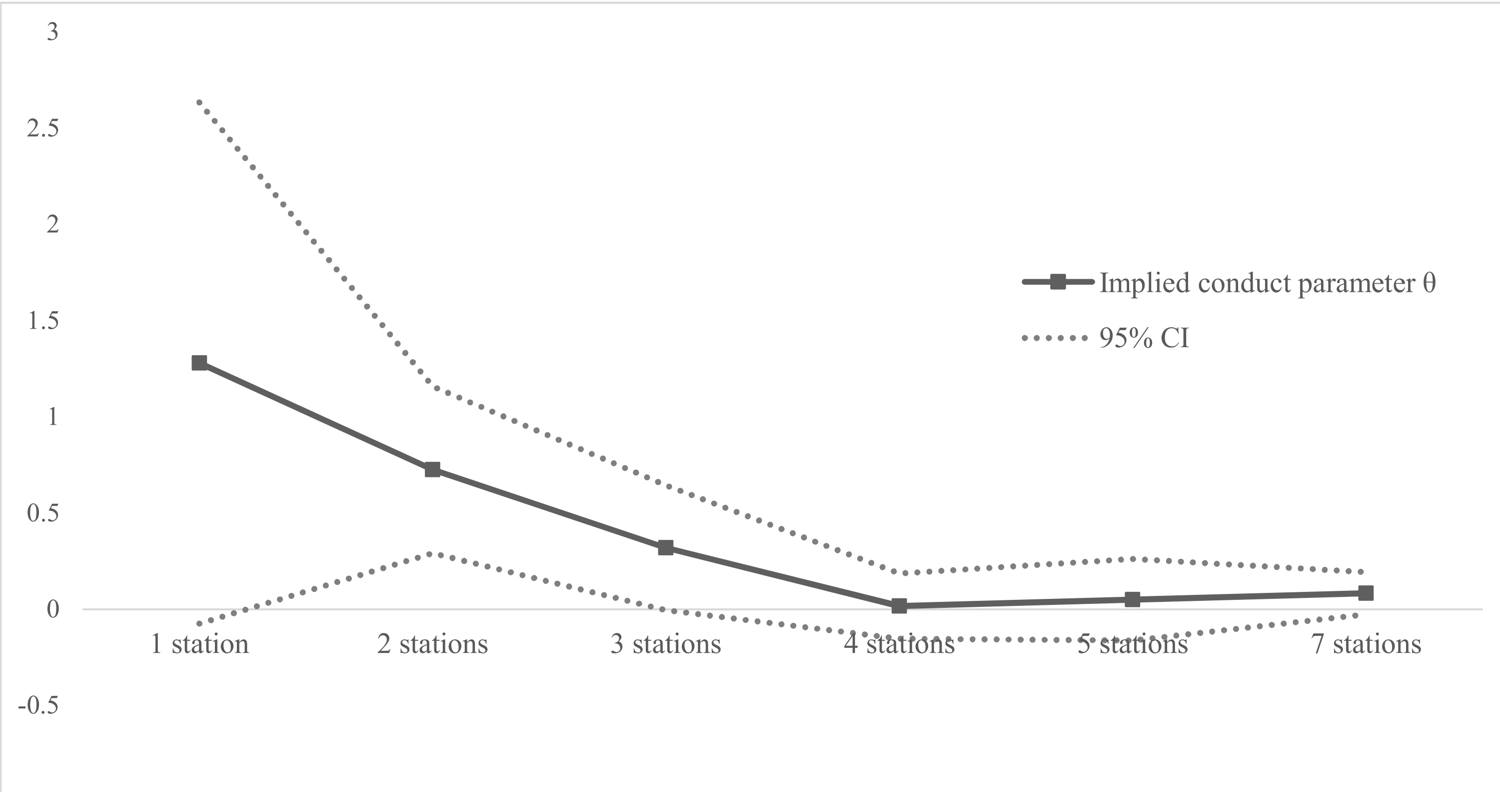
Notes: The three figures plot the average difference between diesel and heating oil ten days before and after the changes in excise duties for each of the three increases as detailed in Table 1. Figure 1 in the Appendix plots the same differences for the three other products (Unleaded95, Unleaded100, Super) for each of the three tax changes. Also, Figure 2 in the Appendix plots the average prices for diesel and heating oil separately.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 6: PASS-THROUGH AND COMPETITION.



