# PRICING GASOLINE ON A HIGHWAY:

# A NATURAL EXPERIMENT

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## Abstract

In my thesis I examine the pricing behavior of petrol stations on the M7 highway, taken into account the spatial characteristics of the market. After using simple statistical tools to describe the market, I introduce an extended version of the Hotelling model, in which it is possible to analyze the effect of an exogenous market size increase. This market size increase i.e. the finishing of a viaduct can be handled as a natural experiment. Based on the extended version I calibrate a model which describes the behavior of nearby gasoline stations. I find, that the effect of the market size increase depends on the procurement cost of the stations, although in the analyzed cases it increases the margin charged by them.

Acknowledgement

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# 1. INTRODUCTION

My thesis seeks to examine the factors affecting the pricing behavior of gasoline stations on a highway. I try to show how the price of gasoline at a station is affected by the pricing behavior of its close competitors and by an exogenous change in the market environment. My study is a geographic spatial analysis of pricing behavior. The advantage of analyzing gasoline markets is that the product is almost perfectly homogenous at least in its physical and chemical properties (Clemenz and Gugler, [2002]), and the number of substitutes is limited.

In my analysis I focus not on the whole Hungarian market, but on a well-defined submarket i.e. on a specific highway, specifically the M7. I use this approach, since an exogenous change in the market environment has been observed, namely the construction of the Kőröshegyi viaduct, which increases the length of the continuous highway from 120 to 170 kilometers. This exogenous change in the market environment can be interpreted as a shock in the demand side, hence I am going to make a shock analysis in this paper. Accordingly, before finishing the viaduct, using the highway in its full length could only happen with an interruption, since the construction of the viaduct drivers have been able to use it uninterrupted. This observation is important, since this change in the highway length can be interpreted as an exogenous change in the size of the market. In this thesis I try to answer, whether the finishing of the viaduct has a significant effect on prices charged at the gas stations on the highway.

The lucky feature of the demand side shock is twofold. First, on Hungarian highways there is no free entry in the market i.e. a gasoline station can be founded only with government permission. Second, the demand side shock did not take place gradually, but the finishing of the viaduct in August 2007 rapidly increased the length of the highway. The first feature simplifies my analysis while the second provides me the chance to analyze a natural experiment on the demand side.

Furthermore, on Hungarian highways for the establishment of gas stations a permission from the government is needed, but on the newly built part no permission have been given. So the experiment is clearly a change in the spatial structure of the market, thus the effect is exactly identifiable. Hence, my research question is: what effect does the finishing of the viaduct have on the pricing behavior of nearby gasoline stations and whether or not the spatial theory of competition applicable for this market.

The study is organized as follows: first (in section 2), I give an introduction to the relevant literature both in theory and in empirics. In section 3, I present the data used for the analysis and the spatial characteristics of the market i.e. this section is more like a market situation analysis, than a data description. In section 4, I analyze the market with basic statistical tools and try to derive some important features from my observations, from which I can derive some consequences on the adequate theoretical model in section 5. In section 6, I make some descriptive statistics based on the suggestions by the theoretical model, and interpret the results. Section 7 describes the basic elements of the extended model (which has no closed form solution), the parameters used for calibration and the results of it. Finally, in section 8 some concluding remarks are made.

## 2. LITERATURE REVIEW

Building on the paper of Hotelling [1929] a large number of theoretical models have been developed and the differences between the results from these models and perfect competition have been analyzed. The focus of these theoretical papers is mostly twofold: first, what determines the location decision of market participants, and second, how the pricing behavior is affected by competitors. Although the results and the conclusions highly depend on the model setup, there are several general conclusions. On the one hand, the results show that the higher the demand in a given geographical area, the more market participants enter into it. On the other, the less is the distance between sellers,[1] the lower the price charged. Both results are highly intuitive, since markets with higher demand are more attractive to new entrants,[2] and the closer the sellers, the less is the difference between them, and the market structure is closer to perfect competition.

In the basic Hotelling model the competitors are located in a linear city. Each consumer has a one unit demand and they decide where to consume. They decide on the basis of the observed prices at the different locations and their distance from it. For the theoretical framework I will use an extended version of the spatial model of Hotelling. The extensions which are needed for the analysis, will be presented later.

In the case of gas markets, because of the good's great advantages (in particular product homogeneity and data availability) previous studies (Clemenz and Gugler [2002], Götz and Gugler [2006], Barron et al. [2002] [2004], Bettendorf et al. [2003], van Meerbeck [2003]) mostly examine the factors affecting the average price and its variance in a wider geographical region,

[1] And thus the less is the observed difference between them by the consumers. So the observed difference in this model comes from the location of a given firm. Furthermore, the mixing of the location theory and Bertrand competition is a possible answer to the Bertrand paradox.
[2] According to for example the theory of monopolist competition, if the total demand is higher in a market, the more firms are able to enter it.

and try to describe the effect of an increase in petrol station density. The framework of these models is mostly the following: they observe average prices in a wider region (for example zip-code level) and estimate the connection between the average prices and the density of stations. A further issue, which has been widely analyzed, is the dispersion of prices. The results from previous papers shows, that the higher is the level of competition, the lower is the price dispersion. To better see the differences and the similarities between these papers, I present them briefly one by one.

Clemenz and Gugler [2002] analyzed the Austrian retail gasoline market and find that higher seller density reduces average prices, but ownership concentration has an insignificant effect on it. In their estimation they used a dummy variable indicating whether the station is in the Alps or not, and they found a significant positive effect on average prices. This result suggests that the more separated a market, the higher the average price in it. Götz and Gugler [2006] also analyzed the Austrian retail market and found that mergers decrease the socially optimal product variety, hence it is possible to underestimate market power. The paper of Barron et al [2002] focuses on observed price differences in two geographical areas. They find that the source of price difference is the difference in demands. A unique study of gasoline markets is the one of Chan et al. [2007]. Compared to the previous studies, in this article individual gasoline station prices are the dependent variables. They analyzed the market of Singapore, which has some very lucky features.[3] Furthermore, they model both the entry decision of separate stations and their pricing behavior. In their setup, they found that the retail margins are approximately 21 percent, and



[3] The most difficult problem of analyzing the spatial characteristics of a market is the chain effect. This means, according to the basic Hotelling model, that if a station changes its price it has an effect in the whole market. The result of this is the problem of simultaneity, which is difficult to handle, since in most cases it is almost impossible to find good instruments. Hence, the authors in their article used GMM. Furthermore, the market of Singapore is separated, since it is forbidden by law to deliver any gasoline across borders.

consumers are willing to travel one mile for a savings of $ .03 per liter. They also use their results for analyzing the potential effect of a merger in the case of two firms.[4]

There are some common elements in these studies (except the one of Chan et al. [2007]). First, they all aggregate station level data and analyze difference between wider geographical regions. Second, each uses density as a control variable, which is derived from the location of the stations.[5] Third, they also assume that there is a difference between station level prices, which is caused by the brand of petrol stations. Since they mostly focus on average prices and compare wider geographical regions, this approach can be used. On the other hand, my thesis focus on a change in the environment in a smaller market, so I cannot use average values, but I have to focus on individual behavior.[6]

My analysis is different in some important aspects from the previously presented papers. First of all, I focus on a natural experiment, thus I do not use econometric techniques but a modeling framework. Second, I interpret the effect of location in a different way, since interpreting transportation in the case of gasoline markets is slightly different than other in the case of other goods. For example in Davis [2001] the market of movie theaters is analyzed. In this case the consumers' decision (in a very simple version) consists of the travel cost to the theater from the residence and the price charged for watching a movie. So the setup is perfectly the same as in the Hotelling-type model. In the case of gasoline consumers choose in a different manner, since they are on their way in their cars between two points. Furthermore, consumers do not take into account a lot of irrelevant alternatives i.e. they mostly choose from the stations by which they pass on their way. The spatial difference can be interpreted, that each consumers have their own

[4] In their estimation they also find, that the gasoline stations on the highway significantly charge higher prices.
[5] In the regressions they estimate, they use independent variables like the number of stations within a given radius.
[6] In my opinion the greatest advantage of using averages, that the authors can handle endogeneity in the data. Endogeneity is a result of the market structure, since we can assume that close competitors affect each others behavior, thus we cannot use individual prices as dependent variables (without handling endogeneity).

ideal point where to fill-up,[7] deviation from this point is costly. So the optimal location is not necessarily either their home or their workplace, but can be anywhere between these two points. And third, the entry decision of the firms is not modeled, which is the result of the special submarket, since in Hungary the location decision of gasoline stations on the highways is centralized, thus there is no free entry on these markets.

