Location analysis and price variations of fuel stations in the island of Lesvos, Greece

Dr. Dimitris Kavroudakis
Assistant Professor, University of the Aegean, Geography Department, Mytilene, Lesvos, Greece, 81100, dimitrisk@geo.aegean.gr

Abstract

Liquid fuels prices are among the factors affecting transportation cost. Transportation is important for agricultural products as well as tourist-services which are among the main local products of Lesvos island, Greece. The multiplier effects of fuel prices to other products may have a great influence in local economy. Subsequently, it is of vital importance to monitor and analyse fuel prices and the spatial distribution of fuel-stations in the island in order to identify cases of price-stickiness and system irregularities with negative effects. Lesvos island is a single entry economy regarding liquid fuels as fuels are transported to the island by sea and then distributed from the main harbour to the 36 fuel stations located in various areas of the island. This special characteristic of the island is a unique opportunity to study the effects of geographical space and location selection on fuel stations and prices variations and the formation of a network of competitive actors (fuel stations). This work will analyse the location characteristics of this network of fuel-stations and examine how daily prices vary with respect to demand (population), competition (proximity to fuel-stations) and network location selection. After analysing the point pattern of the suppliers, we examine daily price variations with respect to geographical characteristics of each fuel-station and discuss the relationship between geographical space, price variations and location selection.

Keywords

geographical analysis, fuel stations, location selection, proximity, competition

1 Introduction

Liquid fuels such as petrol related fuels, is a highly additive value product as it is one of the main energy sources in Greece. Petrol related products have multiple effects at crucial sectors of economy such as transportation, agricultural production and tourism. Due to liquid fuels **importance** to the economy, it is important to establish and monitor a healthy competition and distribution of relevant products and prices as this contributes to the good working of the market. A healthy competition landscape of fuels market influences local products-market and establishes a stable economic environment for investments and innovation. The 97% of land transportation in Greece, use petrol related products according to the Ministry of Environment, Energy & Climate Change (2014). The **aim** of this work is to examine the relationship between retail fuel prices and geographical factors in a single entry economy such as the island of Lesvos in Greece. The first **objective** is the examination of the current spatial distribution of populated areas and fuel stations in order to understand the provision of fuels on the island and gain insight into the spatial scale of fuel pricing. The second objective is the quantification of the most important geographical factors that contribute to the variations of fuel prices in the area of study.

During the last years, the spatial **distribution of business** has been analysed extensively with the use of

Geographical Information Systems (GIS) (Cohen 2000, Longley et al. 1995) as well as with Agent Based Modelling (North et al. 2007). Business location selection process is also in the centre of a number of other research projects (Ridley et al. 2010, Mejia-Dorantes et al. 2012, Zentes et al. 2012). More specific, **location selection** for fuel retailers has also been the subject of a number of papers such as the one from Ioja et. al. (2012) which focused on the analysis of proximity between residential areas and fuel stations. Also, Kerzmann et. al. (2013) have developed computational modelling approaches for the optimization of natural gas fuelling stations placement based on traffic volume. GIS modelling approaches have been used from Nicholas et. al. (2004) for the evaluation of possible location selection for hydrogen fuel stations. Finally, regarding location selection, Clemenz et. al. (2006) have used data from Australia to examine the effects of location choice on price competition and found that higher density reduces average prices. Jimenez at al (2010) elaborated on the concepts of accessibility and fuel prices by examining accessibility and distance to the nearest petrol station in search for lower price. In the relative literature there are some attempts to analyse and examine fuel price variations and asymmetries. Heppenstall et al (2005) have used agent based methodology and spatial interaction models to examine fuel prices in Leeds UK. Also, Driffield et al (2003) have analysed price asymmetries and discussed possible improvements of the Asymmetric Price Transition approach. Finally another similar attempt is the work of Deltas (2008) which uses monthly fuel prices data to examine the response of fuel retailers to wholesale price increases. Literature shows that spatial factors influence in a certain extent prices and proximity may determine price policies and market power of fuel stations. This work will quantify the effects of geographical factors to fuel price variations for Lesvos island in Greece which is a single entry economic space. All fuels are transported to the island from the main harbour of the island and then transported to each of the 36 fuel stations of the island. This is a unique geographical space where we expect to find price variations with respect to distance from entry point, as well as the location of competition in the road network.

2 Case study

The majority of liquid fuels in **Greece** is mainly imported by sea with large boats and then transported with road vehicles to most of the mainland areas in Greece. Island economies are supplied by sea vessels of medium to small size, transferring liquid fuels to local storage facilities located in the most of the islands. Importing of liquid fuels in Greece is conducted by two big companies: EL.PE. and MOTOR-OIL (ELPE 2014, Motor Oil 2014) with fuel storage installations in Aspropirgos, Elefsina, Thessaloniki and Corinth located in mainland Greece. The two companies trade homogeneous fuel products with small product differentiation, mainly for local consumption. There are 2 big **refinement** companies in Greece, 20 trading companies supplying the market sector and 8000 retail stations with 600 of them being independent. The relevant energy regulation agency in Greece holds an advisory role with auditing and recommendatory responsibilities regarding the trading of oil products in the Greek economy. Its role is to facilitate fail competition in the market and monitor prices, market operations and licensing.

According to a recent legislation of the Greek Ministry of Development, all fuel station should record and submit their retail prices to the Ministry of Development for statistical purposes. The ministry of development is publishing daily-fuel-prices online. The **Geocoded Fuel Prices Database** (GFPD) which is developed for the purpose of this study, is a collection of 3288 daily prices for the 36 fuel stations of Lesvos island from July-2011 to May-2014. This database contains publicly available information which has been collected, formatted and managed for academic purposes. The 36 fuel stations are geocoded and associated with the GFPD. Each daily price case contains date of publication, id of the fuel station and the price in Euros. The GFPD contains daily values for Brent Crude oil as well as daily prices of Dollar currency for further examination and analysis of price asymmetries. The main objective of the GFPD is to provide academic researchers with a complete time-series of geocoded price cases along with Brent oil prices for possible further analysis of the effects of oil price variations to the retail prices of fuels. In the near future the database will be published online for researchers to download it.

The island of **Lesvos** is located in the north east part of the Aegean sea in Greece, and consists of 73 populated areas (small villages and towns) with total population of 86436 individuals and total area of 1632.8 km^2. There are 36 fuel retailers (Figure 1) who are supplied from the main harbour of the island. The island consists of 93.2% rural and 6.8% urban areas. The rural character of the island as well as the spatial distribution of the populated areas over a large geographical space are two of the most important reasons for the increased transportation demand across the island. The areas in the island can be categorized with respect to altitude as 37% lowlands (close to mean sea level), 41.1% middle altitude up to 699m. and 21.9% mountainous areas above 700m. altitude. Figure 2 depicts the increasing number of vehicles in the island from 2005 to 2010 which indicates the relatively increasing importance of liquid fuels in the island over the past years. The greater the number of vehicles in the island, the greater the demand for fuels.

The GFPD database contains a sequence of daily prices for all 36 fuel stations in the island. This **time-series** dataset contains price values which can be aggregated by time period. The island's global price mean (IGPM) is computed weekly, monthly and quarterly, which enables the comparison between fuel stations. For every fuel station, aggregated measures of fuel prices have been computed for comparison against the IGPM. Figures 11 and 12 present this relationship between stations average price and IGPM in four different time-windows for stations 1 and 23. Station 1 belongs to the second quantile of stations with regard to distance from entry point and station 23 belongs to the fourth quantile. As can be seen from the following graphs, the station which is relatively further away from the island entry point has the tendency to present aggregate values of prices above IGPM and on the other hand station 2 which is relatively close to the island's entry point presents relatively more harmonized prices with IGPM.

In the network of fuel stations in the island, there are 9 stations which are relatively **isolated**. The isolation measure used to categorize the stations is the “average driving distance” to all other fuel stations which is an indicator of how far is on average to the competitors. As seen in figure 8 the upper quantile of the driving distance distribution includes 9 stations which have been the focus of this part of the paper. We argue that geographically isolated fuel stations may have different price policy than all other stations in the island as they have a relatively more valuable location in the road network of the island. This location value may be reflected in their fuel prices. This is because for the 9 isolated stations, all other alternative providers are located further away which makes them less favourable for the customers as customers have fewer choices. According to literature there is a relationship between fuel stations concentration and relative market power of each fuel station. As supply of fuels is provided by small number of stations, each station has more local market power if demand is not changing.

3 Methodology and Theory

This section will explore and analyse properties of the spatial point patterns of fuel stations and populated places. Two significant properties of fuel stations examined in this paper are their relative location on the island and their prices. By means of Point Pattern Analysis we examine how these properties are affected, if so, by competition and their spatial association with populated places. Also, of great interest is the quantification of scale of interaction between fuel prices, primarily. For a comprehensive overview of the summary functions please refer Illian et al “Statistical analysis and modelling of spatial point patterns” (2008).