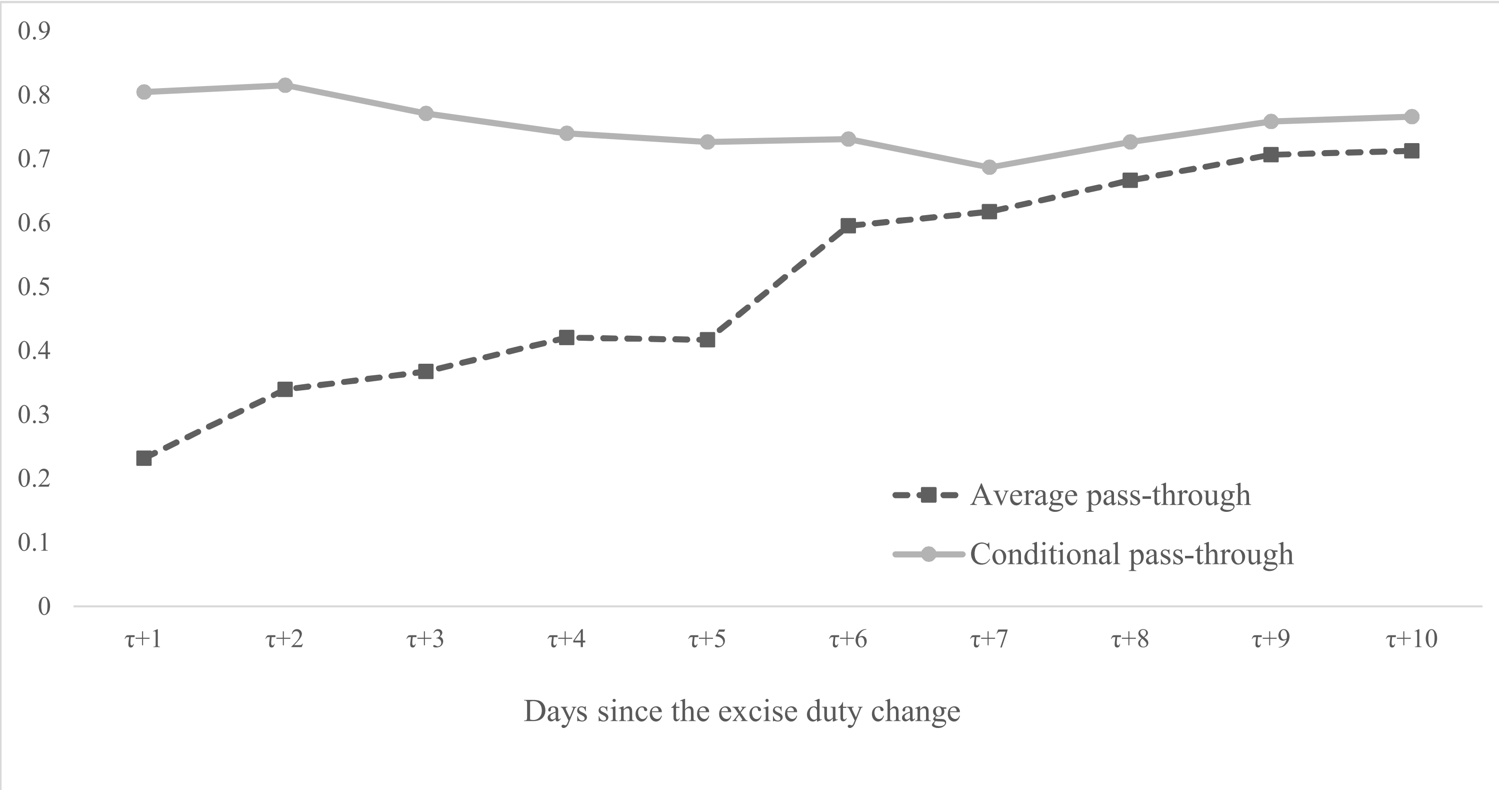
Notes: The figure plots the estimated coefficients from Table 5, column 1, together with the 95% confidence interval.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 7: IMPLIED CONDUCT PARAMETER



Notes: The figure plots the conduct parameter implied by our estimates (assuming constant marginal cost and linear demand).
Source: Authors' calculations based on estimated results.