I handle highways as separate markets which decision is based on two main things. First, in almost every empirical study the authors found that the more separated is the market, the higher is the price charged their. This effect is the Alps dummy in Clemenz and Gugler [2002] or the highway dummy in Chan et al [2007]. Furthermore, the Directorate General for Competition of the European Union investigates the merger between Totalfina and Elf. In their decision they analyzed highways as well and found that these are separate markets i.e. not the part of a wider region (European Commission [2000]).

In summary, in this thesis based on simple statistical and econometric results I introduce an extended version of the Hotelling model, in which it is possible to analyze the effect of a change in the market size. Furthermore, in the extended version a demand function is introduced which has non zero price elasticity. Compared to previous empirical studies of gasoline markets, the main difference is that I analyze individual behavior and the focus is not the price charged at a given location, but the margins (the difference between the price and cost). Hence, my paper is different from previous studies: i) in the theoretical framework, ii) in the focus and iii) in the methodology.

The extended version of the Hotelling model does not have a closed form solution (or at least the solution highly depends on the parameter values), but I can define some equations from

[7] In this paper it is not a goal to determine what determines the consumers' ideal point.

which I can give a numerical solution to it. I found that the extended model gives better results for the estimation than the simpler ones. Furthermore, the estimates show that the finishing of the viaduct significantly increases the margins charged by the two closest gasoline stations. An interesting result is that the level of the effect of the viaduct depends on the wholesale price, and at high wholesale prices the effect is a decreasing function.

## 3. MARKET SITUATION ANALYSIS

The sample consists observations for prices charged at petrol stations along the highway and nearby cities at 55 different locations (different addresses) for a period of 61 weeks between 10.06.2006 and 11.30.2007, although in case of four weeks the data are missing. The dataset is unbalanced in every sense. We can assume, that one of the most important factors affect the pricing behavior is the procurement cost of gasoline. In Hungary the wholesale price for gasoline is determined on a weekly basis, therefore I use weekly observations.[8] As a proxy for potential demand I will use the data from traffic counting, unfortunately these are collected on a monthly basis, so the frequency is different in this case.[9]

The spatial structure of the market is shown on the Figure 1., on which the simplified map of the M7 highway is represented. On the figure, the petrol stations on the highway, the nearby cities, the traffic counters and the distances between the highway stations are shown. The petrol station number 0 is assumed to be the part of the stations at Budaörs (they are almost embedded into the city). Hence on the highway, we can observe 7 different places, where at least one station is taken place. Mostly at a location on the highway, we can find a petrol station on both sides of it, the only exception is the petrol station at Gorsium service area, where a station is located only at the toward Budapest side (henceforth indicated as right). The table below the map shows the traffic counting data for the year 2006 at the 7 different traffic counters, and to the right from this table is the legend of the map. To each petrol stations and cities, a small table is linked, in which the

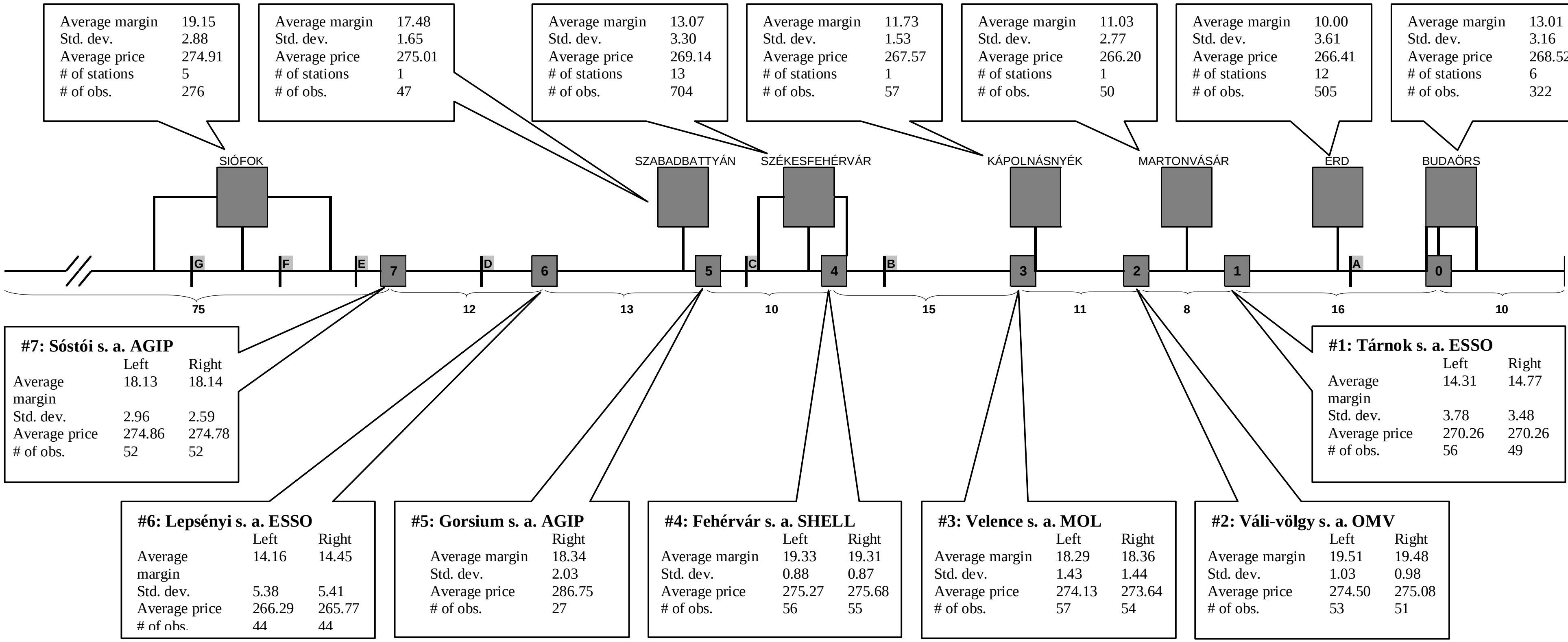


[8] In the analyzed region I assume, that each station purchase gasoline from the Hungarian Oil Company, which after consultations with oil industry experts seems to be reasonable. On the other hand, I do not have the possibility to set a retail company specific wholesale price, since these are highly confidential information. This weakens my analysis, since it can be assumed, that the Hungarian Oil Company discriminates between retailers at least on a quantity basis.

[9] In the case of petrol station characteristics (prices, location, brand) the source of the data is the webpage holtankoljak.hu (’where to fill-up’), which collects prices in each week from about 1200 petrol stations in Hungary. The source of wholesale prices is the portfolio.hu online economic news agency. In the case of traffic counting data, I use the reports of Magyar Közút Kht. who operates and maintains the Hungarian motorways.

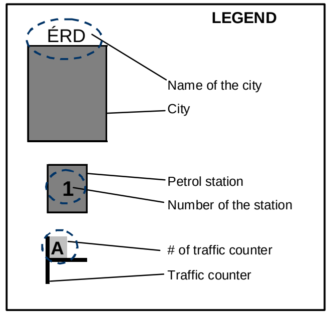
average margin, its standard deviation, the average price, the number of petrol stations (where relevant) and the number of observations are shown.