One of the most common approaches for examining the spatial order of a spatial pattern is the **Nearest Neighbour Analysis** (NNA). It quantifies the spatial differentiation between the spatial events by using the *mean observed nearest neighbour distance*. For more information regarding the principles and pitfalls of this approach please see Pinder & Witherick (1972). Equation 1 shows the Nearest Neighbour Analysis formula used in this study:

$$Rn = \frac{\bar{D}\,(Obs)}{0.5\sqrt{\frac{a}{n}}} \qquad \text{(Equation 1)}$$

Rn: Nearest Neighour Value

$\bar{D}$***(Obs)***: mean objerved nearest neighbour distance

a: Study area

n: number of observations

Another approach to quantify the characteristics of the spatial distribution of fuel stations as well as populated places in Lesvos island is the **Pair Correlation Function** (PCF). This approach is related with the probability of finding a spatial observation a given distance from another spatial observation in the study area. It examines the spatial distribution of fuel stations and populated places by calculating how many spatial observation exist within a distance band away from other similar spatial observation. The conditional probability density of finding a fuel station or a populated area at distance *r*, given there is a fuel station or a populated place at the origin can be calculated with the following formula:

$$g(r) = \frac{1}{2\pi r}\frac{A^2}{n_i n_j}\sum_{i=1}^{n_1}\sum_{j=1}^{n_2} w_{ij}^{-1} k_h(r - |x_i - y_i|) \qquad \text{(Equation 2)}$$

g(r): the PCF at a specific radius

A: total study area

$\mathbf{n_i}$ and $\mathbf{n_j}$: number of observations of type 1 and type 2 respectively

$\mathbf{x_i}$ and $\mathbf{y_i}$: locations of points type 1 and type 2 respectively

$\mathbf{w_{ij}}$: weighting function for accounting for edge effects bias

r: distance band

Another approach for quantifying the spatial distribution of fuel stations in Lesvos island taking under consideration the spatial distribution of the populated places is the **Marked Correlation Function**. This approach estimated the Stoyan's (Stoyan 1994, p.262) mark correlation for a point pattern with two types of spatial objects (fuel stations, populated places). It quantifies the spatial dependence of one type of spatial points against the other type.

$$k_{mm}(r) = \frac{E_{xy}(M_x * M_y)}{E(M * M')} \qquad \text{(Equation 3)}$$

$\mathbf{E_{xy}}$: conditional expectation given there are points at locations x and y

r: distance factor

$\mathbf{M_x}$ and $\mathbf{M_y}$: types of observations

M and **M'**: random types drawn independently from the marginal distribution of types

E: usual expectations

Another measure of examining not only the location of fuels stations but also the mean price values of gas products for each fuel station is by using the **Empirical Mark Variogram Function**. This approach examines the relationship between spatial differentiation of stations and the numerical differentiation of their mean prices. The quantification of how fuel prices are related with distance between fuel stations is realized by using the empirical variogram. The variogram has three parameters which are often used for description of the results (Wälder 1996): The *nugget* which is the height of the graph at the beginning of the vertical axes, the *still* which is the limit of the graph tending to infinity and finally the *range* which is the distance after which the difference between the graph and the sill becomes very small (almost negligible).

$$\gamma(r) = E[(1/2) * (M_1 - M_2)^2] \quad \text{(Equation 4)}$$

E[ ]: expectation

M_1 and M_2 are the fuel prices of two fuel stations

r: distance between fuel stations

4 Results

In order to test for spatial clustering of fuel stations in specific geographical areas of the island and obtain some useful information about this spatial distribution, we use the four aforementioned methods. Initially we used the **Nearest Neighbour Analysis** for the quantification of proximity between fuel stations. The distance to the k=1 nearest neighbour was estimated for each of the 36 fuel stations, as shown in figure 3. Table 1 shows the results of this method:

Observed mean distance:	0.025
Expected mean distance:	0.035
Nearest neighbour index:	***0.444***
Z-Score:	-1.984

Table 1: Results of the “Nearest Neighbour” Statistic

The results of the NNA (0.444) show that spatial distribution of fuel stations have a minor tendency towards spatial clustering. The results of this analysis show that it is quite common for fuel stations to have competitors under the proximity of 2 km. This is the typical nearest distance between fuel stations. Mean values for the 2^{nd} and 3^{rd} order nearest-neighbour are between 4 and 5 km respectively, indicating that it is not unusual for fuel stations to have just one competitor quite near while other competitors lie at a safer distance of 4-5 km. further away. Although fuel station locations practically consist with a clustered point pattern, their relative location selection seems to be more dependent on populated places and less on proximity to other stations. Since fuel stations cover a certain demand for fuels, they are dependent upon the populated places therefore the two spatial distributions, of fuel stations and populated places, are expected to be spatially correlated.

In figure 4 the estimated **Pair Correlation Function** g(r) for the point pattern of populated places reveals a profound clustering around distances of less than 1 km and a much milder around 2 km. This is an indication that moving away from a populated place it is highly probable to meet another one at the aforementioned distances. The spatial configuration of populated places directly affects the characteristics of fuel station point pattern, as displayed next.

Moving on to the next function in figure 5, the results of **Mark Correlation Function** shows a clear dependence between the two spatial point patterns. The area above the theoretical function shows attraction as an increased expectation for points of the other type at the respective distances, whereas the area below shows repulsion. Obviously this dependence works only one way since the locations of populated places can't be conditioned upon the relative location of fuel stations but only the other way around. We argue that the scale of interaction between fuel station locations, represented by clusters of approximately 2 km., are not governed by intrinsic properties of the distribution of the stations, such as competition, but rather they are dependent upon the spatial configuration of populated places.

In support of the Mark Correlation Function, the results of **Empirical Mark Variogram Function** in figure 7 shows that prices at small distances tend to be more similar to each other. Fuel stations that are closer than 2 km to each other tend to have highly dependent pricing. As distance increases so does dissimilarity between prices until a point of indifference is reached at approximately 9 km, which may be considered as a rough boundary of dependence between prices, beyond of which the forces of competition become less relevant (Stoyan et al. 1994, Ohser 1983).

The previous summary functions were using only the relative distance between points of the spatial point patterns of fuel stations and populated places. The next part will examine the **spatial association of fuel prices**. We take into consideration the actual fuel prices along with the spatial structure of the fuel prices point pattern, which in this part is treated as marked by a continuous numeric variable. As the spatial configuration of populated places mainly affects fuel station clustering, competition should affect the spatial distribution of fuel prices. The Mark Correlation Function in figure 5, shows that fuel prices cluster at short distances below 2 km., right from near to zero distances. This means that prices tend to be similarly higher at shorter distances instead of fluctuating around 1 in the case of an independent marked point pattern and more specifically if pricing wouldn't have been affected by the prices of near fuel stations There is also evidence of inter-dependent prices at distances centred around 4 km.

5 Geographical factors affecting fuel prices

In order to identify factors affecting price anomalies as well as identify the form and extend of the factors contribution, a multiple regression model need to be evaluated. This **model** includes a number of factors and evaluate the extent of their influence on the retail price of liquid fuels in the fuel stations of Lesvos island. Local agglomeration externalities such as spatial potential demand and proximity to competitors are calculated. The price setting process is a complex process that may be influenced not only from economic or geographic factors but also from other more complicated forces which are beyond the scope of this work. Nevertheless, this part examines which geographical factors influence price variations for the period of the January-2011 to May-2014. The first variable that will be examined with respect to fuel prices is the period in which the price sample has been collected. During **summer period** (June, July, August and September) the island of Lesvos is a popular tourist destination for 34 to 38 thousand individuals from Northern Europe (Kathimerini 2014, Emprosnet 2014). As public transportation in the island is relatively sparse and time consuming for a 4 to 5 day stay, there is a relative higher number of vehicle renting services. There is an increase of vehicles in the road network of the island during summer period which increases the demand for fuel products from the fuel stations. The model will include a boolean variable as an indicator for the summer period in order to examine the effect of this period on the variations of fuel price. Fuels are transported to the island by sea and the main **entry point** of this commodity is Mytilene harbour (main town of the island). After arrival of the commodity in the island, road transportation is used to supply fuel-stations around the island. This transportation, add extra costs which is associated with the distance from the entry point to the station. In the context of this research we include this variable to the regression model in order to examine the effects of this distance to the variations of the fuel price. The distance from entry point is calculated as a "driving distance" and is taking under consideration the road type and speed limit. Fuel stations in the island of Lesvos are located in various locations across the road network of the island. This network of stations can be considered as a mathematical graph where each station represents a "graph node" and the driving distance between stations is the "value" of each of the edges. In order to quantify the effects of relative location of a fuel station on the variations of fuel price, we use the average driving distance to the other fuel stations as a variable in the regression model. The "**average distance to competition**" (ADC) has been computed in order to illustrate the degree of isolation for each of the stations. The higher the ADC, the more isolated a fuel station is. Isolated fuel stations may show different price policies than other stations which have a more central location in the network of stations. The last factor of the model is **population** of station's catchment area which is related to demand of gas-related products and possibly related to the price policy followed by the station owner. In order to examine the effects of the size of local population in the catchment area over the variations of the fuel price, we compute the population around 1km driving distance of each fuel station. A **regression** model has been developed for the analysis of 4 independent variables against a dependent variable which is the "*retail price*" of fuels in the 36 fuel stations of the island. The independent variables are:

- $\mathbf{x_1}$: Period of the price sample. If a price value refers to summer period of June, July, August and September then x_1=1 otherwise x_1=0
- $\mathbf{x_2}$: Driving distance (in meters) from the main port (island's entry point) to the location of a fuel station.
- $\mathbf{x_3}$: Average driving distance (in meters) from a station to all other competitors.
- $\mathbf{x_4}$: Population in 1km driving distance around the fuel station