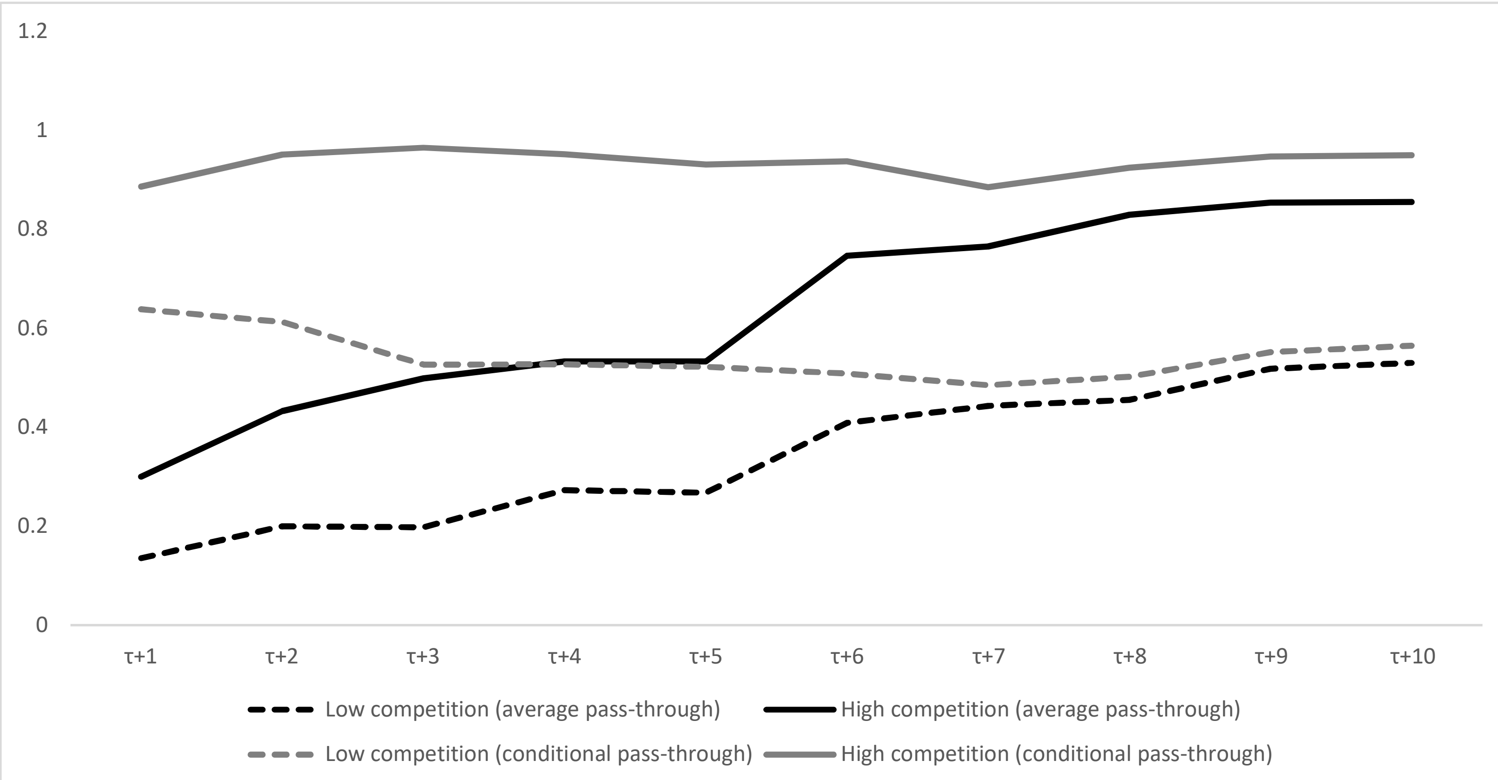
FIGURE 8: PASS-THROUGH AND SPEED OF ADJUSTMENT



Notes: The figure plots the estimated coefficients from Table 6. The average pass-through is estimated using all the data. The conditional pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and τ+δ, where τ is the date of the excise duty change and δ=1,...,10.