**Figure 1.: Spatial characteristics of the data**




| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | SUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 35 560 | 40 182 | 42 240 | 47 974 | 50 060 | 53 691 | 62 003 | 58 777 | 52 682 | 52 318 | 50 626 | 50 698 | **49 734** |
| **B** | 16 634 | 16 050 | 20 027 | 25 335 | 27 065 | 30 471 | 35 947 | 37 789 | 28 046 | 25 637 | 23 048 | 22 882 | **25 744** |
| **C** | 10 247 | 11 327 | 13 462 | 18 114 | 19 843 | 23 760 | 33 568 | 30 519 | 20 725 | 18 740 | 16 038 | 15 335 | **19 306** |
| **D** | 9 596 | 10 616 | 12 312 | 16 636 | 18 609 | 22 942 | 33 128 | 29 850 | 18 572 | 16 816 | 14 284 | 13 284 | **18 054** |
| **E** | 7 292 | 8 155 | 9 385 | 12 285 | 13 566 | 16 910 | 25 333 | 23 122 | 13 906 | 12 922 | 11 146 | 10 519 | **13 712** |
| **F** | 6 116 | 6 831 | 7 908 | 10 247 | 11 190 | 13 747 | 20 342 | 19 324 | 11 652 | 10 708 | 9 450 | 8 938 | **11 371** |
| **G** | 4 593 | 5 063 | 5 928 | 8 140 | 9 086 | 11 609 | 17 401 | 16 706 | 8 020 | 8 225 | 7 255 | 6 730 | **9 063** |





The place of the viaduct is indicated by the breakpoint on the left part of the graph. The length of the highway to the left from this point is 50 kilometers. It would be useful to found a petrol station at the left end of the highway, unfortunately this is almost impossible, since at the end drivers can choose between three different directions. On the other hand, if I would introduce the a station at the left end, the distance would be more than 50 kilometers. Therefore, the assumption of no station at the left end is a compromise, which I expect not to have a strong effect on my results. The lucky feature of the finishing of the viaduct, is that there still have not been any permission on constructing a service area i.e. a petrol station on the new part of the highway.

At first, let's see the nearby cities. I use 7 nearby cities as competitive fringes, hence the petrol stations in these markets do not have market power i.e. they are price takers. Although, there are 3 cities, where I found only 1 petrol station, I handle them also as price takers. I do this, since these are very small cities, so the relevant market of these stations is quite small. The biggest competitive fringe is Székesfehérvár, where I observed 13 different stations.

It seems like, that as going further away, the average margin in the cities increase, if we do not take into account Budaörs, which is highly integrated into Budapest. The average margin is the lowest in Érd and the highest in Siófok, the difference between them is about 9.15 HUF.[10] The standard deviation in these cities varies between 1.53 and 3.61, but as it is expected, the number of stations affects the variance of the margins.

On the highway I observed 7 different locations, where mostly a petrol station in both directions can be found. The only exception is at Gorsium service area, where the AGIP petrol station can

[10] HUF is the abbreviation of Hungarian forint, and one euro is about 250 HUF.

be found only in the toward Budapest direction. On the highway the lowest margin stations are at Lepsényi and at Tárnok service area and they belong to ESSO, (which sets the lowest margin from the big brands as it will be shown later). On the other hand, these two petrol stations show the highest variation in their prices during the analyzed period, which will be analyzed later. The whole sample average of margins is about 14 HUF/liter, which will be shown on the Figure 3., and as we can see the figure below, each of the stations on the highway sets higher margin than this one.

From the table under the map of the highway, we can say, that the number of cars at the traffic counters is a decreasing function of the distance from Budapest. The cars passing at a petrol station can be interpreted as a proxy for the potential demand at a given station, since this is the maximum of cars enter to a petrol station.

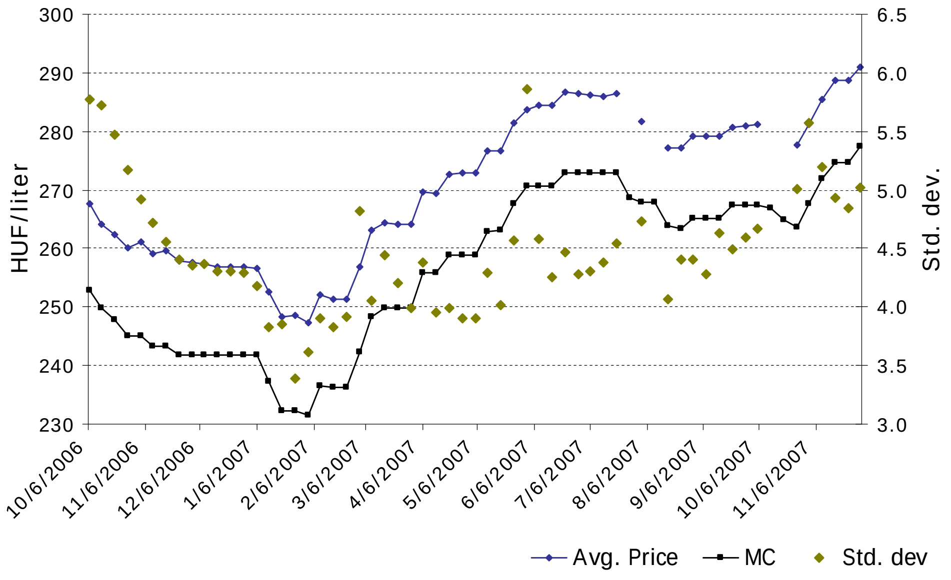
# 4. STATISTICAL ANALYSIS OF GASOLINE MARKET

The descriptive statistics are divided into three groups. First, I examine the descriptive statistics of the whole sample i.e. my basis is the market. Second, I analyze the differences between different brands, since there could be significant differences among competitors, just because consumers have their own preferences toward brands (for example because of brand loyalty). And third, I show some differences petrol stations, which could caused by the spatial and other station specific characteristics, such as different potential demand.

## a) Market level

Furthermore I observed 5 separate changes in the ownership structure of the stations, which I will present later. On Figure 2. I show the weekly average prices of petrol stations, the weekly wholesale price (the constant marginal cost) and the weekly standard deviation of the prices.

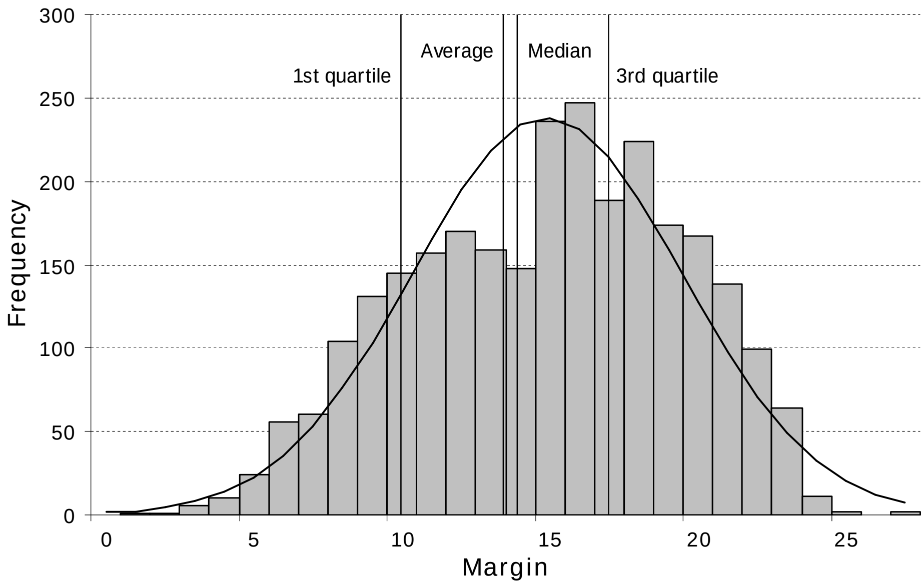
**Figure 2.: Average values in the sample**




As it can be seen, the weekly average price is highly and positively correlated with the petrol stations marginal cost. Therefore, in the following analyses I will use the margin (price minus the marginal cost) of the different stations. From this graph, I cannot observe connections between the standard deviation and the other two weekly characteristics.

