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What is the "right" geographic market definition?[1]

Christos Genakos[2] and Themistoklis Kampouris[3]

Abstract

This paper examines the "right" geographic definition of relevant markets by analyzing how excise tax pass-through varies with local competition in the retail gasoline market of a large metropolitan city. Using a natural experiment from three unanticipated and exogenous fuel tax hikes and detailed station-level price data, we show that average pass-through is invariant to the number of nearby competitors across various geographic definitions. This contrasts with theoretical predictions and prior island-based evidence, suggesting that the entire metropolitan area functions as a single market. Our findings challenge standard isodistance- or isochrone-based market delineations used in academic research and competition policy.

JEL: H22, L1

Keywords: geographic market definition, gasoline market, competition, pass-through, market structure

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1. Introduction

Geographic market definition is a fundamental element of antitrust analysis. Whether it is used to calculate market shares and concentration ratios to determine if a firm holds a dominant position or to evaluate the anticompetitive effects of mergers, defining the relevant geographic market is as important as understanding the relevant product market (EC, 1997; OECD, 2012; Fletcher and Lyons, 2016). Spatial competition and differentiation are particularly prominent in retail markets where suppliers directly interact with end consumers, such as supermarkets, pharmacies or gas stations. The central question is how geography limits the willingness and ability of consumers to substitute from one supplier to another.

Geographic boundaries depend not only on consumer preferences, but also on transportation costs. Theoretical models of spatial differentiation, such as the Hotelling (1929) line model and the Salop (1979) circle model, capture the idea that stores closer to a consumer are better substitutes than stores located farther away. However, because the geography of actual retail marketplaces is more complicated than the line or circle paradigms typically assumed, quantifying the degree of spatial heterogeneity is not a simple task. Moreover, as with competition in the product space, learning about potential substitutes comes with search and information costs.

Economists have used various approaches and methodologies to define geographic markets, such as price correlation or cointegration tests, or product shipment patterns. Competition authorities worldwide have operationalized the theoretical insights of "closeness" by calculating the number of competitors located nearby using isodistance and isochrone measures. The more recent literature has emphasized the role of incorporating consumers' mobility either through single address models (Davis, 2006; Thomadsen, 2005) or multi-address models (Houde, 2012; Pennerstorfer et al., 2020), recognizing that consumers do not always "start" from home and connectivity along the road network and commuting flows matter. More recently, Doshi et al., (2024) use consumer card spending data and clustering algorithms to estimate the average distance travelled by good category.[4] While more realistic, none of these approaches can guarantee the absence of substitution effects outside the geographic area considered.

We offer a new perspective on the "right" geographic market definition by measuring how tax pass-through[5] varies with competition in locally defined markets within a typical metropolitan area. Our data comes from the retail gasoline market, a market that has been subject to intensive and recurring antitrust investigations around the world (OECD, 2013). We use Athens, Greece's capital, as an example of a large, densely populated urban area that can be divided, in principle, into many local submarkets. We apply isodistance and isochrone market definitions, similar to those used by competition authorities worldwide, and compute for each station the number of competitors within different kilometer radius (geography), different kilometer driving distance (road structure) or different minute driving time (road structure and geography).

We then take advantage of a natural experiment when the Greek government increased the excise duty on petroleum products (gasoline, unleaded gasoline, diesel) three times during 2010. The increments were large and unannounced and provide us with an ideal exogenous shock for estimating the pass-through to retail prices. Heating diesel was exempt from the excise hikes, as it was considered a necessity good. Using daily gas station-level data, we study how pass-through of the excise duty tax varied across markets with different numbers of competitors, while using heating diesel as a control group.

[4] There is also a parallel literature on equilibrium entry in oligopoly markets (Bresnahan and Reiss, 1991; Berry, 1992; Mazzeo, 2002; Toivanen and Waterson, 2005; Sutton, 1991; 1998) that emphasizes that market size is a crucial determinant of entry and competition. Pennerstorfer and Yontcheva (2021) use data on the spatial distribution of the population to identify residential clusters and define local markets.

[5] Throughout the paper we refer to absolute pass-through, which is the degree to which a given absolute change in cost causes a given absolute change in price.

We then compare and test our results against both the theoretical predictions and the findings in Genakos and Pagliero (2022) that measure retail prices' pass-through for the same tax changes across the many small islands Greece is known for. These islands provide an ideal benchmark, since their naturally occurring variability in size and population provides an exogenous source of variability in the number of competing gas stations and they clearly define local markets, as substitution between islands is zero.

Our results reveal two key findings. First, the average pass-through across the whole of Athens is high (0.87) and very close to one, consistent with the literature on tax pass-through in urban areas, indicating a highly competitive market in which consumers bear most of the tax burden. Second, the number of competitors has no impact on the level of pass-through, regardless of which isodistance or isochrone geographic market definition we use. This finding stands in marked contrast to the theoretical predictions of Adachi and Fabinger (2022), who show that pass-through rates should differ from unity in markets where firms possess substantial market power, but should converge towards one, as competition intensifies, either from above or below. This pattern is also in sharp contrast to the empirical results observed in the Greek islands in Genakos and Pagliero (2022), where for the same tax changes, the pass-through is 0.43 on monopolistic islands and grows to about 1 on islands with four or more competitors.

Overall, our results suggest that defining "local" geographic markets based on arbitrary distance or time metrices can be seriously misleading. Even though these metrics may define "local" markets with few competitors that look monopolistic, firms do not exhibit pass-through behavior consistent with significant market power. This suggests that in retail markets, where sellers and consumers interact directly, there is a lot of substitutability that goes undetected, most likely due to consumer mobility and spatial integration. The actual local markets are significantly broader and more overlapping than the current definitions of "local" markets are able to capture. This insight is relevant for academic research and competition policy alike. Interestingly, it supports recent unanticipated decisions, such as the FTC's (2010) decision on the proposed merger of Pilot and Flying-J, two of the largest chains of petrol stations along interstate highways. The commission ruled that the relevant market for these two national companies is the entire country, rather than metropolitan areas or major highway segments. The main reason provided was the strong substitutability driven by trucking companies that use sophisticated information systems to track diesel prices and optimize fuel stops accordingly.

Our findings add to the empirical literature that uses different methodologies to define geographic market boundaries, such as shipment patterns (Elzinga and Hogarty, 1973; 1978), price correlations and cointegration (Audy and Erutku, 2005; Werden and Froeb, 1993), semi-parametric estimation (Pinkse et al., 2002), and willingness to travel circles (Ulrick et al., 2020). In cases where demand elasticities can be estimated, Brenkers and Verboven (2006) offer an econometric approach to define the relevant markets consistent with the SSNIP-test. Unfortunately, we do not observe quantities, which is also the case in many antitrust investigations, and cannot replicate their analysis. We see our pass-through approach as complementary to these other methodologies, as it tries to tackle the question of the existence and effect of market power from an alternative perspective.