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

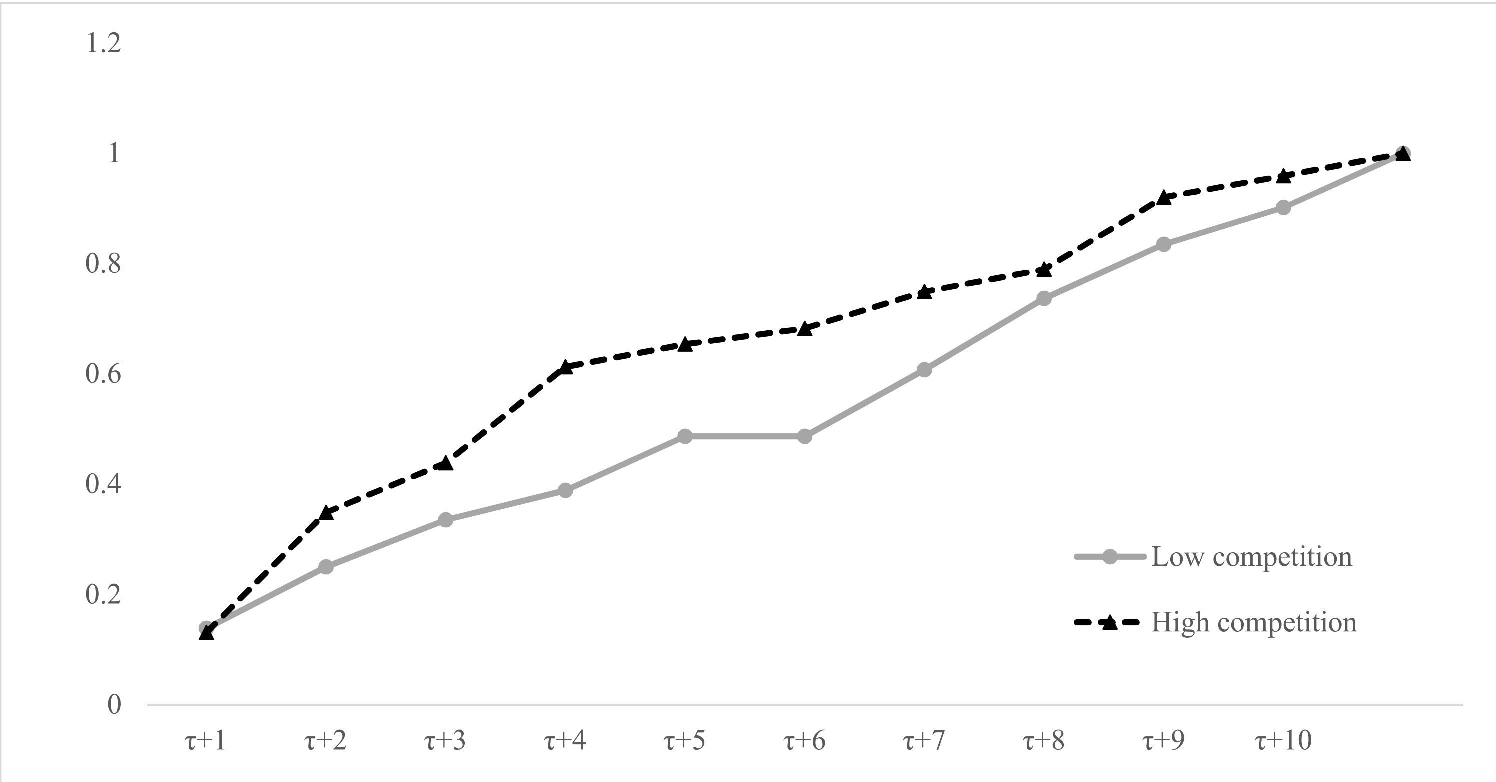
FIGURE 9: SPEED OF ADJUSTMENT AND COMPETITION.



Notes: The figure plots the average and conditional pass-through on islands with 1-3 (low competition) and 4-7 (high competition) gas stations. The average pass-through is estimated using all the data. The conditional pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and $\tau+\delta$, where τ is the date of the excise duty change and δ=1,...,10. Estimated coefficients are reported in Table 7.