All driving distance have been computed based on Google Directions Service (Google 2014) and population data are from the 2011 Census of Greece (2014). The results of the regression model is presented in table 3 which shows the estimates (betas) for each of the four independent variables. The histogram in figure 9 depicts the histogram of the model's residuals which are distributed around 0. The "*Std.Error*" column depicts the variability in the estimate for the coefficient. Column "t value" is the division between "Estimate" and "*Std.Error*" and is a measure of whether the coefficient for this variable is meaningful for the model. Last column (Pr(>|t|)) refers to the probability a variable to be ***not*** relevant to the model. Also, in order to quantify the quality of the model, figure 10 presents four plots: the Residual versus fitted plot (top-left), Normal Q-Q plot(top-right), Scale location plot of the predicted values (bottom-left), Residuals versus Leverage (bottom-right). In residuals versus fitted values plot the points do not have any obvious pattern and are randomly scattered around the centre line of 0. There is no obvious violation of linearity or homoscedasticity. The normal Q-Q plot helps towards the examination of residuals normality. The residuals of the regression model appear to be normally distributed across all theoretical quantiles which is an indicator of model residuals' normality. The "scale location plot" which uses the square root of the standardized residuals in order to identify violations in the normality of the residuals shows that there is no obvious pattern in this plot as well which is an indicator of no violation of linearity and homoscedasticity.

The regression equation for this case study can be seen in formula 1. **Summer** period ($\mathbf{x_1}$) has a positive and relatively high effect on the variations of fuel price which means that for this dataset and under this model structure, it seems that summer period prices are relatively higher than prices collected in fall, winter and spring period. More specifically, according to the results of the regression model, during summer months fuel station owners can earn additionally 25 euros per 1000 litres of fuels on average. Distance to **entry point** of the island (**x_2**) has a week positive effect on the variations of fuel price which means that this variable has a small and positive responsibility towards the variations of fuel prices. For example, a fuel station which is located 50 km from entry point offers on average 0.04 euro more expensive fuels than fuel stations that are located in the main city of the island. This of course is just an indication and does not imply that all fuel station owners follow this price policy. Average **distance to competition** (**x_3**) has a positive effect on the variations of fuel price. This refers to the relative position of each fuel station on the network of stations. This measure seems to be relevant and it explain a small part of the fuel price variations. More specifically, according to the results of the regression model, for every 10 km of average isolation distance there is an increase of 0.0125euros per litre. Population in catchment area of 1km (**x_4**) is the fourth variable of the regression model and has a negative effect on the variations of fuel price. This may be due to security, stability and risk mitigation offered by increased demand.

We use two measures for the explanatory power of the model: R^2 and AIC. The R^2 of the regression model is 0.7457612 which means that ~74% of the observed variance of fuel prices can be explained from the regression model we developed. The R^2 is the squared value of the correlations between the dependent and independent variables of the model. The Akaike information criterion (AIC) of the model is -2063 which is has been used for model selection among other potential regression models.

In order to check for multicolinearity of the model predictors, we used the Variance Inflation Factor (VIF) diagnostic approach. The VIF for each of the parameters has been estimated using the following formula:

$$VIF_i = \frac{1}{1 - R_i^2} \qquad \text{(Equation 5)}$$

R_i^2 is the R^2 from a model predicting X_i using all other covariates as predictors as for example:

$$X_1 = \delta_0 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_4 + \nu \qquad \text{(Equation 6)}$$

This approach examines the independence of the predictors as some predictors may be related. VIF, quantifies the proportion of variance of a predictor, explained by all other predictors. Values of 1 correspond to non co-linearity whereas higher values indicate collinearity. The following table shows the results of the VIF approach of our model.

	Predictor	**VIF**
x_1	Summer Period	1.086
x_2	Distance to Entry Point	1.012
x_3	Average distance to competition	1.072
x_4	Brent price (25 ago)	1.018
x_5	Dollar-Euro exchange rate (60 days ago)	1.059
x_6	Population in 0.5 km	1.065

Table 2: Values of Variance Inflation Factor for the six predictors of the regression model

As can be seen from the above VIF values, there is no profound co-linearity between the model's predictors.

6 Discussion and further work

The results of the spatial exploratory data analysis show that the relative locations of fuel stations on Lesvos might be balanced between two competing forces, competition which compels them to be as far as possible from each other and their dependence on populated places which binds them to closely follow a particular spatial configuration, clustering at less than 2 km. Furthermore, inserting the fuel prices into the analysis confirmed that this 2 km scale of interaction is indeed very important to pricing among competitors but also revealed that the spatial interaction goes beyond that scale, up to approximately of 8 km away. This is important because it sets the scale of fuel pricing from local scale to a regional scale. To further examine this wider scale of interaction, we need to survey car drivers on the matter of how far are they willing to travel for better fuel prices. Another point worth noting is that the wider scale of interaction between prices is probably a distance threshold beyond which isolation begins and pricing is conducted more or less independently of the competitors, as the regression results have shown regarding the relationship between increase of average distance to competition and price.

The results of the regression model show that there is a relationship between price variability and summer period. If this relationship is not based on increased price of the wholesale prices, then it indicates an opportunistic approach mainly aiming to the increased traffic of vehicles in the island. Tourist services include hiring of vehicles (cars or motorbikes) for commuting around the island. The relatively increased prices of fuels in the island during the summer period, may trigger those activities. According to results of the regression model, average spatial isolation of some fuel stations enables them to have a more favourable location in the island's road network which consequently gives those actors a competitive advantage over their price strategy. Increased prices of fuel products from those stations may be the result of increased market power. Furthermore, there is some evidence showing that spatial asymmetries of mean prices between stations exists in this single-entry economy. Nevertheless, the dataset size does not allow for throughout examination as it contains only 4 years of daily data. Driving distance is a factor which affects prices differently in each locality and each station is affected uniquely. This is that there is no common estimate of how geographical distance form entry point affects fuel prices. Each station is affected in different way. Nevertheless, there are some cases where the geographical space affects prices variations not only in space but in time as well. Over the time period of 4 years there are some cases where the mean prices of a station are above the average price of the island but after some time this relationship changes and mean prices of a station appear well bellow the island's average price. In order to further examine this space-time variation, we need to include a greater number of cases in the GFPD database and incorporate wholesale prices as well as Brent prices. This will enable the examination of the total flow of prices from Brent crude oil to wholesale product and then to retail end-product. This relationship has to be examined in a greater time period (more than 4 years) in order to conclude on the variability of space-time relationship. Another possible extension of this work could be the incorporation of brand information for each fuel station in the island in order to examine if there is any obvious relationship between brand and price strategies. There may a possible common approach in calculating transportation cost of fuels from the entry point of the island to the fuel station between stations of the same brand. This will enable the inter-brand comparison of fuel prices across the island.

The results of this work may be of potential interest to the industry monitoring agencies for the understanding of price variations across geographical space and the early warning of potential asymmetries in price setting forces. Monitoring current supply and demand of fuel prices may also be of potential interest to new station owners for the identification of valuable locations for the opening of a new business. This type of analysis may designate under-served areas and areas where isolated stations have relatively increased prices as a result of their market share. A potential extension of this work may include an analysis of asymmetrical relationship between Brent oil price and retail prices of fuels as there are concerns that reductions in crude oil prices are not passed on to consumers in form of lower retail prices mainly because prices changes are not fully transmitted as well as because there is a time lag between the price adjustments at the respective stages.