We also contribute to the empirical literature on exploiting plausibly exogenous variability in costs to infer the magnitude of pass-through. Past literature has used changes in sales taxes (Barzel, 1976; Poterba, 1996; Besley and Rosen, 1999; Marion and Muehlegger, 2011), exchange rate fluctuations (Campa and Goldberg, 2005; Gopinath et al., 2011), or changes in input prices (Borenstein, Cameron and Gilbert, 1997; Genesove and Mullin, 1998; Nakamura and Zerom, 2010; Miller, Osborne and Sheu, 2017). We finally add to the small but growing literature that examines the impact of competition on pass-through. Existing evidence is somewhat mixed with Doyle and Samphantharak (2008), Miller et al. (2017), Duso and Szücs (2017) and Stolper (2018) finding that pass-through is decreasing in competition, while Cabral, Geruso and Mahoney (2018), Montag et al. (2020), Fuest, Neumeier and Stöhlker (2021), Genakos and Pagliero (2022) and Dimitrakopoulou et al. (2024) conclude the opposite.

2. Theoretical background

Economic theory provides general guiding results related to the tax incidence and competition in differentiated oligopoly markets (Weyl and Fabinger, 2013; Miklós-Thal and Shaffer, 2021; Adachi and Fabinger, 2022). To highlight these results, consider an oligopolistic market with n symmetric firms. The demand for firm i's product $q_i = q_i(p_1, \dots, p_n)$ depends on the vector of prices charged by each firm and is symmetric. The cost function $c(q_i)$ is also symmetric for all firms. The conduct parameter $\theta(q)$ measures the degree of competition and is determined independently of the cost side. Perfect competition corresponds to $\theta(q) = 0$ and monopoly to $\theta(q) = 1$. Denote $q(p)$ the per-firm industry demand under the symmetric prices and define the price elasticity of industry demand as $\epsilon(p) = -pq'(p)/q(p)$. Then, firm i's profit function, when there is a specific tax (excise duty) t, is $\pi_i = p_i(q)q_i - tq_i - c(q_i)$. At symmetric output q, the government's tax revenue per firm is $R(q) = tq$. Denote $\tau(q) = R(q)/pq = t/p(q)$, the fraction of firm's pre-tax revenue collected by the government as taxes. Finally, define the specific tax pass-through rate $\rho_t = \frac{\partial p}{\partial t}$. Using the generalized results in Adachi and Fabinger (2022) for non-zero initial taxes ($t > 0$), the pass-through for unit tax is given by the following formula in a symmetric oligopoly:

$$\rho_t = \frac{1}{1+((1-\tau)\epsilon-\theta)\chi+\frac{\theta}{\epsilon_\theta}+\frac{\theta}{\epsilon_{ms}}}$$

where, χ is the elasticity of the marginal cost with respect to quantity, ϵ_θ is the elasticity of the conduct parameter and ϵ_{ms} is the elasticity of the inverse marginal consumer surplus (or the curvature of the demand function).[6] Hence, in general, the sign and magnitude of the relationship between pass-through and intensity of competition is ambiguous and open for empirical research.

To focus ideas and guide our reading of the empirical results in this paper, it is worth noting that the relationship between unit tax pass-through and intensity of competition greatly simplifies under a set of assumptions that seem realistic in our environment. If the marginal cost is constant and θ is also assumed constant, then the formulas above simplify to $\rho_t = \frac{1}{1+\frac{\theta}{\epsilon_{ms}}}$. Assuming that the marginal cost is constant at the firm level is realistic in our environment, at least in the short run (few days before and after the tax changes), and for the range of quantities typically sold by gas stations in our sample. We also assume the conduct parameter to be constant, given that we investigate a short time window around the policy change, without putting any restrictions on its magnitude. Empirically, we proxy the conduct parameter, which is meant to reflect the intensity of competition among firms, with the number of "local" competitors. Following a long literature on equilibrium entry in oligopoly markets (Bresnahan and Reiss 1991; Berry 1992; Mazzeo 2002; Toivanen and Waterson 2005), the rationale is that in markets with more competitors there would be stronger pressure on prices to reflect and follow marginal costs. Hence, we categorize different "local" markets based on the observed number of competitors and then we compare *across* these "local" markets how the increase in the intensity of competition affects pass-through. The theoretical expectation is that an increase in the conduct parameter (less competition) would lead to lower pass-through if the demand is

[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 (see Weyl and Fabinger, 2013, p.538-539). If demand is linear then $\epsilon_{ms} = 1$, if concave $\epsilon_{ms} < 1$, if convex $\epsilon_{ms} > 1$.

concave, or to higher pass-through if the demand is convex. Demand curvature is clearly an important parameter, as analyzed by Mrazova and Neary (2017) and Miravete et al. (2023). In this paper we cannot estimate it, since we do not have quantity data. However, it is reasonable to assume that it remains constant in the short time frame of our analysis, without affecting the main relationship we aim to quantify.

Therefore, the key theoretical result that we will take to empirics is that pass-through would deviate from one in an environment where firms have significant market power and would converge towards one, either from above unity, as in Miller, Osborne and Sheu (2017), or from below unity, as in Genakos and Pagliero (2022), as competition increases.

3. Institutional and policy change background

The oil industry's market structure in Greece is three-tiered (refining, wholesale, and retail), as is common in many advanced economies. Two companies operate at the refinery level: Hellenic Petroleum operates three refineries, while Motor Oil Hellas operates one. The wholesale market level is also quite concentrated, with Hellenic Petroleum controlling 72% of the market in 2010.[7] Lastly, at the retail market level, there were 20 fuel trade companies operating in 2010, the largest of which were EKO (a subsidiary of Hellenic Petroleum), Shell, BP, Avin Oil (100% subsidiary of Motor Oil), and Jet Oil. EU member states are required to impose a minimum array of energy taxes, but each member state has significant freedom in setting tax rates.[8] Two main taxes 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. The retail price is determined as $P_{retail} = (P_{refinery} + taxes\&fees + margins)(1 + VAT)$. In

[7] The Greek government owns 35.5% of Hellenic Petroleum, but no shares in Motor Oil Hellas.
[8] EU guideline 2003/96/EU.

this paper, we focus on the impact of changes in excise duties on prices, which are reported net of VAT.[9]