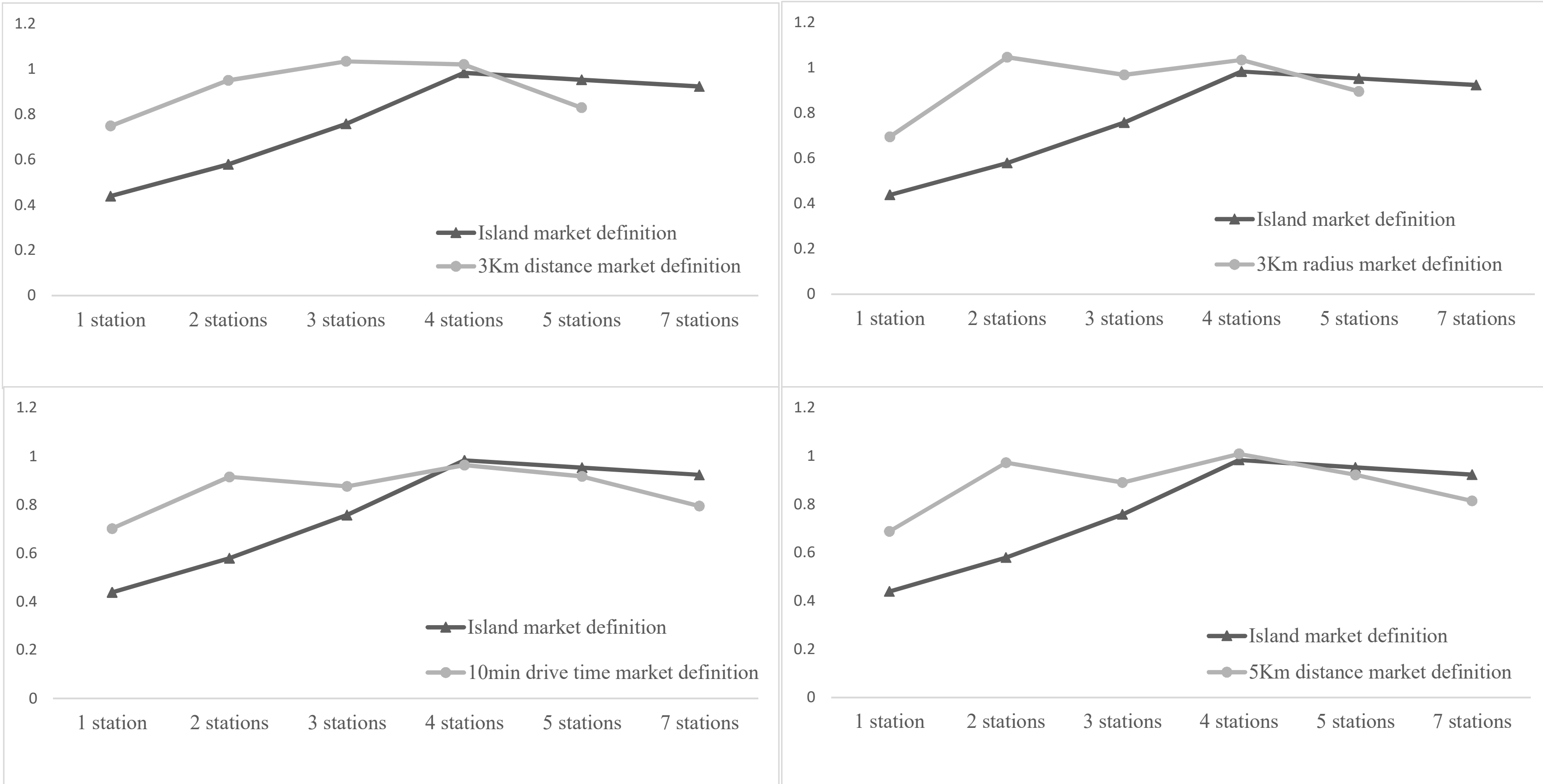
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 10: CUMULATIVE FREQUENCY OF PRICE CHANGES.



Notes: The figure plots the cumulative frequency of station-product combinations that changed their prices between τ and $\tau+\delta$, where τ is the date of the excise duty change and δ=1,...,10, on islands with 1-3 (low competition) and 4-7 (high competition) gas stations.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 11: 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 oil
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 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 oil	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%

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	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$
Sample	Excise change 1	Excise change 2	Excise change 3	All excise changes
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 change × Product type FE				yes
Excise change × Station FE				yes

Notes: The dependent variable is the retail price of product k, on island i, in gas station s, and day $t \in \{\tau - 1, \tau + 10\}$, where τ is the date of each of the three excise duty changes. The pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and τ+10 (conditional pass-through). Standard errors clustered at the gas station level are reported in parentheses below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 4 - PASS-THROUGH AND COMPETITION.

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	FE	FE	IV	FE	FE	IV
Dependent variable	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$
Sample	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes
Tax_{it}	0.449***	-0.736	0.464***	0.139	-0.601	-0.702
	(0.091)	(1.040)	(0.104)	(0.186)	(0.897)	(0.466)
Tax_{it} × Number of $competitors_s$	0.086***	0.082**	0.082***	0.289***	0.265	0.821***
	(0.020)	(0.034)	(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)
First stage F-test (Number of competitors)			54.63***			108.01***
First stage F-test (Number of $competitors^2$)						42.01***
Within R^2	0.937	0.939		0.939	0.939	
Observations	915	915	879	915	915	879
Time FE	yes	yes	yes	yes	yes	yes
Product × Station FE	yes	yes	yes	yes	yes	yes
Excise change × Product type FE	yes	yes	yes	yes	yes	yes
Excise change × Station FE	yes	yes	yes	yes	yes	yes
Additional controls (interactions with income, education, number of ports, and airports, distance from Piraeus and tourist arrivals).		yes			yes	