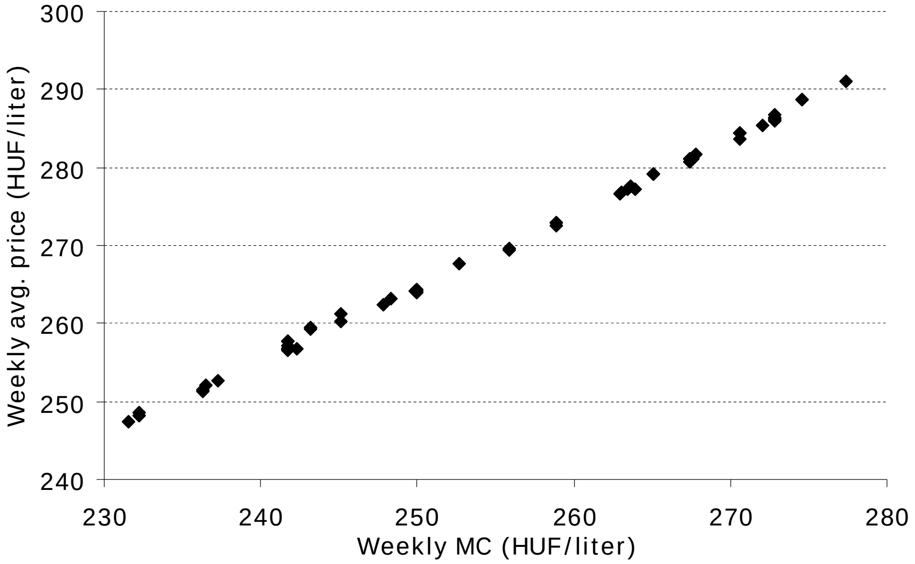
The frequency and the descriptive statistics of the petrol station margins are shown on Figure 3. As it can be seen, the distribution of the margins is skewed to the right. The average margin in the whole sample is 14.4 HUF, which in relative term is about 5%. Among the margins there are no outliers, which were checked by a box-plot.

**Figure 3.: Frequency and descriptive statistics in the sample**



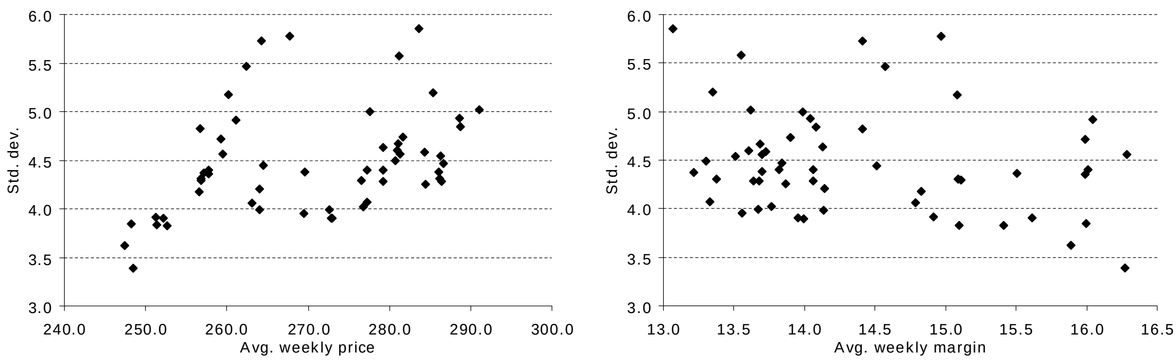

I found (as it was expected) that there is a positive correlation between the weekly marginal cost and the weekly average prices (the correlation coefficient is about unity). On the next figure I show the connection between average weekly prices and weekly marginal cost. It can be seen, that the connection is almost linear, moreover the slope is very close to unity (but significantly smaller than it).

**1. figure: Effect of marginal cost on average price**




To have more ideas about the market I analyzed the connection between the standard deviations and average values between margin and price, which can be seen on Figure 4.

**Figure 5.: Connection between the average weekly price and its standard deviation (left) and between margin and its standard deviation**




Based on these figures, we can say, that the connection between the prices and standard deviation is more intensive than the connection between the margin and the standard deviation (the former's correlation coefficient is 0.37 and the latter's is approximately -0.24). According to this result to handle the problem of possible heteroskedasticity during the modeling and further analysis I will use the margin as the dependent variable. In section 4 I derive a possible model of product differentiation which produces the results of linear dependence of prices in the marginal cost and the independence of price variance.

The more important result of this part, is that if we analyze a panel dataset, then it is needed, to involve the procurement cost of gasoline. The between period differences can be explained by changes in the procurement cost. Compared to previous analyzes in this study in the center is the margins charged at different station instead of prices.

### b) Different brands

One of the key petrol station characteristics which could affect the price charged at a given location is the brand. As it can be seen on Table 1. there are 14 different brands in the sample, from which the most frequent is the MOL which has 12 petrol stations, with 612 separate observations.

**Table 1.: Number of stations and observations**

| | Number of stations | Number of observations | Average price | Average margin | Std. deviation of margin |
|---|---|---|---|---|---|
| MOL | 12 | 612 | 271.26 | 15.69 | 3.98 |
| OMV | 8 | 338 | 270.98 | 15.87 | 4.80 |
| AGIP | 7 | 284 | 273.36 | 16.13 | 3.03 |
| SHELL | 7 | 388 | 273.19 | 17.29 | 2.60 |
| ESSO | 5 | 249 | 267.71 | 13.47 | 4.57 |
| TESCO | 4 | 217 | 268.12 | 12.04 | 3.90 |
| METRO | 2 | 98 | 266.30 | 9.11 | 2.44 |
| PJ | 2 | 92 | 275.68 | 17.52 | 1.28 |
| AUCHAN | 1 | 57 | 263.37 | 7.53 | 1.92 |
| AVIA | 1 | 13 | 277.05 | 9.34 | 1.35 |
| ERMOIL | 1 | 7 | 275.71 | 3.24 | 1.15 |
| JET | 1 | 40 | 263.75 | 7.77 | 3.20 |
| LUKOIL | 1 | 56 | 271.65 | 15.40 | 1.63 |
| OIL | 1 | 48 | 265.82 | 10.52 | 1.01 |
| PRIVATE | 7 | 226 | 266.21 | 10.00 | 3.07 |

The 14 different brands are shown on Table 1. with the number of observations. The direct comparison of average prices charged within a brand is difficult, since as it was shown on Figure 2., there is a connection between the marginal cost and the price charged. Thus a brand price average could be higher just because we have price observations for them in those periods, where the marginal cost was higher. A better basis for comparison is the average margin (the difference between the average price and the marginal cost). As it can be seen, the highest margin is charged by PJ and SHELL. Furthermore, the famous brands (MOL, OMV, AGIP, SHELL, ESSO) mostly are the most expensive, the only exception is ESSO. a further interesting observation, is that from these five brands, the lowest is the within brand standard deviation in the case of SHELL.

**Table 2.: ANOVA table of station margins**

| ANOVA - Margin | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 21,721 | 14 | 1,552 | 121 | 0.000 |
| Within Groups | 34,771 | 2,710 | 13 | | |
| Total | 56,492 | 2,724 | | | |

On Table 2., I analyze the variance of the whole sample, which can be decomposed into the within and between brands parts. As it can be seen, the total variance of the margin is mostly explained by the within group difference, but also a large part can be explained by between groups variance. Therefore, we can make two conclusions. First, the margin is affected by brand type, which could be caused since consumers have their preference over brand types: Thus, if the stations would charge the same price, the consumers could choose between them according to their preference relation over brands. Second, since the variance of margin is also strongly explained by within brand differences, thus we can conclude, that the station level differences also cause differences. In my opinion the most important difference between gasoline stations is their spatial characteristics.



### c) Station level

In this section I analyze the petrol stations located on the highway. On the M7 highway 13 petrol stations can be found, from which 7 are on the way toward Budapest (henceforth used as right side) and 6 on the way toward Lake Balaton (henceforth used as left side). The descriptive statistics are shown in the next table.