In 2010 the inability of the Greek government to borrow funds from the international markets led to a €110 billion bailout loan from the European Commission, the European Central Bank, and the International Monetary Fund. As part of the loan agreement, the Greek government implemented a series of austerity measures. One of the first measures taken to increase tax revenues was to increase excise duties on petroleum products. Excise duties on fuel were raised three times in 2010. Table 1 shows that the tax changes were significant (between 8% and 29%) and different across products. As the government pushed for the use of more energy-efficient fuels, the excise tax rise on diesel was lower than the one on petrol. Remarkably, excise duties for heating diesel remained unchanged, as it was considered a necessity good.[10]

[Insert Table 1 here]

4. Data

We combined multiple datasets for our analysis. First, we obtained daily station-level retail prices for the year 2010 across the whole Attica prefecture, that encompasses the entire Athens metropolitan area, the country's capital and largest city and some peripheral regions. The dataset contains information on five gasoline products: unleaded 95, unleaded 100, super (or leaded gasoline), diesel, and heating diesel. The data on prices were officially collected by the Greek Ministry of Development and Competitiveness via a mandatory reporting system, which

[9] Prices used are equal to $P_{retail}/(1 + VAT)$ since our focus is on excise duties (a unit tax).

[10] Heating diesel is chemically identical to diesel (although colored differently to prevent substitution) and is sold by the same gasoline stations throughout the country. A lower excise duty is applied to it, since most households use heating diesel during the winter months. Obviously, it is illegal to sell and use heating diesel for transportation and the prohibition is actively enforced.

required station managers to record changes in retail prices. The dataset is publicly available (fuelprices.gr) with the explicit aim of facilitating comparison and reducing search costs for consumers. Table 2 presents the descriptive statistics from January until June 2010 for each of the five gasoline products. Unleaded 100 is the most expensive followed by Super, Unleaded95 and Diesel. Heating diesel is significantly cheaper, given its lower tax rates.

[Insert Table 2 here]

Second, we geolocated all the gas stations in the Athens metropolitan area (henceforth, Athens for short) using the address provided in the Ministry's database and the 2010 versions of Google maps and Google Street view. Figure 1 depicts the spatial distribution of gas stations, where different boundaries represent different prefectures and different colors indicate different municipalities. The area we consider includes the Athens and Piraeus prefectures and all municipalities adjacent to them. Central Athens is more congested than the suburbs, as expected.

[Insert Figure 1 here]

To measure competition, we follow the standard practice of defining local markets based on geographic proximity or driving distance between gas stations. In particular, using a combination of tools from Google Maps API and Stata's modules, we consider the number of competing gas stations within a given radius, driving distance or drive time.[11] Table 3 summarizes the distribution of competitors for a representative cutoff from each market

[11] Driving times were extracted using the Google Maps API on a weekday at 13:00, holding the time constant across all stations to ensure consistency and minimize the influence of traffic conditions.

definition (500m radius, 0.5km driving distance, and 3-minute driving time). The full distributions for all alternative cutoffs are reported in Appendix Tables A1.1–A1.3.[12]

[Insert Table 3 here]

We focus on Athens as an example of a large, metropolitan area that combines urban and sub-urban areas. Our goal is to evaluate how tax pass-through varies with competition and compare these patterns to the theoretical predictions analysed earlier, but also to the empirical patterns observed on the Greek islands during the same period and for the same tax changes to identify the proper geographic market definition. Islands offer an ideal benchmark for local market analysis, as substitution effects between islands are zero.[13] As such, we would expect a gas station with strong local monopoly power in Athens to pass-through the tax increases in a similar way to a station in a monopoly island, and similarly for duopolies and triopolies etc. The objective is to ascertain the appropriate isodistance or isochrone criterion for delineating the pertinent geographic market through this comparison.

5. Empirical Methodology

We use a difference in difference methodology, and we start by estimating the aggregate pass-through in this market:

$$P_{jst} = \beta_0 + \rho Tax_{jt} + \beta_{js} + \beta_t + e_{jst} \qquad (1)$$

where P_{jst} denotes the retail price of product j, 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 $\delta = 1, \dots, 13$ is

[12] We also included the gas stations belonging to nearby prefectures, outside Athens, when it came to stations at the borders of the whole region.

[13] 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.

the length of the adjustment period considered. We use a thirteen-day adjustment window as we observe that most of the gas stations (more than 90 percent) had their prices updated by that point. Tax_{jt} 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 similar to Genakos et al. (2018) is based on the comparison of prices for a treatment (gasoline and diesel) and a control group (heating diesel) on two separate dates (before and after the policy change), and it is based on a long literature on difference in difference estimation.[14] We use this model to measure aggregate pass-through, considering the Athens region as a unified single market.

We then focus on the interaction between pass-through and competition and estimate the following model:

$$P_{jst} = \beta_0 + \rho(n_i)Tax_{jt} + \beta_{js} + \beta_t + e_{jst} \quad (2)$$

where the pass-through $\rho(n_m)$ is a linear or quadratic function $\rho(n_m) = \rho_0 + \rho_1 n_m + \rho_2 n_m^2$ of the number of competitors n_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 competing gas stations.

The identifying assumption is $E(e_{jst}|X) = 0$, 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 followed the same trend before the policy changes. Figure A1 shows that during the pre-treatment period

[14] 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), Genakos and Pagliero (2022).

(ten days before the first regulation) the price trends for both treatment and control groups are similar. We also formally test for parallel trends estimating the following model:

$$P_{jst} = \beta_0 + \gamma Trend_t + \gamma_T Trend_t \times Treat + \beta_{js} + e_{jst} \quad (3)$$

where P_{jst} denotes the retail price of product j, in gas station s, on day t and $Treat$ is an indicator variable for products in the treatment group (diesel, gasoline, unleaded gasoline). We separately estimate (3) using data for the ten days before each excise duty change. We then test and cannot reject the null hypothesis that the coefficient γ_T is equal to zero at the 5 percent confidence level. In addition, we replace the treatment indicator with product specific dummies and test the difference in trends between pairs of products. Again, we cannot reject the null hypothesis of parallel trends across products at the 5 percent confidence level in most cases (Table A2).