Notes: The dependent variable is the retail price of product k, on island i, in gas station s, and day $t \in \{\tau-1, \tau+10\}$, where τ is the date of each of the three excise duty changes. The pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and $\tau+10$ (conditional pass-through). Standard errors clustered at the gas station level are reported in parentheses 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	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$
	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 k, on island i, in gas station s, and day $t \in \{\tau-1, \tau+10\}$, where τ is the date of each of the three excise duty changes. The pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and τ+10 (conditional pass-through). *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 changes	All excise changes
	Average pass-through	Conditional pass-through
Tax_{it}	0.232***	0.805***
(τ-1, τ+1)	(0.074)	(0.097)
Tax_{it}	0.339***	0.816***
(τ-1, τ+2)	(0.087)	(0.127)
Tax_{it}	0.368***	0.771***
(τ-1, τ+3)	(0.088)	(0.116)
Tax_{it}	0.421***	0.741***
(τ-1, τ+4)	(0.088)	(0.106)
Tax_{it}	0.417***	0.727***
(τ-1, τ+5)	(0.088)	(0.105)
Tax_{it}	0.596***	0.732***
(τ-1, τ+6)	(0.083)	(0.080)
Tax_{it}	0.618***	0.687***
(τ-1, τ+7)	(0.081)	(0.077)
Tax_{it}	0.667***	0.727***
(τ-1, τ+8)	(0.080)	(0.076)
Tax_{it}	0.707***	0.759***
(τ-1, τ+9)	(0.075)	(0.071)
Tax_{it}	0.713***	0.767***
(τ-1, τ+10)	(0.073)	(0.069)

Notes: Every coefficient comes from a separate regression, where we vary the time window. The dependent variable is the retail price of product k, on island i, in gas station s, and day $t \in \{\tau - 1, \tau + \delta\}$, where τ is the date of each of the three excise duty changes and $\delta = 1, \ldots, 10$. The average pass-through (column 1) is estimated using all the data. The conditional pass-through (column 2) is estimated using observations for station-product combinations that have changed the price at least once between τ and $\tau+\delta$. Standard errors clustered at the gas station level are reported in parentheses 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 7 - SPEED OF ADJUSTMENT AND COMPETITION

PANEL A. AVERAGE PASS-THROUGH.

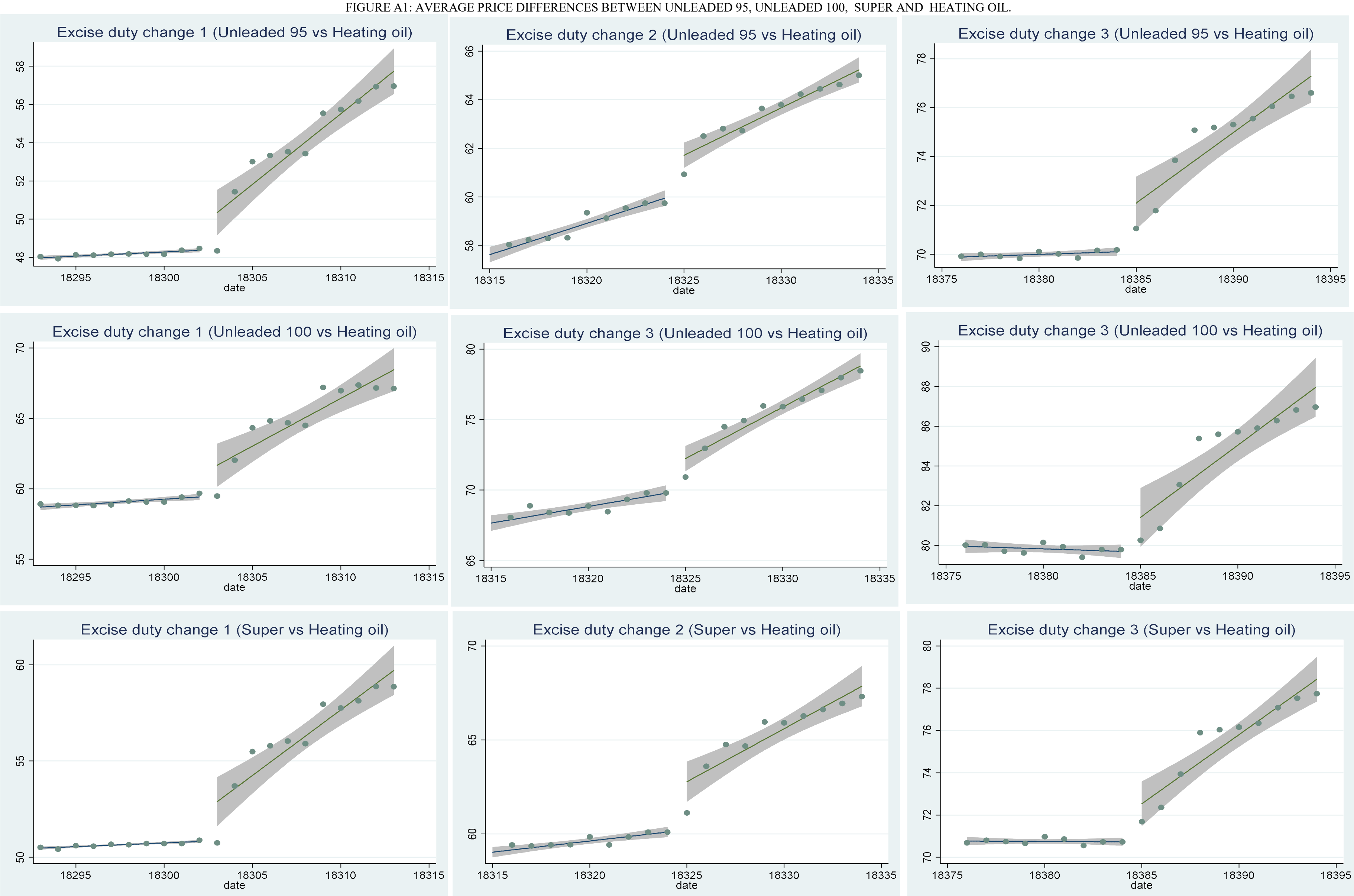
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Estimation method	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Dependent variable	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$	$Price_{ist}$
Sample	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes
	(τ-1, τ+1)	(τ-1, τ+2)	(τ-1, τ+3)	(τ-1, τ+4)	(τ-1, τ+5)	(τ-1, τ+6)	(τ-1, τ+7)	(τ-1, τ+8)	(τ-1, τ+9)	(τ-1, τ+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)