**Table 3.: Station level characteristics on the highway**

| | ID on Figure 1. | Name of service area | Brand name | Distance from Budapest (km) | Average margin (HUF) | Std. dev. |
|---|---|---|---|---|---|---|
| Left side | 1 | Tárnok | ESSO | 26 | 14.79 | 3.55 |
| | 2 | Váli-völgy | OMV | 34 | 19.48 | 0.99 |
| | 3 | Velence | MOL | 45 | 18.36 | 1.46 |
| | 4 | Fehérvár | SHELL | 60 | 19.31 | 0.88 |
| | 5 | Gorsium | AGIP | 70 | 18.34 | 2.07 |
| | 6 | Lepsényi | ESSO | 83 | 14.45 | 5.48 |
| | 7 | Sóstói | AGIP | 95 | 18.14 | 2.62 |
| Right side | 1 | Tárnok | ESSO | 26 | 14.31 | 3.81 |
| | 2 | Váli-völgy | OMV | 34 | 19.51 | 1.04 |
| | 3 | Velence | MOL | 45 | 18.29 | 1.45 |
| | 4 | Fehérvár | SHELL | 60 | 19.33 | 0.89 |
| | 6 | Lepsényi | ESSO | 83 | 14.16 | 5.44 |
| | 7 | Sóstói | AGIP | 95 | 18.13 | 2.99 |

As it can be seen on this table also, there lowest margin is charged by the ESSO stations, and the SHELL stations have the most stable margin i.e. in the case of these stations we can say that the margin is almost constant. Compared for example the two ESSO or the two AGIP stations on the left side, we can see, that there is a small difference between the margins of them. Furthermore, the farther is the station from Budapest, the lower margin is charged. Behind this observation is possibly the fact, that the margin charged by a station is not only affected by the competitors margins and by the marginal cost, but also by the different potential demand.

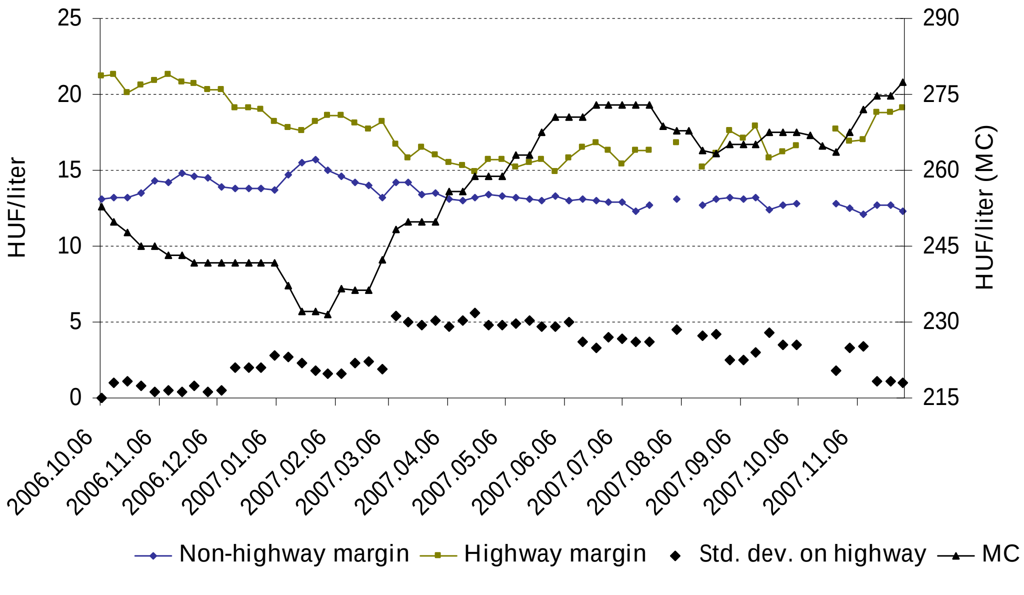
Since the price and margin charged by a petrol station is affected by the potential demand, I also show which traffic counter I will take into account. The problem of traffic measurement, that traffic counters have a different frequency than the petrol stations. Therefore, I have to use the results of the same traffic counter in some cases for different stations. The yearly averages of traffic counting are shown in the following table, with the ID of the petrol stations.

It is also useful to compare the brand averages in the whole sample to stations on the highway (the former are shown on Table 1.). According to my results I can say, that in each cases of the five brands, which has a station on the highway, the on-highway station charges higher margins than the no-highway stations of the same brand. On the other hand it is mostly true, that the variance of margins is lower in the case of highways, but the ESSO stations are exceptions. Unfortunately in the case of them the comparison is problematic, since in the whole sample the number of ESSO stations is 5, from which 4 are located on the M7.

### d) The comparison of highway and non-highway stations

In this subchapter to get more precise results I compare the highway and non-highway stations' margins. On the following figure, the marginal cost, the average margin of the two types of stations and the weekly standard deviation of margins on the highway are shown. At first sight we can see, that the difference between the margins of highway and non-highway stations are much higher before the March of 2007. in The gap before this month is decreasing and after that for a few months become more or less standard and started to increase at the end of the summer 2007.

**Figure 6.: Comparison of highway and non-highway stations**

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The viaduct is finished in August 2007, thus the increase in the difference (the one sided increase in the margins on the highway), can be the result of the exogenous change in the demand. On the other hand, the highway margins possibly suffer from seasonality, which I cannot test because of the length of the analyzed period (to analyze seasonality I would need a few more month with observations).

An other possible explanation of the change in the margins on the highway is the fact, that in Hungary at the beginning of the year 2007, the Hungarian ESSO stations were sold to AGIP. According to this fact, there could be changes in the behavior of AGIP stations. Fortunately, I have data on individual prices, so I can analyze them as well. Checking the primary data, it can be seen, that there is a structural change in the behavior of the gasoline station at Sóstó in March 2007, which is an AGIP station. Therefore, I divide the analyzed period into three sub-periods. The first is before March 2007, the second is between March and August 2007 (the latter is the date of finishing the viaduct), and the last is after August 2007. According to this observation in the case of margin comparison I will divide the 61 week into three periods.

# 5. SIMPLE THEORY AND EMPIRICS

In this chapter, first I introduce the simple theory of spatial competition, which is extended in order to be able to analyze the effect of an exogenous change in the market size. Second, I examine whether my results are according to the theory.

## a) Simple theory of spatial competition

In this subchapter I introduce the theoretical framework of spatial competition, which was first analyzed by Hotelling (1929). For simplicity I use the common zero elasticity consumer demand, and the in the derivations I follow Tirole (1988). The analyzed market has two firms, 1 and 2, who are competing in prices. The firms are located in a linear city, which has a length $A+L$, and the firms are located at 0 and A respectively, therefore the market looks as follows:

**Figure 7.: The market structure**


The consumers distributed uniformly in the linear city, and their value is N. The consumers derive their utility from the price of the good and from the transportation cost. Their consumption is normalized to unity and their utility is quadratic in the distance from their most preferred choice, thus their utility has the following form:

$$U(p,t,d) = -p - td^2 \tag{1}$$

Where $p$ is the price charged by the supplier, $t$ is the transportation cost and $d$ is the distance between the consumer's and the supplier's location. We can introduce a consumer between the two firms location, who is indifferent between the two firms at given prices, the utility of the indifferent consumer, and her location are:

$$U(p_1, p_2, t, x) = \begin{cases} -p_1 - tx^2 \\ -p_2 - t(A-x)^2 \end{cases} \rightarrow \hat{x} = \frac{A}{2} - \frac{1}{2t}(p_1 - p_2) \tag{2}$$

The demand for firm number 1 is $Q_1 = \frac{\hat{x} + L}{A + L} N$ and for firm 2 is $Q_2 = \frac{A - \hat{x}}{A + L} N$. I assume that the suppliers face with the same constant marginal cost, thus their profit function has the form:

$$\pi_2(p_1, p_2, N, L) = \left[\frac{A}{2} + L - \frac{1}{2t}(p_1 - p_2)\right]\frac{N}{A+L}(p_1 - c) \tag{3}$$

$$\pi_2(p_1, p_2, N, L) = \left[\frac{A}{2} + \frac{1}{2t}(p_1 - p_2)\right]\frac{N}{A+L}(p_2 - c) \tag{4}$$

From their profit maximization we get the following best response functions (the term $\frac{N}{A+L}$ can be ignored):

$$r_1(p_2, L) = \frac{1}{2}(tA + 2tL + p_2 + c) \tag{5}$$

$$r_2(p_1, L) = \frac{1}{2}(tA + p_1 + c) \tag{6}$$

The resulting pair of optimal prices is:

$$p_1^* = \frac{4tL}{3} + tA + c \tag{7}$$

$$p_2^* = \frac{2tL}{3} + tA + c \tag{8}$$

From this the following three propositions can be seen:

Proposition 1: If the marginal cost increases, the price of the firms increase with the same amount i.e. the equilibrium price are linear in the marginal cost, and the slope of them is 1.