7 Appendix

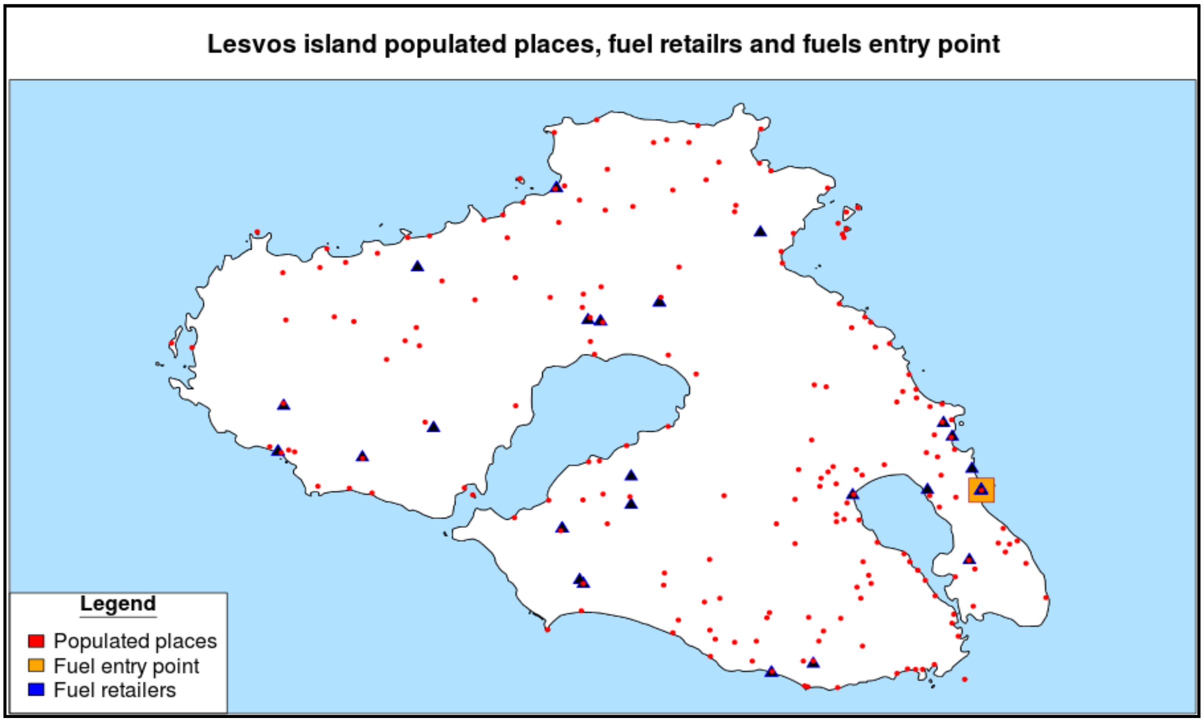

Figure 1: Populated places and liquid fuels retailers of Lesvos island

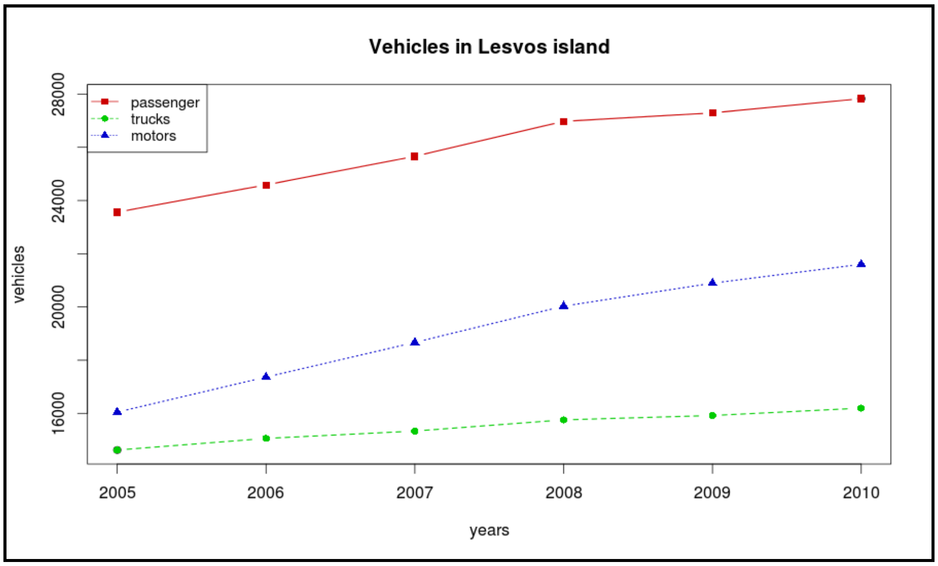

Figure 2: Increasing number of vehicles in Lesvos island from 2005 to 2010

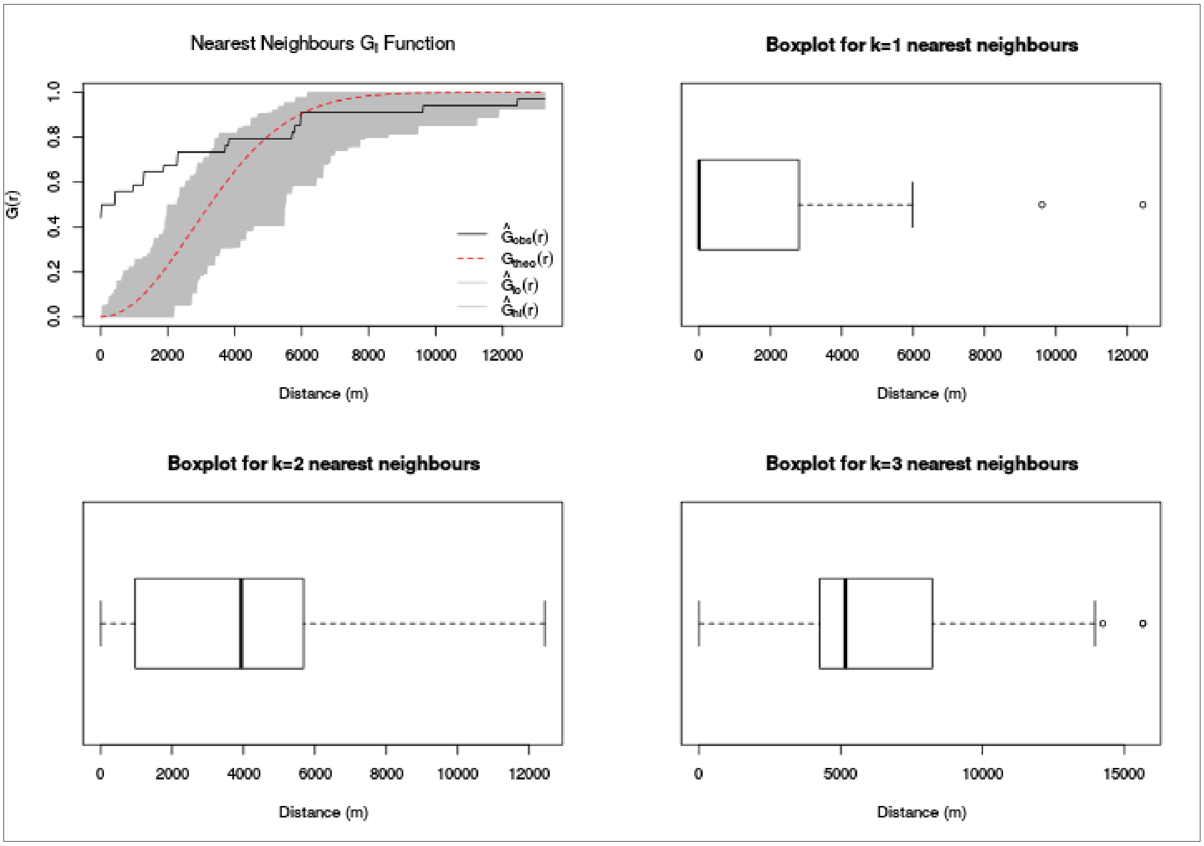

Figure 3: Nearest neighbour G(x) function for the point pattern of the 36 fuel stations and boxplots of distances for k = 1, 2 and 3 neighbours. The solid black line of the first graph corresponds to the observed G(x) function, whereas the dashed red line and grey area correspond to the theoretical function and simulated envelopes respectively of Complete Spatial Randomness. The observed function displays the strong clustering effects of fuel stations at distances less than 2km apart, contrasting to the theoretical case of fuel stations independently distributed across the island

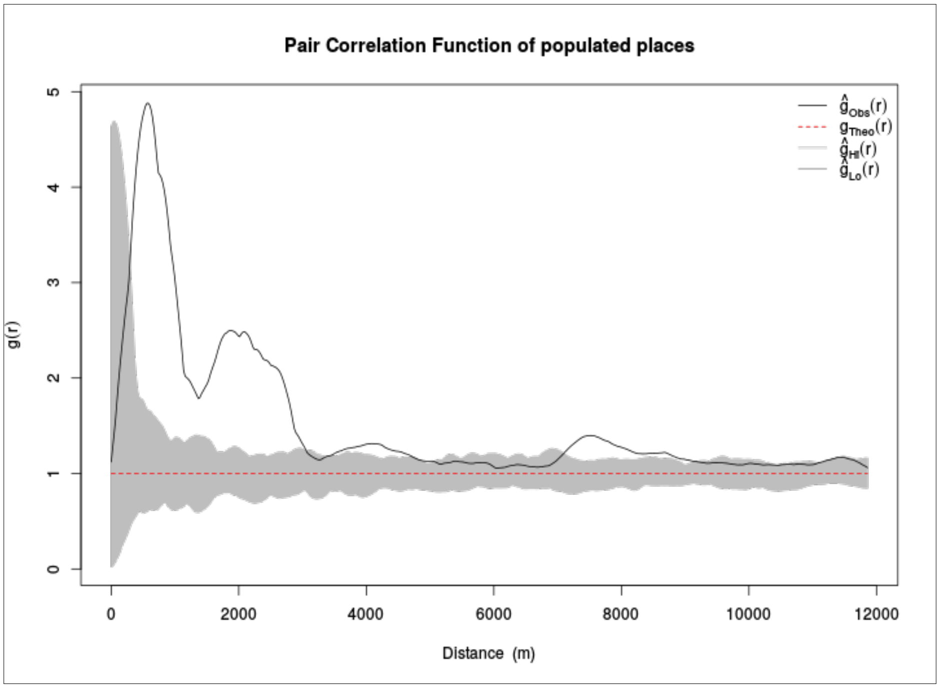

Figure 4: Pair Correlation Function g(x) for the populated places spatial point pattern. The observed pattern is represented by the solid black line while the comparison against Complete Spatial Randomness is represented by the dashed red line for the theoretical function and the grey area for the simulated envelopes