PANEL B. CONDITIONAL PASS-THROUGH.

	(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 changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes
	(τ-1, τ+1)	(τ-1, τ+2)	(τ-1, τ+3)	(τ-1, τ+4)	(τ-1, τ+5)	(τ-1, τ+6)	(τ-1, τ+7)	(τ-1, τ+8)	(τ-1, τ+9)	(τ-1, τ+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)

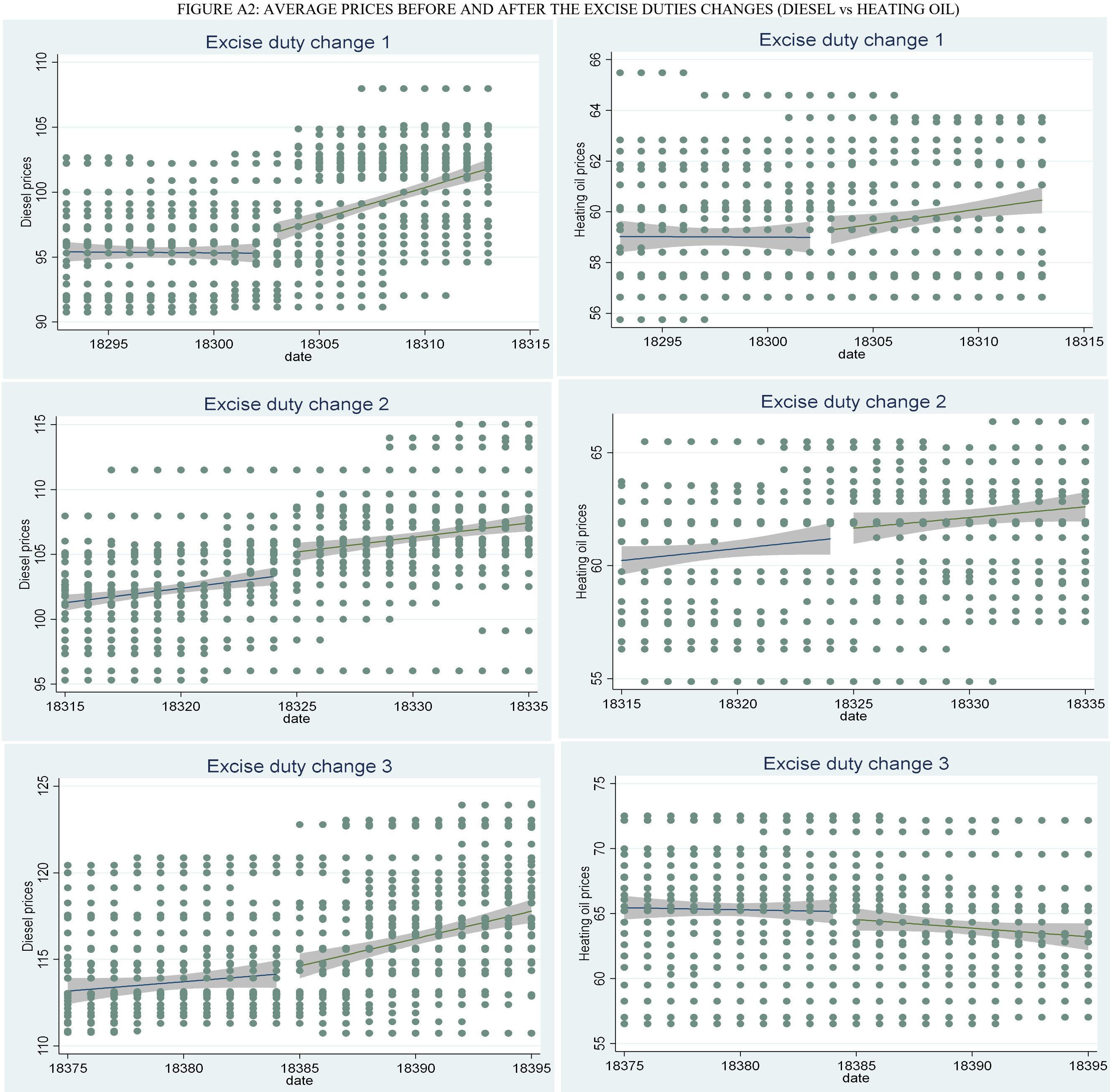
Notes: The dependent variable is the retail price of product *k*, on island *i*, in gas station s, and day $t \in \{\tau-1, \tau+\delta\}$, where τ is the date of each of the three excise duty changes and δ=1,…,10. The average pass-through is estimated using all the data. The conditional pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and $\tau+\delta$. Standard errors clustered at the gas station level are reported in parentheses below coefficients: *significant at 10%; **significant at 5%; ***significant at 1%.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 parentheses 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: AVERAGE PRICE DIFFERENCES BETWEEN UNLEADED 95, UNLEADED 100, SUPER AND HEATING OIL.



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

FIGURE A2: AVERAGE PRICES BEFORE AND AFTER THE EXCISE DUTIES CHANGES (DIESEL vs HEATING OIL)



Notes: The figures plot the evolution of average prices for diesel and heating oil separately ten days before and after the changes in excise duties for each of the three increases as detailed in Table 1.
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	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$
Sample	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes
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 Piraeus					-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 k, on island i, in gas station s, and day $t \in \{\tau-1, \tau+10\}$, where τ is the date of each of the three excise duty changes. The pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and τ+10 (conditional pass-through). Standard errors clustered at the gas station level are reported in parentheses 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	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$	$Price_{kist}$