Proposition 2: If the marginal cost increases, the difference between the two equilibrium prices remains the same.

Proposition 3: If there is an asymmetric market size increase i.e. $L$ goes up, the both equilibrium prices will increase, but the increase of the closer firm's price is higher.

The first two facts more or less understates, that the Hotelling model is a possible one to analyze this market (although, we saw that the connection between the marginal cost and the price is different), since we get the same result in the descriptive analysis. Furthermore, I expect that the market size increase, the finishing of the viaduct has a positive effect both on the prices and on the margins charged by the firms on the market. In the next section I will analyze this effect.

### b) The effect of the market size increase

As I mentioned in the introduction the finishing of the Kőröshegyi viaduct can be seen as a natural experiment. Compared to other highway constructions, the lucky feature of this one, is that the length of the new segment of the highway is very long (50 kilometers). As I wrote at the end of section 4 there is a structural break at the beginning of the year 2007, hence I divide the 61 weeks into three groups. The first is the before March 2007, the second is between March and August 2007 and the third is after August 2007. The problem arise from the first structural break, is that we can assume, that the market environment was different i.e. the acquisition of ESSO stations strongly affect the behavior of stations.

In the next table I present the average margins and the number of observations in the two periods, and in the last column I show the difference in average margins in the last two periods. The sign of the test statistic value shows the sign of the change in the average margins. For example if it is positive, then the margin after finishing the viaduct is higher than before the viaduct, but after March 2007.

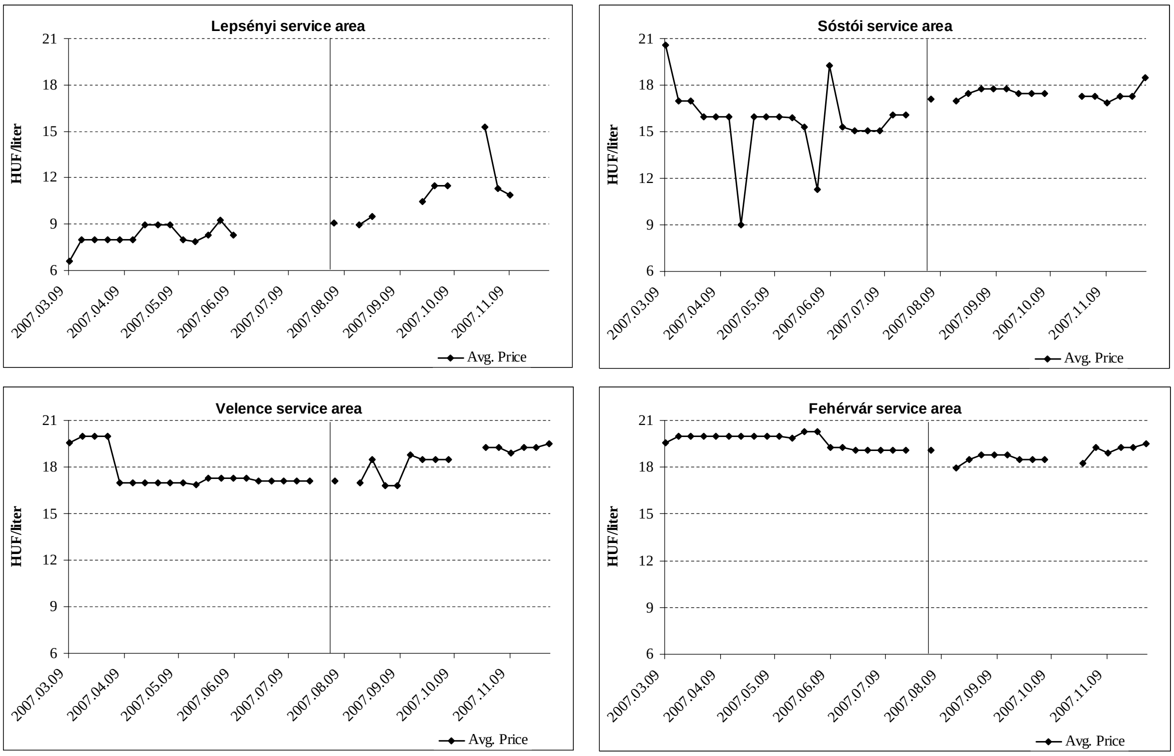
**Table 4.: Margins on the highway in the three periods**

| | | Name of service area | BETWEEN March and August 2007 | | AFTER August 2007 | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Average margin | # of obs. | Average margin | # of obs. | t-statistic | Difference |
| Left side | 1 | Tárnok | 11.99 | 19 | 14.15 | 11 | 8.13 (***) | **2.16** |
| | 2 | Váli-völgy | 19.71 | 18 | 19.08 | 13 | -10.32 (***) | **-0.63** |
| | 3 | Velence | 17.70 | 18 | 18.49 | 14 | 5.65 (***) | **0.79** |
| | 4 | Fehérvár | 19.69 | 20 | 18.79 | 15 | -17.74 (***) | **-0.90** |
| | 5 | Gorsium | 16.61 | 12 | 19.72 | 15 | 15.18 (***) | **3.11** |
| | 6 | Lepsényi | 8.22 | 14 | 11.29 | 8 | 13.02 (***) | **3.07** |
| | 7 | Sóstói | 16.04 | 20 | 17.45 | 15 | 8.86 (***) | **1.41** |
| Right side | 1 | Tárnok | 11.14 | 20 | 13.39 | 15 | 8.97 (***) | **2.25** |
| | 2 | Váli-völgy | 19.71 | 18 | 19.08 | 13 | -10.32 (***) | **-0.63** |
| | 3 | Velence | 17.64 | 20 | 18.39 | 15 | 5.88 (***) | **0.75** |
| | 4 | Fehérvár | 19.69 | 20 | 18.79 | 15 | -17.74 (***) | **-0.90** |
| | 6 | Lepsényi | 8.22 | 14 | 10.94 | 9 | 11.48 (***) | **2.72** |
| | 7 | Sóstói | 15.69 | 20 | 17.45 | 15 | 8.31 (***) | **1.76** |

From the table it can also be seen, that in the case of Lepsényi and Tárnok service area, there is a sharp drop in the margins. These stations are ESSO brands, so we can assume that the acquisition caused differences in the behavior of them. Based on the previous chapter, we expect, that the finishing of the viaduct i.e. the exogenous market size increase has a positive effect on the margins, which is the case in almost all cases. We can see two exceptions, the stations at Váli-völgy and Fehérvár service area. In the case of them, we can assume that some other changes in the environment affect their behavior (they belong to different brands, the first is an OMV and the latter is a SHELL station). An interesting and toward the previous model finding is that the difference between the two periods is not a decreasing function of the distance from the viaduct.

We know from the previous chapter, that the farther is the station from the point of market size increase, the lower is the effect on prices and thus margins. Based on the table we can see, that the stations which are closer to the viaduct significantly charge higher margins than those, which are farther away from it. In the case of the closest stations (at Sóstói and Lepsényi service area) the finishing of the viaduct induce a 2-3 HUF/liter increase in the margins charged by the stations. In relative terms this is about 10-30 percents, which is really high.