Second, we replace the trend variable in equation (3) with more flexible period-specific dummies β_t. We also replace the interaction of trend and the treatment group indicator with $\beta_t \times Treat$ and then test the null hypothesis that the coefficients of the period-specific interactions are all equal to zero (individually and jointly). Even with this more flexible specification, we cannot reject the null hypothesis of parallel trends at the 5 percent confidence level (Table A3).[15]

In summary, the differential changes in excise duties across products (Table 1) provide identification of the tax pass-through, while fixed effects capture station-product specific characteristics as well as the macroeconomic shocks that affected the whole economy. The control group accounts for aggregate changes in the prices of petroleum products. Our aim is

[15] We also estimate these specifications using longer windows for tax change 1 and 3. The results are not significantly affected.

to measure how pass-through varies with competition assuming different geographic market definitions.

5. Results

Figure 2 shows the average price difference between treated (diesel, unleaded 95, unleaded 100 and super) and control (heating diesel) products for thirteen days before and after each change in excise duty tax.[16] Each plot consists of two linear prediction lines separately estimated before and after the tax changes. In each case there is a notable jump corresponding to the day of the tax change, without any signs of an anticipation effect. Prices continue to rise gradually after the tax changes, indicating that not all gas stations adjust their prices immediately. Instead, it is a process that takes about two weeks to complete. In principle, we can distinguish between the "average" pass-through and the "conditional" pass-through ("conditional on starting to adjust"), using respectively all the data or only the data for firms that have changed their prices at least once by a given date. Obviously, for long enough periods, the two definitions coincide, as all stations adjust their prices.

[Insert Figure 2 here]

We report results for the average pass-through using a thirteen-day adjustment period and report the equivalent conditional pass-through results in the Appendix. This window is chosen so that it is close enough to the policy change but is also long enough for almost all the gas stations (more than 90 percent) to change their prices. Figure A3 shows the cumulative frequency of gas stations that changed their prices each day after the change in excise duty for all three incidents.

[16] Figure A2 shows the average price difference between each treatment product (diesel, unleaded 95, unleaded 100 and super) and the control (heating diesel) for thirteen days before and after each excise duty change.

5.1. Pass-through estimates

Table 4 provides the average pass-through estimates for all the treated products combined. Columns 1-3 report the measures for each distinct incident, whilst column 4 reports the estimated coefficient for all excise episodes combined. Average pass-through across all episodes is 0.873, with a 95% range [0.843, 0.903], which is very close but statistically different from one. This means that consumers bear most of the tax burden, a result which is in line with the high 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 or in DUrevall (2018), Montag et al. (2020) with pass-through evidence from Europe. Table A4 in the Appendix reports the equivalent conditional pass-through estimates, using only the subset of stations that adjusted their prices within the thirteen-day window.

[Insert Table 4 here]

Table A5 looks at the heterogeneity across products. Diesel pass-through appears higher and more complete than for gasoline. This is also in line with the literature that finds a more inelastic demand for diesel than gasoline (for example, see Ajanovic, Dahl and Schipper, 2012; Karagiannis, Panagopoulos and Vlamis, 2015; Labandeira, Labeaga and Lopez-Otero, 2017; Fridstrøm and Østli, 2021). However, looking overall across all three incidents in column 4, we observe very close to full pass-through across all products.

As a result, there are two key lessons from this subsection. First, we find an average pass-through that is high and very close to one, suggesting a highly competitive market overall. Second, the aggregate pass-through estimates are consistent with existing literature, indicating that petrol stations in Athens have comparable pass-through rates to those in other urban regions, hence enhancing the external validity of the findings.

5.2. Pass-through and competition

Using model (2) we now investigate whether competition is related to the rate of pass-through. Tables A6 to A8 report results using the linear (Panel A) and the quadratic (Panel B) interaction of the number of competitors with the excise duty taxes. In Table A6 competition is measured as the number of competing stations around each station using different radius (0.1km, 0.5km, 1km, 1.5km and 2km). When the number of competitors enter linearly (Panel A) only one of the five estimated coefficients is significant at 5%, whereas when we use the quadratic specification (Panel B) none of the estimated interaction coefficients are statistically different from zero, indicating no effect of local competition on pass-through.

Table A7 repeats the same exercise, but now competition is measured as the number of competing stations within a driving distance (0.1km, 0.3km, 0.5km, 1km and 1.5km) from each station. Again, almost all the interaction coefficients are not statistically significant, with no consistently estimated pattern. Finally, Table A8 looks at the number of competitors around a station for a given driving time (1min, 2min, 3min, 4min and 5min) and reports very similar results, with no statistically significant pattern of how competition affects the tax pass-through.

Next, we use the non-parametric specification that allows for an estimated coefficient for each observed number of gas stations for up to seven stations.[17] Figure 3 plots the estimated coefficients together with their confidence interval for the average pass-through (reported in Tables 5 to 7). Looking at Figure 3.1 that utilizes various isodistance (from 100m to 1500m) metrics, we can see that the relation between pass-through and the number of competitors is

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[17] We distinguish the coefficients for up to six competitors as we know from the literature (Bresnahan and Reiss, 1991; Genakos and Pagliero, 2022) that after three or four firms an additional entrant does not significantly affect competition.

flat. Figure 3.2 and 3.3, use driving distance and driving time respectively, exhibit the same overall flat pattern with respect to the number of gas stations.

[Insert Figure 3 here]

[Insert Tables 5-7 here]

These findings contrast sharply with the theoretical predictions discussed earlier. In monopoly markets we would expect a lower than unity pass-through if the demand is concave, or a greater than unity pass-through if the demand is convex. These results also contradict the increasing and non-linear relationship found in Genakos and Pagliero (2022) for the Greek islands, in which they study the same tax increase events, but island market boundaries are precisely defined and there is no substitutability between markets. They find that on average the pass-through is 0.43 on monopolistic islands and increases significantly to about 1 on islands with four or more competitors and remains flat for further increases in the number of gas stations (see, Figure 3 or Table 7, column 1 in that paper). The fact that monopoly pass-through found here is very close to one, irrespective of isodistance or isochrone, implies absence of market power.[18] The flat pattern between pass-through and competition in Athens suggests that gas stations face stiff competition. Hence, geographic market definitions based on arbitrary measures of distance across sellers may be misleading. The most plausible explanation for this difference is the presence of substitution effects across sellers, likely caused by commuting, which are not captured by any of the distance definitions.

To gauge the robustness of these results we do two perturbations. First, we select only unleaded 95 and diesel as the treatment products, as these are by far the most popular products

[18] In theory, a specific combination of demand (e.g., exponential) and market conduct (e.g., Cournot) could result in an equilibrium where the absolute pass-through rate is independent of the number of firms. However, such a combination is highly specific and does not align with the observed characteristics of the gasoline market in this context. Nonetheless, this theoretical possibility underscores the need for caution when inferring the primitives of an underlying economic model from equilibrium outcomes, as first emphasized by Bulow and Pfleiderer (1983).

in the market. We repeat the whole analysis and plot the estimated coefficients from the non-parametric specification.[19] As we can see in Figure A4 the level of pass-through continues to exhibit a flat relationship with the number of competitors regardless of how the local geographic market is defined.