Sample	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes	All excise changes
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 Piraeus					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 k, on island i, in gas station s, and day $t \in \{\tau-1, \tau+10\}$, where τ is the date of each of the three excise duty changes. The pass-through is estimated using observations for station-product combinations that have changed the price at least once between τ and τ+10 (conditional pass-through). Standard errors clustered at the gas station level are reported in parentheses 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 A3 - FIRST STAGE RESULTS OF PASS-THROUGH AND COMPETITION

	(1)	(2)	(3)
Estimation method	IV- First Stage	IV- First Stage	IV- First Stage
Dependent variable	Tax_{it} × Number of $competitors_s$	Tax_{it} × Number of $competitors_s$	Tax_{it} × Number of $competitors_s^2$
Sample	All excise changes	All excise changes	All excise changes
Tax_{it}	1.692***	0.647**	-5.668**
	(0.299)	(0.250)	(2.161)
Tax_{it} × $Population_s$	0.513***	1.149***	8.246***
(×1000)	(0.069)	(0.101)	(1.131)
Tax_{it} × $Population_s^2$		-0.057***	-0.358***
(×1000000)		(0.010)	(0.100)
F-test	54.63***	108.01***	42.01***
Within R^2	0.814	0.871	0.801
Observations	879	879	879
Time FE	yes	yes	yes
Product × Station FE	yes	yes	yes
Excise change × Product type FE	yes	yes	yes
Excise change × Station FE	yes	yes	yes

Notes: The table reports the first stage results for Table 4, columns 3 and 6. Standard errors clustered at the gas station level are reported in parentheses 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.

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