**Figure 8.: Margin at the closest stations**




On the upper figure I present the margins charged on the highway at the four closest (on the right side) station to the viaduct after March 2007. It can be seen at first sight that the margin at Lepsényi and Velence service area increased and if the first week is ignored the same is true for the station at Sóstói service area. On the other hand, at the station at Fehérvár service area the opposite can be observed. In the next chapter I introduce an extended model of spatial competition, from which I expect more precise forecasts for the behavior of stations.

# 6. THE EXTENDED MODEL

## a) The extended theory of spatial competition

The extended model is also a Hotelling-type model, but some modifications will be made. One of the most challenging questions, is that what are the differences between the main results of the original Hotelling model and a model, in which the consumers demand is not perfectly inelastic. Since, as it can be seen from the first equation, the retail market does not perfectly assign the change in the wholesale price, we can assume that the demand structure is a bit different than in the Hotelling model. Therefore, I should find a model in which a one unit change in the procurement cost of the competitors cause a smaller than one unit change in the retail price on average. On the other hand, based on the station level descriptive statistics, we can see, that there are significant differences between the margins charged at petrol stations with different brands. Thus, in the extended model there should be some factors, which capture this effect. Finally, we can assume, that the price and thus the margin charged at a given station on the highway does depend also on the potential demand, where potential demand means the highest possible demand at a station. Although, the demand for the stations is not observed, we have observations on the traffic i.e. the number of cars passes by them. We can assume that the number of cars passing by a given station is a good proxy for the potential demand.[11]

Fortunately, both the differences in brand characteristics and potential demand can be captured by a factor which measures the difference between two stations pricing potential. Such a factor in the standard Hotelling model can be explained as follows. Assume that the two station charge the same prices, then in the standard model the market share of the two firms will be equal. A factor which measures the pricing potential affects the market shares. If the consumers are more likely

[11] Do not forget, that the potential demand is no the actual demand, since the actual demand is a function of both the potential demand and the price charged at a given station.

to choose firm one based on its characteristics, then if the two firms charge the same price, firm 1 will have a higher market share.

The model consists consumers and two firms (labeled by 1 and 2). The consumers have a constant (non-zero) elasticity demand function, and during consumption they face with the mill price. The mill price is the sum of the price charged by the firms and the per unit transportation cost.[12] Hence the consumers' demand depends also on their location, which is by assumption uniform. The individual demand is the following:

$$q_i = \left(1 + p_j + t_j \left|x_i - a_j\right|\right)^{-1} \quad (9)$$

Where $q_i$ is the consumption of consumer i, $p_j$ is the price charged by firm *j*, $t_j$ is the transportation cost toward firm j, $x_i$ is the location of consumer $i$, and $a_j$ is the location of firm j (the market structure is the same as on Figure 6., so firm 1 is located at the point zero, and firm 2 is at A). The transportation cost measures every firm differences such as the difference in potential demand and consumers' brand preferences.

The indifferent consumer's location can be expressed from this demand function. The consumer who is indifferent observes the same mill price in the case of both firms. Thus the indifferent consumer's location is:

$$\hat{x} = \frac{-p_1 + p_2 + t_1 a_1 + t_2 a_2}{t_1 + t_2} \quad (10)$$

The total demands for the two firms can be expressed by the following two integrals (using that $a_1 = 0$ and $a_2 = A$.



[12] The way of extension of the Hotelling model is not straightforward. One possible way is the using of the mill price, which is done by for example by Smithies [1941], Hartwick and Hartwick [1971], Capozza and van Order [1977] and Chao-cheng and Shin-kun [1999]. The demand function in each of these studies are given and has a very simple form, mostly linear, but Hartwick and Hartwick used a quite similar demand specification as I do in this paper.

$$Q_1 = \int_{-L}^{0} [1 + p_1 - t_1 x]^{-1} dx + \int_{0}^{\hat{x}} [1 + p_1 + t_1 x]^{-1} dx \quad (11)$$

$$Q_2 = \int_{\hat{x}}^{A} [1 + p_2 + t_2 (a_2 - x)]^{-1} dx \quad (12)$$

Furthermore, the firms face with the same wholesale price i.e. marginal cost, and their profit function is linear in the cost, so it has the form:

$$\pi_j = Q_j (p_j - c) \quad (13)$$

From this and the demand functions I can derive the first order conditions of the profit maximization, which are the following:

$$\begin{aligned} \frac{\partial \pi_1}{\partial p_1} &= t_1 \{-2\ln(1 + p_1) + \ln(1 + p_1 + t_1 L) + \ln(1 + p_1 + t_1 \hat{x})\} + \\ &+ (p_1 - c) t_1 \left\{ -2(1 + p_1)^{-1} + (1 + p_1 + t_1 L)^{-1} + \left(1 - \frac{t_1}{t_1 + t_2}\right)(1 + p_1 + t_1 \hat{x})^{-1} \right\} = 0 \end{aligned} \quad (14)$$

$$\begin{aligned} \frac{\partial \pi_2}{\partial p_2} &= t_2 \{-\ln(1 + p_2) + \ln(1 + p_2 + t_2 (a_2 - \hat{x}))\} + \\ &+ (p_2 - c) t_2 \left\{ -(1 + p_2)^{-1} + \left(1 - \frac{t_2}{t_1 + t_2}\right)(1 + p_2 + t_2 (a_2 - \hat{x}))^{-1} \right\} = 0 \end{aligned} \quad (15)$$

When calibrating the model (setting the values of $t_1, t_2$), I solve these two equations with respect for the following conditions: $\frac{\partial^2 \pi_1}{\partial p_1^2} < 0$, $\frac{\partial^2 \pi_2}{\partial p_2^2} < 0$, $c \le p_j$. Furthermore, I have to take into account, that the difference between $t_1$ and $t_2$ should not be so high.

### b) Calibration of the model

Based on the model of the previous section, I calibrate a model in which I try to describe the behavior of the stations. To simplify the problem I only model the behavior of the two closest station, which can be done, since in the Hotelling model the behavior of a competitor is only affected by its neighbors. Thus, the price of my neighbor consists all the information further away. There are three variables, for which I try to find the values, which gives the most precise results. Namely I use the parameters $t_1$ and $t_2$ i.e. the relative valuation of the two stations. Since

I have two equations and two choice variables, I am able to solve the system of equations numerically with an exact solution.

For measuring the efficiency of my modeling results, I use the value of the average squared residual, but I also report the average absolute error. The steps of the modeling are the following: first, I set the values of $t_1$ and $t_2$, and calculate the hypothetical prices for the two stations, from which the given constraints are true. There are two periods, the first is before the viaduct and the second is after. The only difference in parameters is that the value of $L$ is 25 in the first and 75 in the latter case. After I get the modeling results, I compare the hypothetical prices with the true one, and calculate the average squared residual and the average absolute error.

### c) Modeling results

For the calibration of the model I cannot use the whole 61 weeks, since in several cases at least one of the observations is missing. Furthermore, I take into account the break point in March 2007, and as a result I have 21 pairs of prices, for which I do the calibration. During the calibration the values of $t_1$ and $t_2$ varies between 0.05 and 1.5, but I assume that the difference between them is lower than 0.15. On the next two graphs I present the average squared error with the corresponding parameter values.