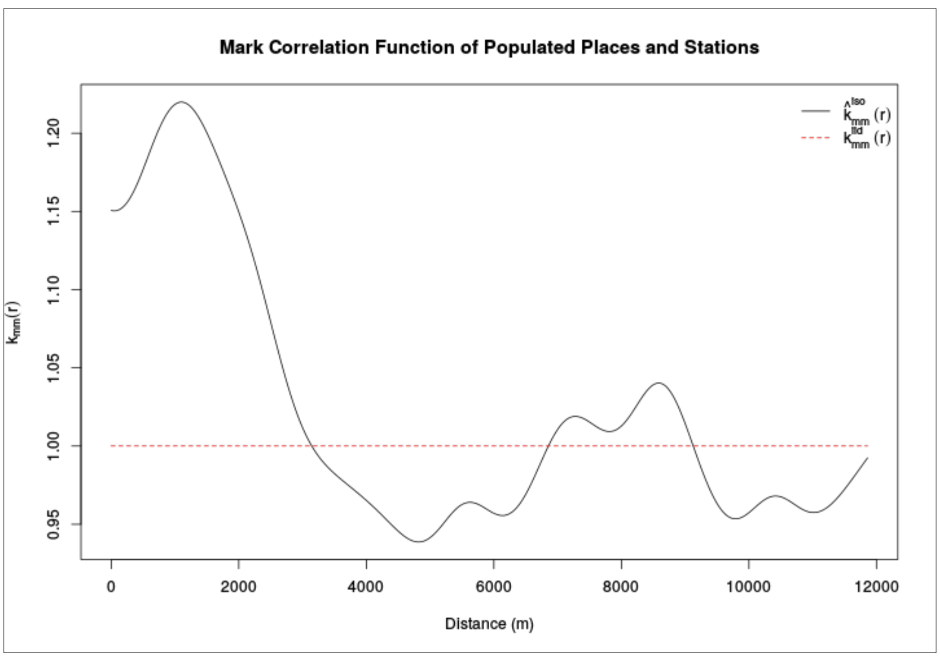

Figure 5: Mark Correlation Function revealing a strong spatial relationship between stations and populated places relative location. The observed and theoretical functions are represented by the black and red lines respectively

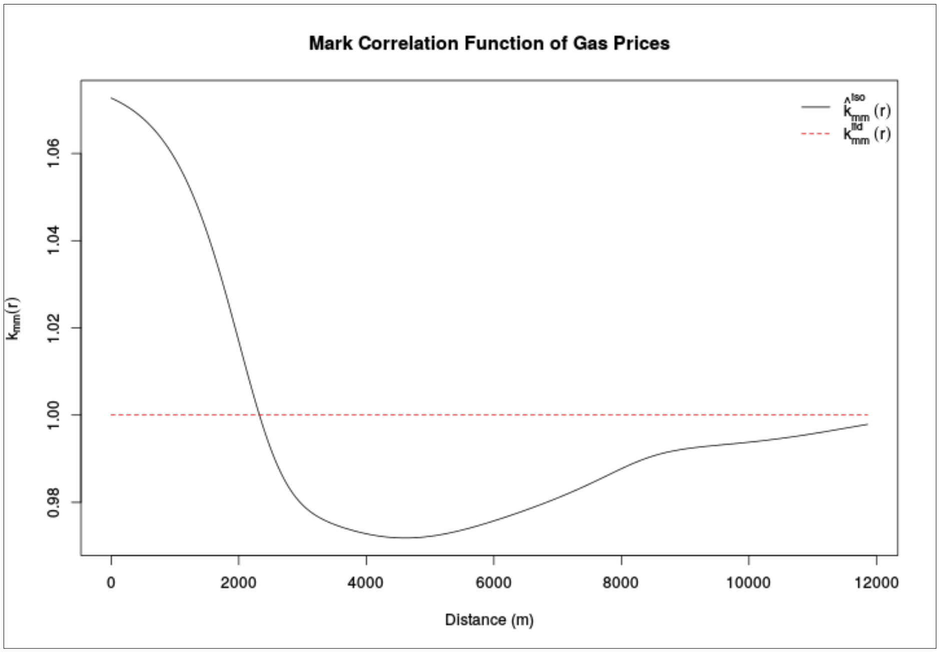

Figure 6: Mark Correlation Function for fuel prices

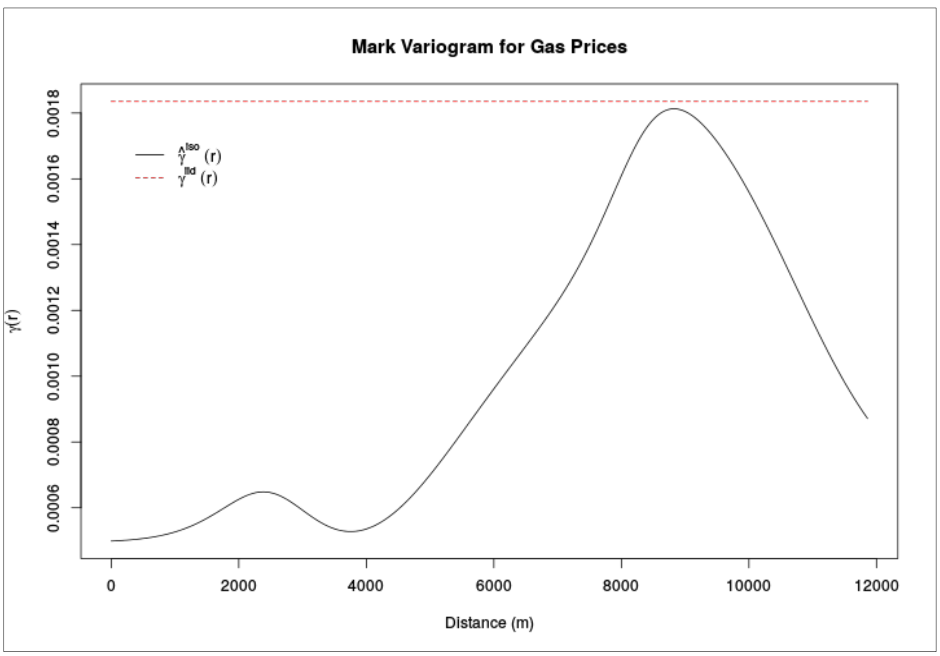

Figure 7: Mark Variogram Function for fuel prices. The dashed red line corresponds to the constant sample variance of the marks while the solid black line represents a measure of dependence between prices of stations r distance apart. Lower values of the measure is an indication of price similarity

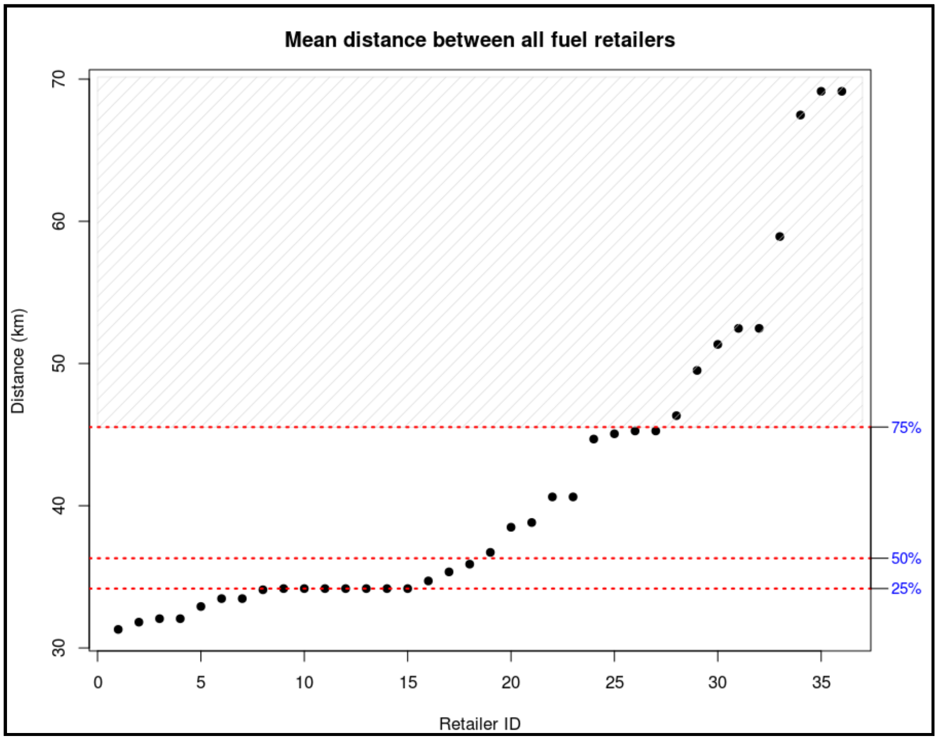

Figure 8 Mean distance between fuel retailers in Lesvos island

$$\mathbf{y = 1.64748994 + 0.02518429\, x_1 + 0.00000080\, x_2 + 0.00000125\, x_3 - 0.00001390\, x_4}$$

Formula 1: The regression equation

		Estimate	Std. Error	t value	Pr(>|t|)
	(Intercept)	1.64748994	0.00523311	67.82050221	~0
x_1	Summer Period	0.02518429	0.00295302	8.52830948	~0
x_2	Distance to Entry Point	0.00000080	0.00000005	15.67485429	~0
x_3	Average distance to competition	0.00000125	0.00000012	10.41618953	~0
x_4	Population in 1km	-0.00001390	0.00000171	-8.14809385	~0