The second robustness exercise we do is to choose from the available petrol stations those for which we have consistent data before and after for all three incidents, while holding the geographic market definitions and hence the number of competitors unchanged as in our benchmark specification above. Again, we repeat the whole analysis, but we report here only the estimated coefficients from the non-parametric specification for brevity. The predominant pattern in Figure A5 is again a flat relationship between the pass-through and the number of competitors, which is smoother but very similar otherwise to one observed in Figure 3.

6. Concluding remarks

The paper presents a new empirical investigation into establishing the “right” geographic market definition. We use Athens, Greece’s capital, as an example of a large, densely populated, urban area, which we divide into many local submarkets using various isodistance and isochrone market definitions. We then measure the pass-through of three large and unanticipated increases of the excise duty on petroleum products (gasoline, unleaded gasoline, diesel), while using heating diesel as a control group.

When examining how pass-through varies with competition in locally defined markets, it becomes evident that petrol stations in the Athens metropolitan region behave as though they all face substantial competitive pressure. For each gas station in Athens to have four or more

[19] All estimated coefficients are not reported here, available on request.

rivals, the relevant radii must be large enough that catchment areas overlap extensively. Competitive constraints then propagate through these overlaps, so prices behave as if the whole metropolitan area is one market. This finding suggests that traditional geographic market definitions, which rely on arbitrary distance-based measures across sellers and often result in the identification of tightly oligopolistic markets or even monopolies, fail to accurately capture the true substitutability faced by these sellers.

Given that isodistance and isochrone-based geographic market definitions are commonly employed by competition authorities worldwide, our findings raise important concerns about the reliability of these tools and the policy decisions informed by them. The results of this study underscore the need to more thoroughly investigate and incorporate consumer travelling, commuting patterns, and purchasing behavior into market definitions. Additionally, it is crucial to deepen our understanding of how sellers perceive competition and the factors they prioritize when making pricing decisions.

We acknowledge that the market for petroleum products may not necessarily be representative of oligopolistic markets for other products. We selected this market precisely because it is routinely scrutinized by competition authorities worldwide and because it is an example of a market where geographic differentiation is believed to affect competition. The findings of this paper show our inadequate understanding of regional substitutability and the need for more research to better quantify this phenomenon.

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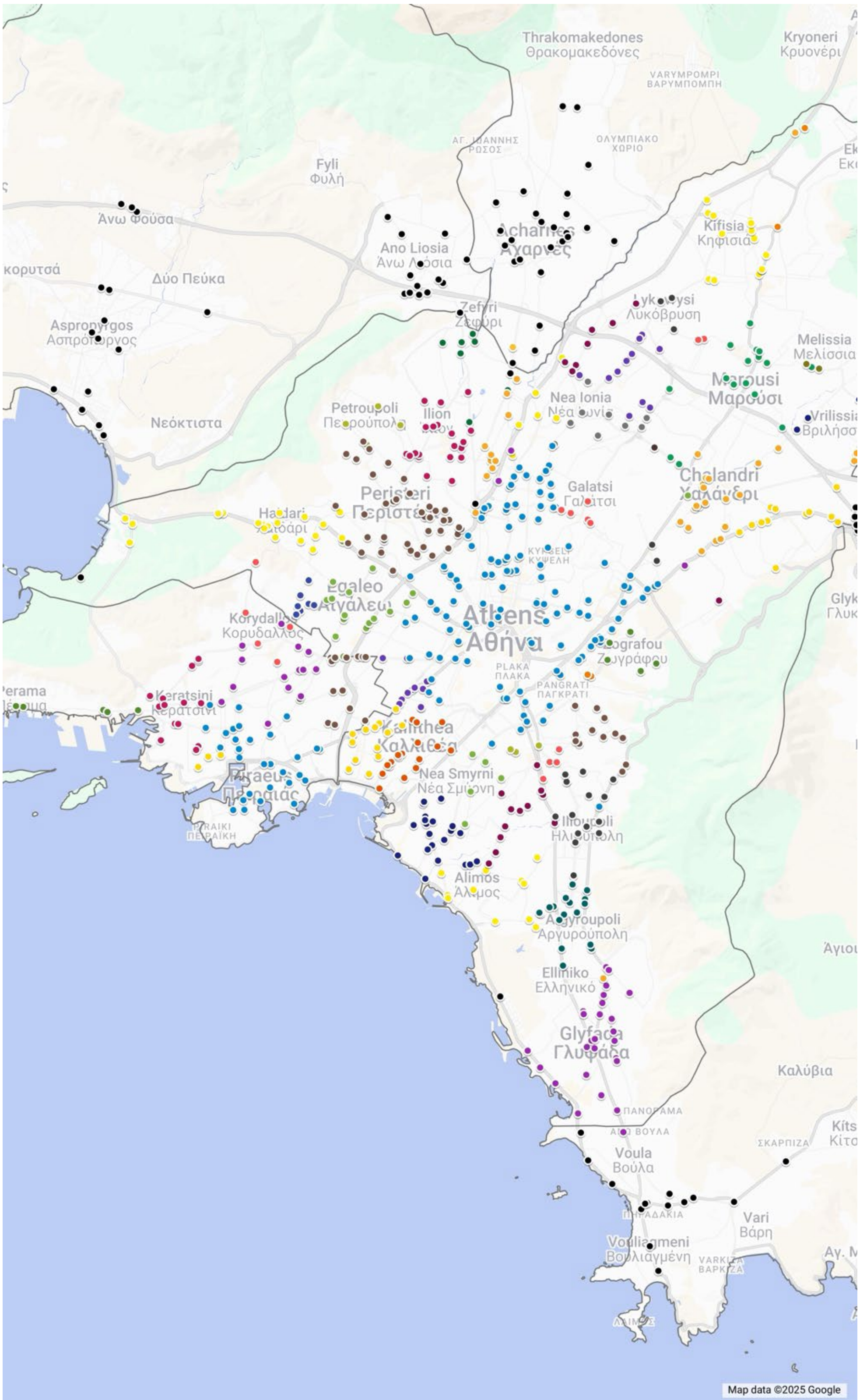
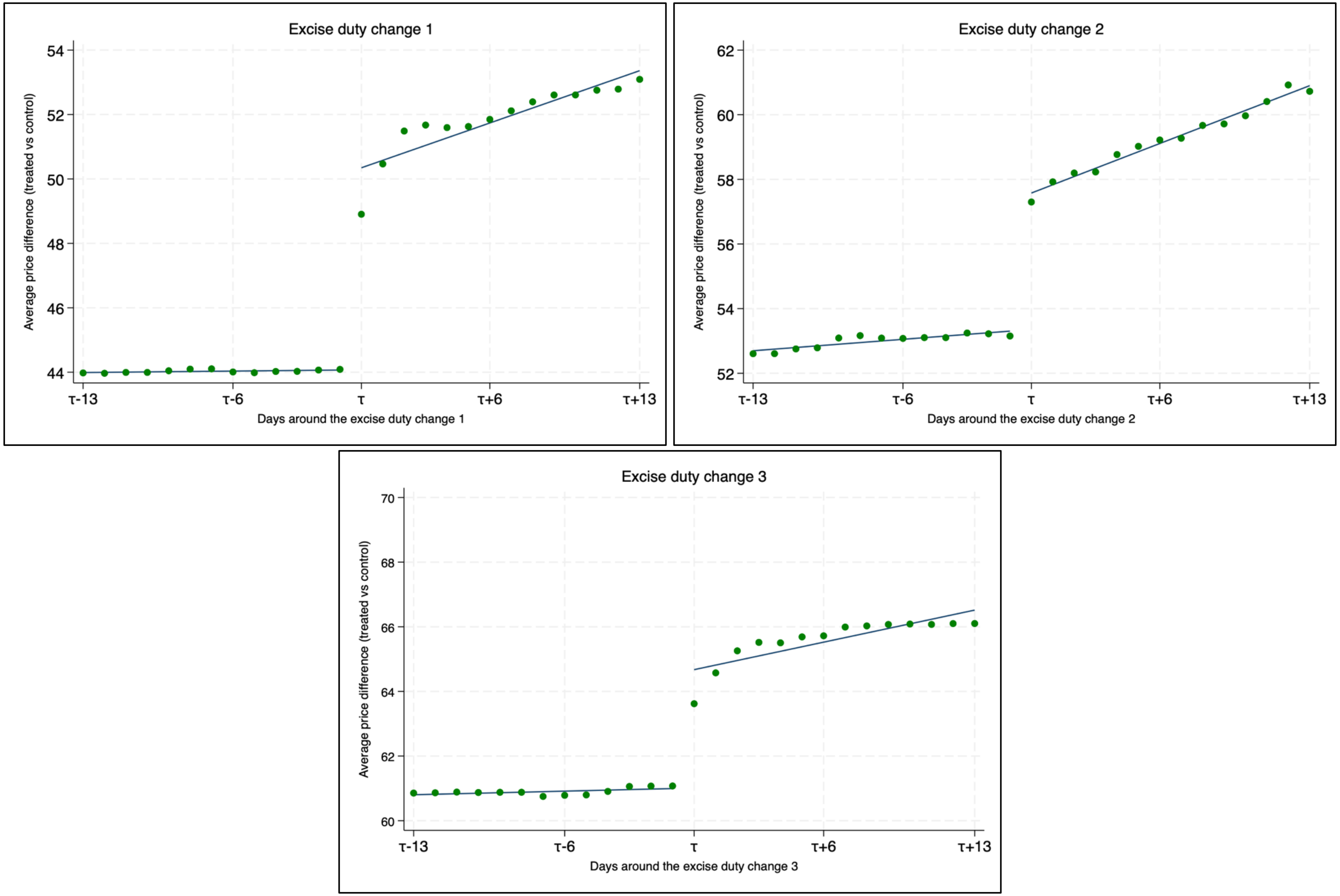
FIGURE 1: GAS STATIONS IN THE ATHENS METROPOLITAN AREA