**Figure 9.: Results of the calibration, average squared error before the viaduct**

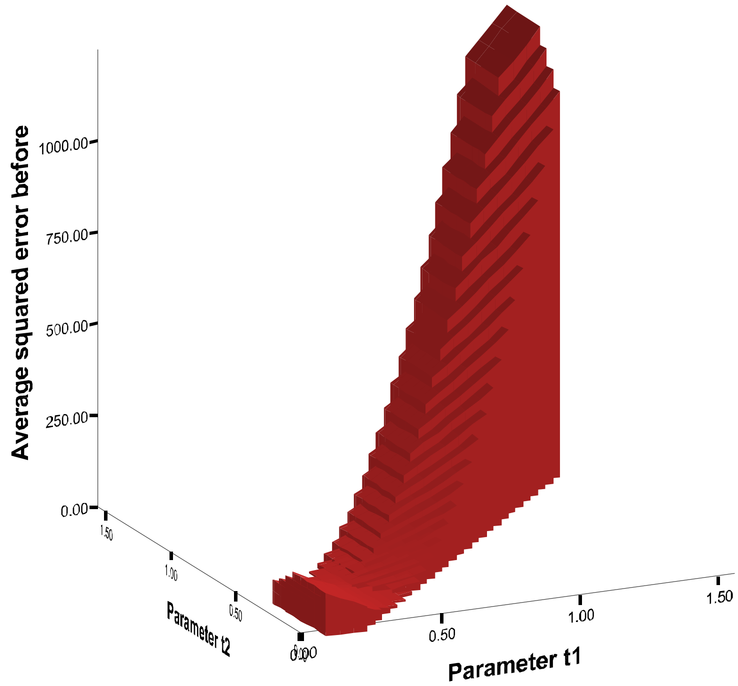
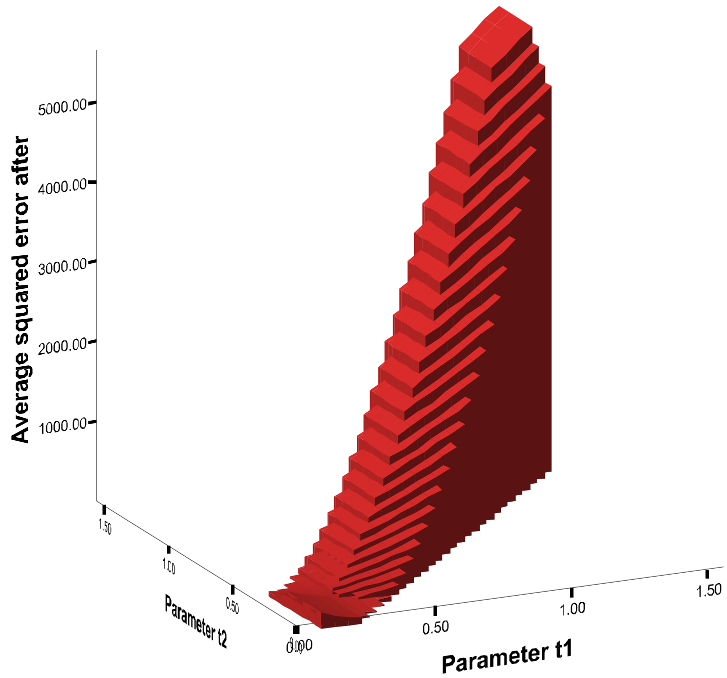
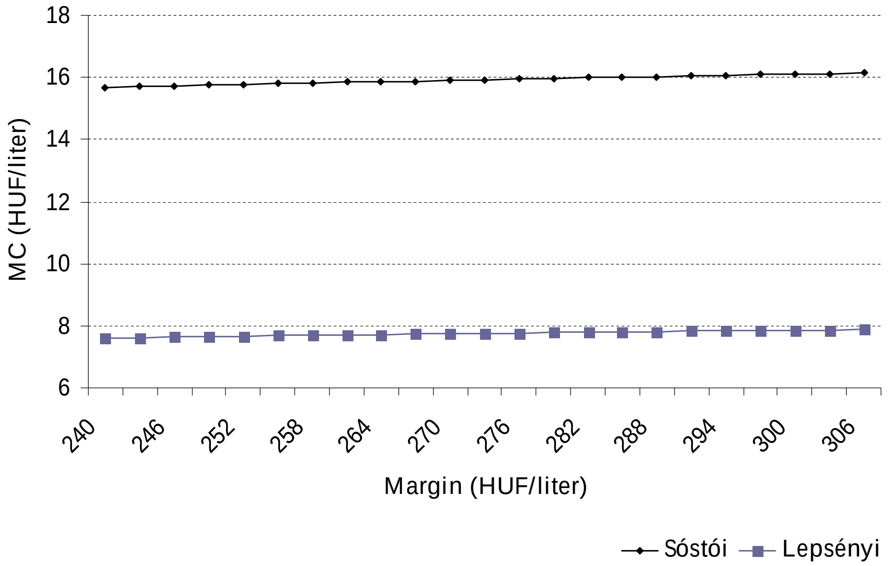



**Figure 10.: Results of the calibration, average squared error after the viaduct**



The minimum of the average squared errors before the finishing of the viaduct is 4.72 (this can be reached with $t_1$ equals 0.3 and $t_2$ equals 0.4), in which case the absolute error before the viaduct is 1.56 HUF. This means that on average the model make a 1.56 HUF mistake in forecasting the margin before finishing the viaduct. On the other hand in this case the forecast for the after viaduct period is quite week. The forecast for the parameters produce a 94.33 average squared error after viaduct. This is the result of over fitting the model in the before viaduct period. Taken into account this observation, I set the values of $t_1$ and $t_2$ equal to 0.2 and 0.35 respectively. In this case the pre-viaduct average squared error is 10.53 and the post-viaduct is 21.5. In this case the model makes an absolute error of 3.15 HUF in the whole sample (2.58 HUF before and 4.03 HUF after the viaduct).

**Figure 11.: Change in individual behavior**






The goal of this study is to analyze the effect of the construction of the viaduct on pricing behavior. On the upper figure, I present the difference between the margins of the two closest gasoline stations in the two cases. Henceforth, the upper line is the difference in the margins of the gasoline station at Sóstói service area between the 25 and 75 kilometers case. The parameters $t_1$ and $t_2$ are set to be equal to 0.2 and 0.35 respectively. On the horizontal axis different procurement costs are shown. For example, if the procurement cost is 246 HUF/liter, then the station at Sóstói service area, charge almost 16 HUF higher margin just because the viaduct is finished i.e. the length is increased by 50 kilometers. Hence this difference in the margins can be explained as the cost of the viaduct as well.

## 7. CONCLUSIONS

My study is a spatial analysis of petrol station pricing. I used a natural experiment, the construction of a viaduct on a highway, to model the effect of a market size increase on the behavior of gasoline stations located on the highway. Based on my simple empirical results I proposed a model, in which I extended the standard Hotelling model in two directions. The first is that I use a non-zero (but constant) elasticity consumer demand, and the second is that consumers value different the cost of deviation in the different directions. Since the closed form solution of this model highly depend on the parameters, instead of solving it, I derive the first order conditions, and use them for modeling pricing behavior.

During the calibration I use the two parameters, which describes the consumer relative valuation toward stations to calibrate my model. In order to avoid counterintuitive results, I set a constraint on the difference between the two parameters (but not on the level of them). This is important to avoid corner solutions. For measuring the efficiency of my model, I used the average squared error. The problem of over fitting the model in the pre-viaduct period is avoided by the analysis of the results. Hence, in the further examinations I do use the model which produces the lowest average squared error in the pre-viaduct period, but a pairs of parameters, at which the model also give better results for the post-viaduct period.

Based on further calculations I can say, that the construction of the viaduct increase the prices of close gasoline stations, but the increase in the margin is affected by the level of marginal cost. As it can be seen on Figure 2., the marginal cost (the wholesale price) increased at the end of 2007, so the potential of charging higher margins decrease. At a level of 279 HUF/liter wholesale price, the average increase in the two stations margins is about 11.9 HUF/liter. So the finishing of the viaduct, and the fact, that there are no new gasoline stations on the highway caused a significant increase in the margins. Furthermore, I can say that the spatial model of Hotelling with simple extensions can be applied for describing the competition and pricing behavior of petrol stations on the examined submarket i.e. on a highway.

A very important policy implication of the above results, is that in the case of building new highways, one of the most important things is to establish new gas stations on it as soon as possible. In my case the Hungarian government still has not given any permission for the new part of the highway. Hence, the monopoly power of the stations on the highway increased, and cause the consumers a significant gasoline price increase.

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