Table 3: Regression results for the analysis local factors contributing to price variations

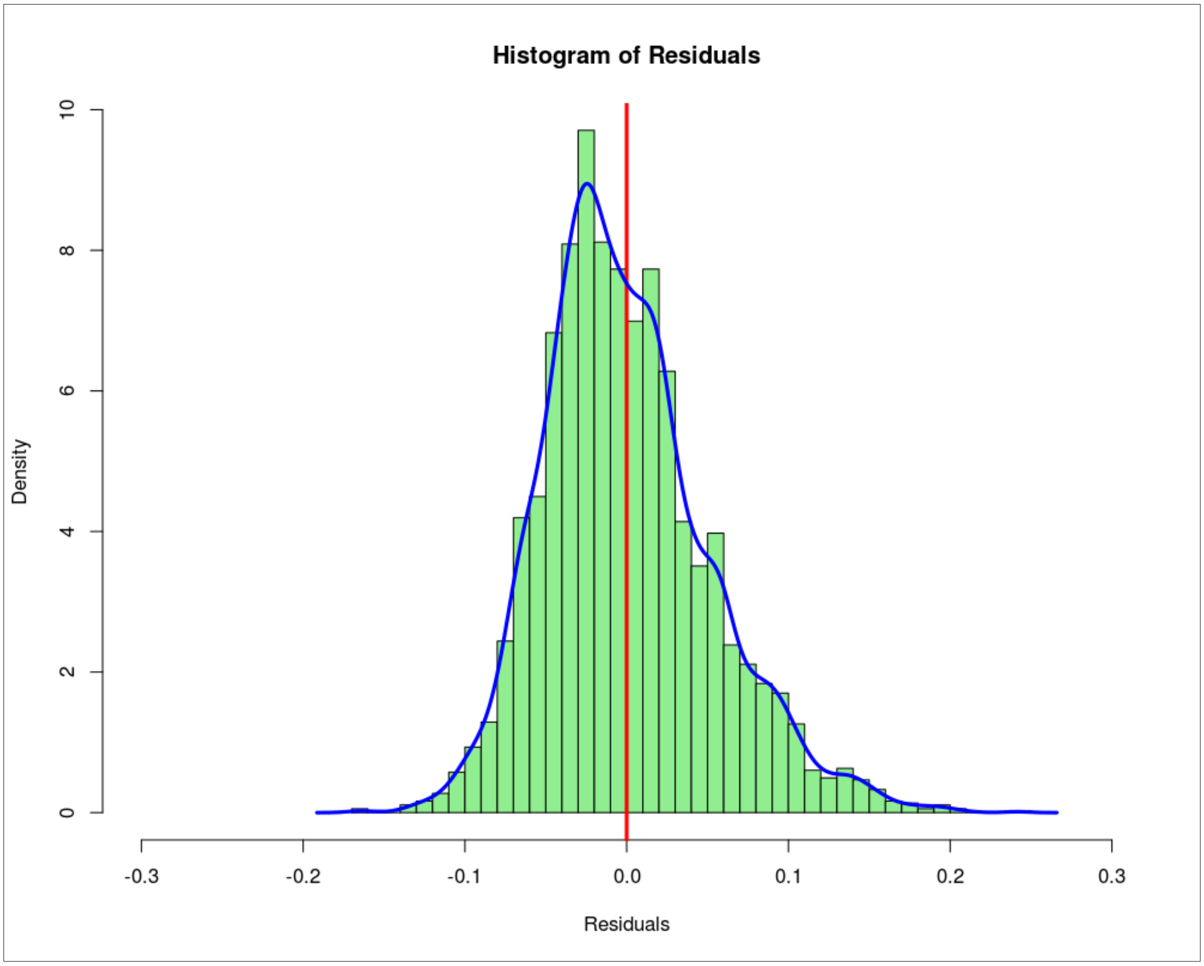

Figure 9: Histogram of the residuals from the regression model

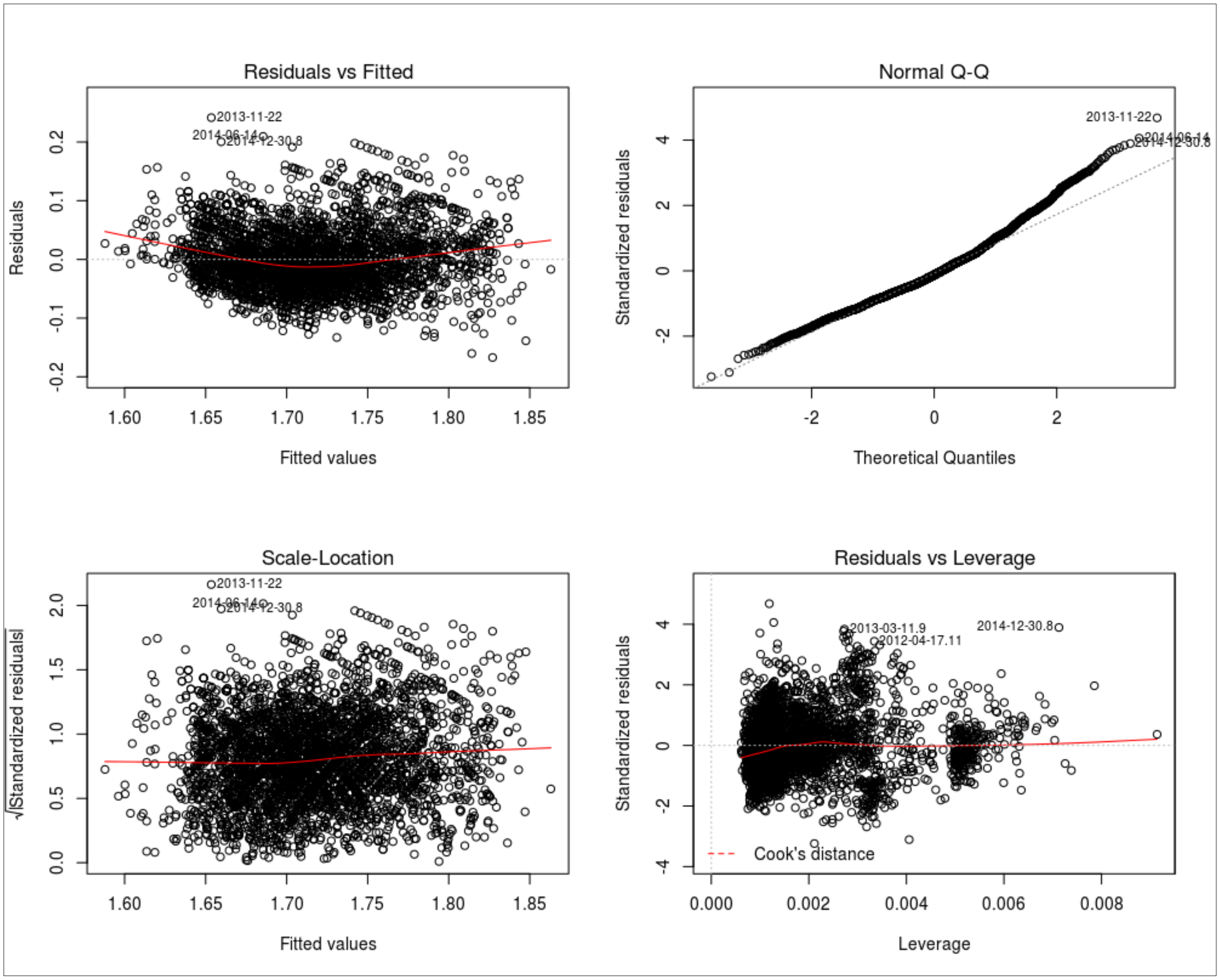

Figure 10: Four plots of the price regression model: Residual versus fitted (top-left), Normal Q-Q plot(top-right), Scale location plot of the predicted values (bottom-left), Residuals versus Leverage (bottom-right)