Notes: The above map demonstrates the structure of the Athens gasoline market, with each dot representing a retailer, every color indicating a different municipality and the grey lines showcasing the borders of each prefecture.

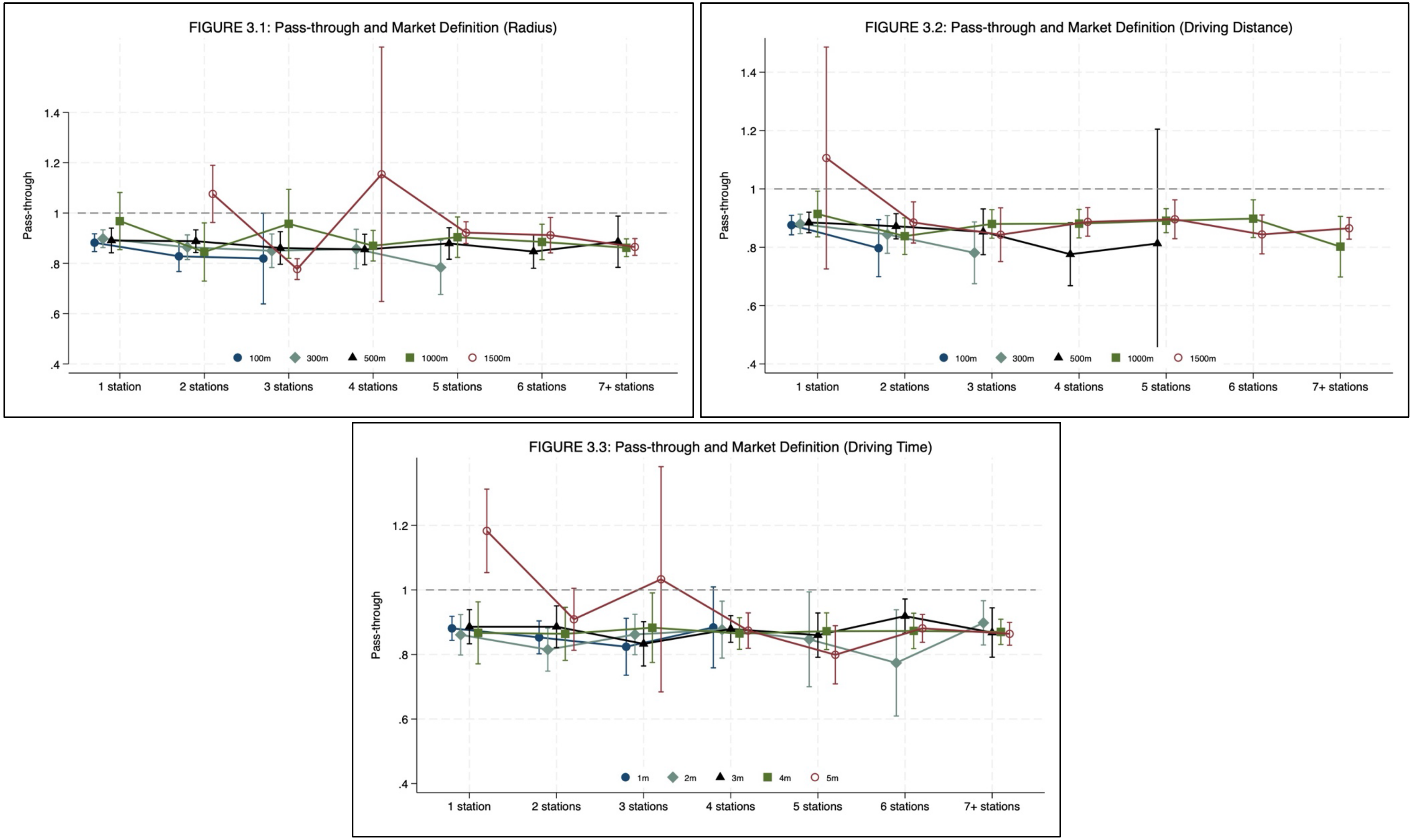
Source: Authors' work based on data from the Ministry of Development and Competitiveness.