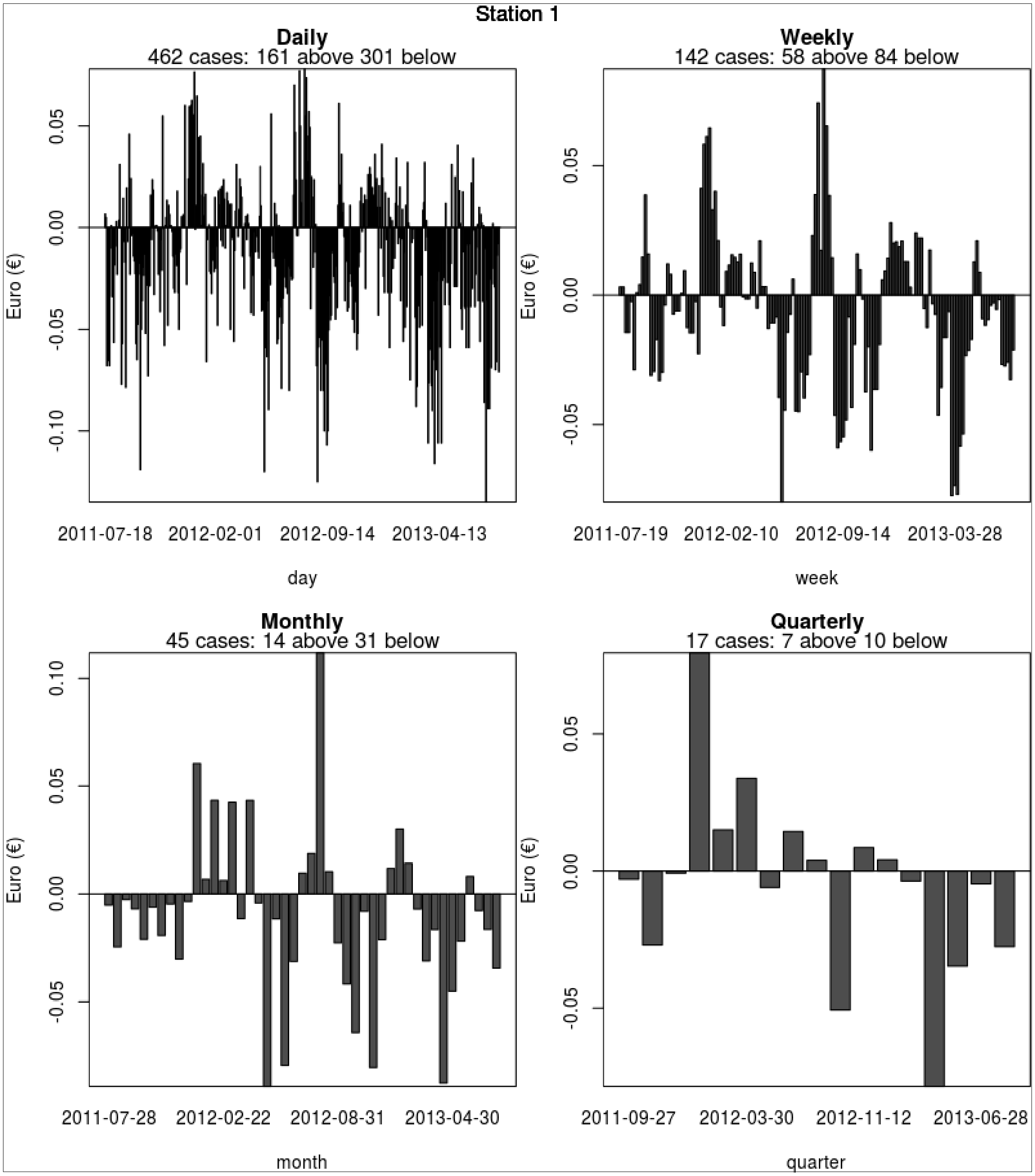

Figure 11: Comparison between aggregate price values and IGPM for station 23 belonging to the second quantile of stations with regard to distance from entry point

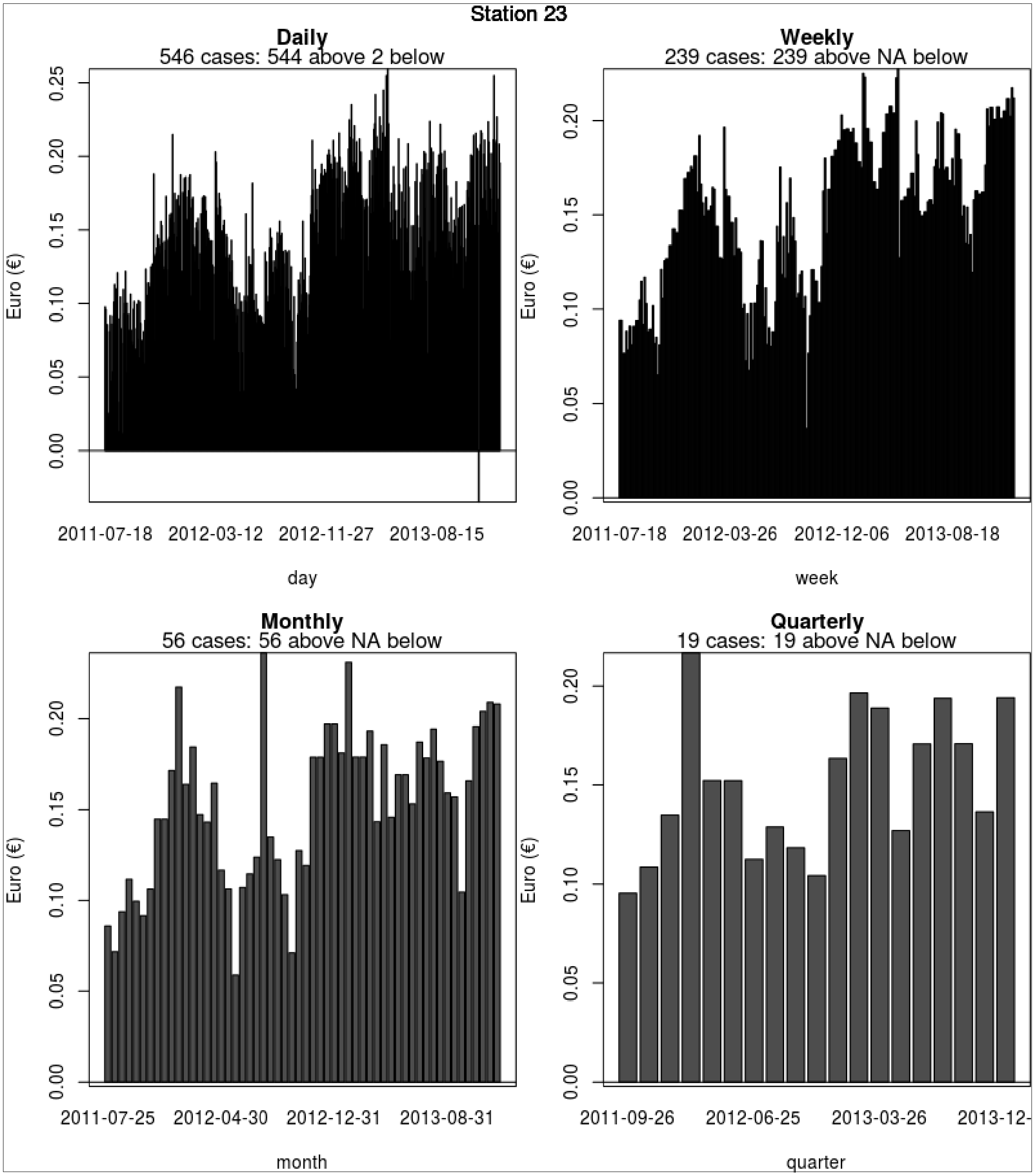

Figure 12: Comparison between aggregate price values and IGPM for station 23 belonging to the upper quantile of stations with regard to distance from entry point

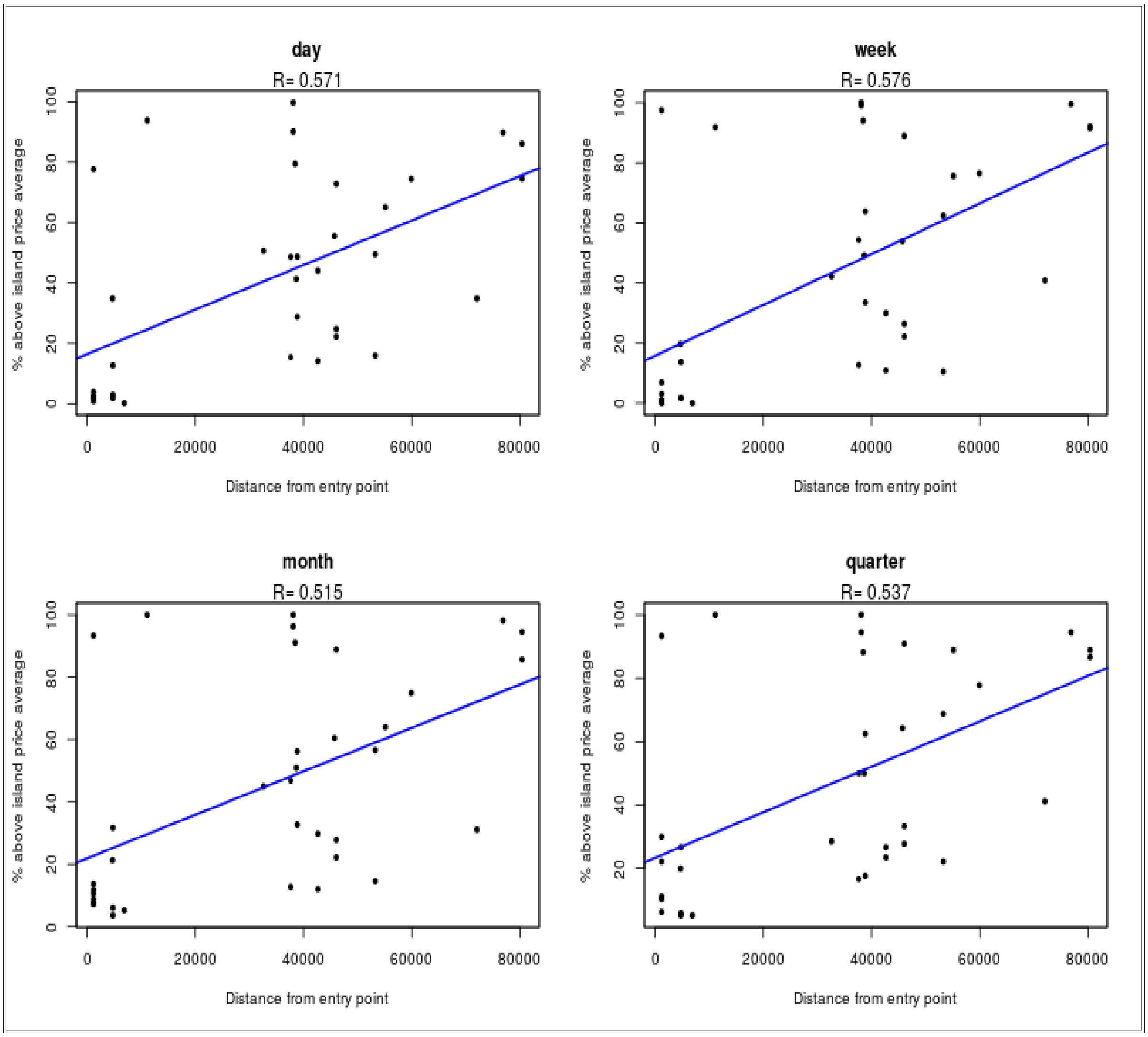

Figure 13: Relationship between distance from entry point and percentage above average prices

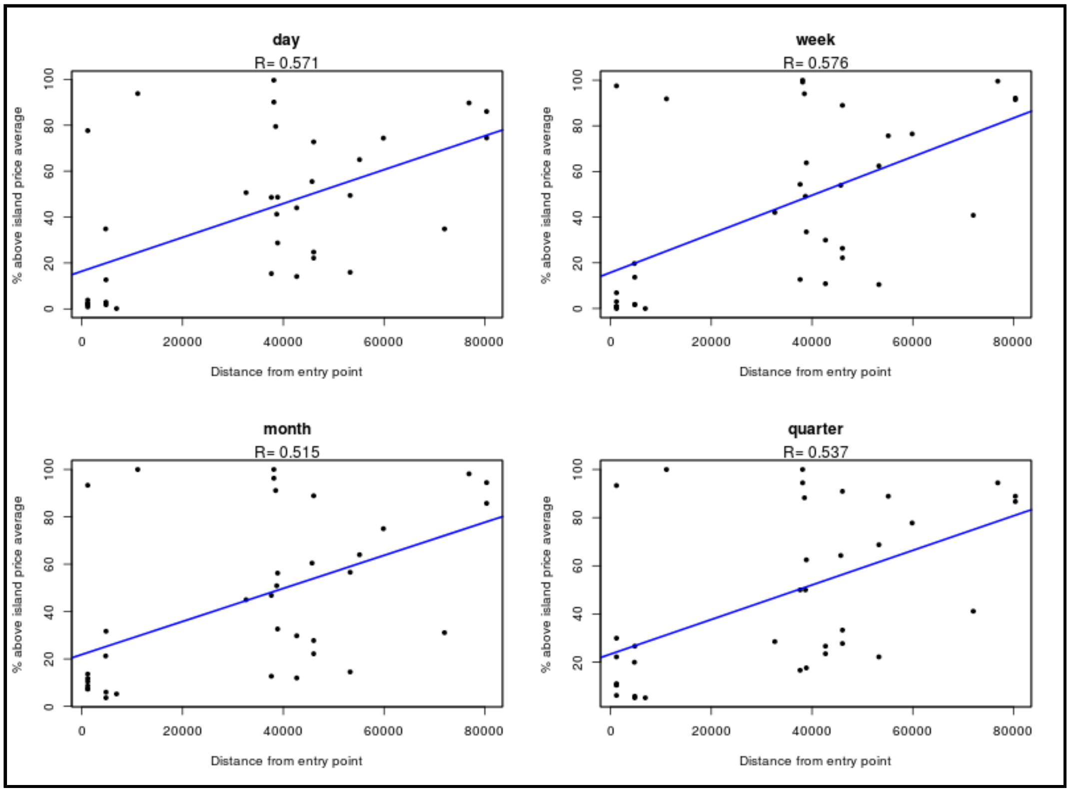

Figure 14: Relationship between distance from entry point and percentage of price values above IGPM

References

Clemenz, G. & Gugler, K., 2006. Locational choice and price competition: some empirical results for the austrian retail gasoline market. *Empirical Economics*, 31(2), p.291–312.

Cohen, N., 2000. *Business location decision-making and the cities: bringing companies back*, Brookings Institution Center on Urban and Metropolitan Policy.

Deltas, G., 2008. Retail Gasoline Price Dynamics and Local Market Power*. *The Journal of Industrial Economics*, 56(3), p.613–628.

Driffield, N., Ioannidis, C. & Peel, D., 2003. Some Further Empirical Evidence on the Impact of Oil Price Changes on Petrol Prices. *International Journal of the Economics of Business*, 10(2), p.195–203.

ELPE, 2014. Elpe. Available at: http://www.hellenic-petroleum.gr/online/index.aspx [Accessed June 6, 2014].

EL.STAT, 2014. Hellenic Statistical Authority. *Hellenic Statistical Authority*. Available at: http://www.statistics.gr/portal/page/portal/ESYE.

Emprosnet, 2014. Tourism arrivals with a tailwind. Available at: http://www.emprosnet.gr/article/58633-toyrismos-me-oyrio-anemo.

Google, 2014. The Google Directions API - Google Maps API Web Services — Google Developers. Available at: https://developers.google.com/maps/documentation/directions/ [Accessed June 10, 2014].

Heppenstall, A.J., Evans, A.J. & Birkin, M.H., 2005. A Hybrid Multi-Agent/Spatial Interaction Model

System for Petrol Price Setting. *Transactions in GIS*, 9(1), p.35–51.
Illian, J., Penttinen, A., Stoyan, H. & Stoyan, D., 2008. *Statistical analysis and modeling of spatial point patterns*, John Wiley & Sons.
Iojă, C.I. & Tudor, C.A., 2012. Temporal Analysis of Incompatible Land-Use and Land-Cover: The Proximity between Residential Areas and Gas Stations in Bucharest Suburban Area. *Procedia Environmental Sciences*, 14, p.49–58.
Jiménez, J.L. & Perdiguero, J., 2010. Does Accessibility Affect Retail Prices and Competition? An Empirical Application. *Networks and Spatial Economics*, 11(4), p.677–699.
Kathimerini, 2014. Increased arrivals of touristic charters. Available at: http://www.kathimerini.gr/766060/article/oikonomia/ellhnikh-oikonomia/megalh-ay3hsh-ton-aprilio-stis-afi3eis-toyristwn.
Kerzmann, T.L., Buxton, G.A. & Preisser, J., 2013. A computer model for optimizing the location of natural gas fueling stations. *Sustainable Energy Technologies and Assessments*. Available at: http://www.sciencedirect.com/science/article/pii/S2213138813000659 [Accessed May 12, 2014].
Longley, P. & Clark, G.P., 1995. *GIS for business and service planning* Geoinformation International., Cambridge.
Mejia-Dorantes, L., Paez, A. & Vassallo, J.M., 2012. Transportation infrastructure impacts on firm location: the effect of a new metro line in the suburbs of Madrid. *Journal of Transport Geography*, 22, p.236–250.
Ministry of Environment, Energy & Climate Change, 2014. GENERAL SECRETARIAT FOR ENERGY AND CLIMATE CHANGE. Available at: http://www.ypeka.gr/Default.aspx?tabid=345&locale=en-US&language=el-GR [Accessed June 6, 2014].
Motor Oil, 2014. Motor Oil. Available at: http://www.moh.gr/Home.aspx?a_id=256 [Accessed June 6, 2014].
Nicholas, M., Handy, S. & Sperling, D., 2004. Using Geographic Information Systems to Evaluate Siting and Networks of Hydrogen Stations. *Transportation Research Record: Journal of the Transportation Research Board*, 1880(-1), p.126–134.
North, M.J. & Macal, C.M., 2007. *Managing business complexity: discovering strategic solutions with agent-based modeling and simulation*, Oxford University Press, USA.
Ohser, J., 1983. On estimators for the reduced second moment measure of point processes. *Statistics: A Journal of Theoretical and Applied Statistics*, 14(1), p.63–71.
Pinder, D.A. & Witherick, M.E., 1972. The principles, practice and pitfalls of nearest-neighbour analysis. *Geography*, p.277–288.
Ridley, D.B., Sloan, F.A. & Song, Y., 2010. *Retail zoning and competition*, Duke University Working Paper. Available at: https://faculty.fuqua.duke.edu/~dbr1/research/zoning-competition.pdf [Accessed October 22, 2013].
Stoyan, D. & Stoyan, H., 1994. *Fractals, random shapes, and point fields: methods of geometrical statistics*, Wiley Chichester.
Wälder, O. & Stoyan, D., 1996. On variograms in point process statistics. *Biometrical Journal*, 38(8), p.895–905.
Zentes, J., Morschett, D. & Schramm-Klein, H., 2012. Store Location–Trading Area Analysis and Site Selection. In *Strategic Retail Management*. Springer, pp. 203–225.