FIGURE 2: AVERAGE PRICE DIFFERENCES BETWEEN TREATED AND CONTROL PRODUCTS



Notes: The three figures plot the average price difference between treated (diesel, unleaded 95, unleaded 100 and super) and control (heating diesel) products (for thirteen days before and after each change in the excise duty tax), together with two linear regression lines for the period before and after the tax change.
Source: Authors' calculations based on data from the Greek Ministry of Development.

FIGURE 3: PASS-THROUGH AND MARKET DEFINITION



Notes: The three figures illustrate the estimated coefficients from Tables 5, 6 & 7. Each line represents a different market definition based on radius, driving distance and driving time.
Source: Author's calculations based on data from the Ministry of Development and Competitiveness with the use of Google Maps API.

TABLE 1: EXCISE DUTY TAX CHANGES (€ cents per litre and Δ%)

Type of energy product	(1) Unleaded 95	(2) Unleaded 100	(3) Diesel	(4) Super (leaded)	(5) Heating diesel
before	41.0	41.0	30.2	42.1	2.1
10-Feb-10	53	53.0	35.2	54.1	2.1
	(29%)	(29%)	(17%)	(29%)	(0%)
04-Mar-10	61	61	38.2	62.1	2.1
	(15%)	(15%)	(9%)	(15%)	(0%)
03-May-10	67	67	41.2	68.1	2.1
	(10%)	(10%)	(8%)	(10%)	(0%)

Notes: The table reports the level and percentage 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
PRICES (N = 227,966)					
Unleaded 95 (€ cents per litre)	117.0	10.8	119.8	99.1	127.3
Unleaded 100 (€ cents per litre)	134.4	12.2	136.3	121.4	148.3
Super (€ cents per litre)	123.4	11.5	126.0	104.1	135.5
Diesel (€ cents per litre)	101.0	8.1	102.4	89.0	110.5
Heating diesel (€ cents per litre)	56.3	6.8	56.5	50.3	59.8

Notes: This table indicates the summary statistics of each gasoline type for the first half of 2010.

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

TABLE 3: MARKET DEFINITION AND COMPETITION

	Radius	Driving distance	Driving time
N. of Gas stations	500m	0.5km	3min
1 competitor	68	256	47
2 competitors	117	151	74
3 competitors	121	71	99
4 competitors	83	12	88
5 competitors	44	6	76
6 competitors	40		52
7+ competitors	23		60
Mean	3	2	4
Median	3	1	4
25th percentile	1	1	1
75th percentile	6	3	7+

Notes: The table reports the distribution of competitors for each market structure using three representative definitions: a 500m radius, a 0.5km driving distance, and a 3-minute driving time from each gas station's location.

Source: Author's calculations based on data from the Ministry of Development and Competitiveness with the use of Google Maps API.

TABLE 4: EXCISE DUTY PASS-THROUGH

	(1)	(2)	(3)	(4)
Estimation method	FE	FE	FE	FE
Dependent variable	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$
Sample	1st excise	2nd excise	3rd excise	All excise changes
Tax_{jt}	0.848***	0.985***	0.821***	0.873***
	(0.030)	(0.039)	(0.025)	(0.015)
Observations	1,024	1,309	3,992	6,325
Within R^2	0.893	0.816	0.728	0.994
Station × Type FE	yes	yes	yes	yes
Day FE	yes	yes	yes	yes
Excise × Station FE				yes
Excise × Type FE				yes
F-test (*p-value*)				
Tax = 1	26.10	0.155	52.99	72.81
	0.000	*0.694*	*0.000*	*0.000*

Notes: The dependent variable is the retail price of product j, in gas station s, and day $t \in \{\tau - 1, \tau + 13\}$, where τ is the date of excise tax change. Standard errors are clustered at the gas-station level and are reported in parentheses below coefficients. ***, **, * mark statistical significance at the 0.01, 0.05 and 0.10 level respectively. The F-test reports whether the null hypothesis of complete pass-through (coefficient = 1) can be rejected.
Source: Author's calculation based on data from the Ministry of Development and Competitiveness.

TABLE 5: PASSTHROUGH AND COMPETITORS BASED ON RADIUS

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	FE	FE
Dependent variable	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$
Radius	100m	300m	500m	1000m	1500m
1 competitor	0.882***	0.898***	0.891***	0.968***	
	(0.018)	(0.018)	(0.025)	(0.058)	
2 competitors	0.828***	0.864***	0.888***	0.845***	1.076***
	(0.031)	(0.025)	(0.023)	(0.059)	(0.058)
3 competitors	0.819***	0.850***	0.861***	0.957***	0.777***
	(0.092)	(0.034)	(0.033)	(0.070)	(0.021)
4 competitors		0.857***	0.855***	0.870***	1.154***
		(0.040)	(0.031)	(0.031)	(0.258)
5 competitors		0.784***	0.879***	0.904***	0.922***
		(0.055)	(0.032)	(0.041)	(0.022)
6 competitors			0.847***	0.885***	0.912***
			(0.034)	(0.036)	(0.036)
7+ competitors			0.886***	0.862***	0.865***
			(0.052)	(0.018)	(0.017)
Observations	6,325	6,325	6,325	6,325	6,325
R-squared	0.994	0.994	0.994	0.994	0.994
Station × Type FE	yes	yes	yes	yes	yes
Day FE	yes	yes	yes	yes	yes
Excise × Station FE	yes	yes	yes	yes	yes
Excise × Type FE	yes	yes	yes	yes	yes
F-test : *p-value*					
Joint F-test (p)	*0.200*	*0.156*	*0.866*	*0.428*	*0.000*
1 competitor = 2 competitors	*0.091*	*0.201*	*0.936*	0.130	
2 competitors = 3 competitors	*0.927*	*0.707*	*0.456*	*0.210*	*0.000*
3 competitors = 4 competitors		*0.881*	*0.897*	*0.237*	*0.145*
4 competitors = 5 competitors		*0.266*	*0.549*	*0.482*	*0.370*
5 competitors = 6 competitors			*0.442*	*0.719*	*0.793*
6 competitors = 7+ competitors			*0.515*	*0.541*	*0.203*

Notes: The dependent variable is the retail price of product j, in gas station g, and day $t \in \{\tau\text{-}1, \tau\text{+}13\}$, where τ is the date of the excise change. Standard errors are clustered at the gas-station level and are reported in parentheses below coefficients. ***, **, * mark statistical significance at the 0.01, 0.05 and 0.10 level respectively.

Source: Author's calculations based on data from the Ministry of Development and Competitiveness with the use of Google Maps API.

TABLE 6: PASSTHROUGH AND COMPETITORS BASED ON DRIVING DISTANCE

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	FE	FE
Dependent variable	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$
Driving distance	0.1km	0.3km	0.5km	1.0km	1.5km
1 competitor	0.876***	0.880***	0.885***	0.914***	1.106***
	(0.017)	(0.017)	(0.018)	(0.040)	(0.194)
2 competitors	0.808***	0.844***	0.872***	0.838***	0.885***
	(0.048)	(0.033)	(0.022)	(0.032)	(0.036)
3 competitors	-0.112***	0.781***	0.853***	0.880***	0.843***
	(0.017)	(0.054)	(0.040)	(0.025)	(0.047)
4 competitors			0.776***	0.881***	0.887***
			(0.055)	(0.025)	(0.025)
5 competitors			0.813***	0.891***	0.896***
			(0.200)	(0.021)	(0.034)
6 competitors				0.898***	0.844***
				(0.033)	(0.034)
7+ competitors				0.802***	0.865***
				(0.053)	(0.019)
Observations	6,325	6,325	6,325	6,325	6,325
R-squared	0.994	0.994	0.994	0.994	0.994
Station × Type FE	yes	yes	yes	yes	yes
Day FE	yes	yes	yes	yes	yes
Excise × Station FE	yes	yes	yes	yes	yes
Excise × Type FE	yes	yes	yes	yes	yes
F-test : *p-value*					
Joint F-test (p)	*0.110*	*0.000*	*0.348*	*0.461*	*0.673*
1 competitor = 2 competitors	*0.156*	*0.256*	*0.573*	*0.120*	*0.260*
2 competitors = 3 competitors	*0.000*	*0.291*	*0.652*	*0.272*	*0.447*
3 competitors = 4 competitors		*0.000*	*0.227*	*0.984*	*0.364*
4 competitors = 5 competitors			*0.856*	*0.728*	*0.825*
5 competitors = 6 competitors				*0.850*	*0.243*
6 competitors = 7+ competitors				*0.102*	*0.532*

Notes: The dependent variable is the retail price of product j, in gas station g, and day $t \in \{\tau\text{-}1, \tau\text{+}13\}$, where τ is the date of the excise change. Standard errors are clustered at the gas-station level and are reported in parentheses below coefficients. ***, **, * mark statistical significance at the 0.01, 0.05 and 0.10 level respectively.

Source: Author's calculations based on data from the Ministry of Development and Competitiveness with the use of Google Maps API.

TABLE 7: PASSTHROUGH AND COMPETITORS BASED ON DRIVING TIME

	(1)	(2)	(3)	(4)	(5)
Estimation method	FE	FE	FE	FE	FE
Dependent variable	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$	$Price_{jst}$
Driving time	1min	2min	3min	4min	5min
1 competitor	0.881***	0.861***	0.886***	0.867***	1.183***
	(0.019)	(0.032)	(0.027)	(0.049)	(0.066)
2 competitors	0.853***	0.815***	0.886***	0.864***	0.909***
	(0.026)	(0.034)	(0.033)	(0.042)	(0.049)
3 competitors	0.824***	0.862***	0.833***	0.883***	1.033***
	(0.045)	(0.032)	(0.035)	(0.055)	(0.178)
4 competitors	0.884***	0.877***	0.879***	0.865***	0.874***
	(0.064)	(0.045)	(0.021)	(0.025)	(0.028)
5 competitors		0.847***	0.860***	0.872***	0.799***
		(0.075)	(0.035)	(0.029)	(0.046)
6 competitors		0.774***	0.919***	0.873***	0.881***
		(0.084)	(0.027)	(0.028)	(0.022)
7+ competitors		0.898***	0.868***	0.870***	0.864***
		(0.035)	(0.039)	(0.020)	(0.018)
Observations	6,325	6,325	6,325	6,325	6,325
R-squared	0.994	0.994	0.994	0.994	0.994
Station × Type FE	yes	yes	yes	yes	yes
Day FE	yes	yes	yes	yes	yes
Excise × Station FE	yes	yes	yes	yes	yes
Excise × Type FE	yes	yes	yes	yes	yes
F-test : *p-value*					
Joint F-test (p)	*0.476*	*0.222*	*0.491*	*1.000*	*0.000*
1 competitor = 2 competitors	*0.315*	*0.108*	*0.983*	*0.964*	*0.001*
2 competitors = 3 competitors	*0.548*	*0.119*	*0.238*	*0.769*	*0.501*
3 competitors = 4 competitors	*0.412*	*0.732*	*0.215*	*0.740*	*0.375*
4 competitors = 5 competitors		*0.706*	*0.627*	*0.824*	*0.138*
5 competitors = 6 competitors		*0.487*	*0.156*	*0.979*	*0.084*
6 competitors = 7+ competitors		*0.126*	*0.225*	*0.926*	*0.470*

Notes: The dependent variable is the retail price of product j, in gas station g, and day $t \in \{\tau\text{-}1, \tau+13\}$, where τ is the date of the excise change. Standard errors are clustered at the gas-station level and are reported in parentheses below coefficients. ***, **, * mark statistical significance at the 0.01, 0.05 and 0.10 level respectively.

Source: Author's calculations based on data from the Ministry of Development and Competitiveness with the use of Google Maps API