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Analyzing the Retail Gasoline Market in Germany: Impact of Spatial Competition and Market Concentration on Prices

Nicolas Fiedler

Ludwig Maximilian University of Munich

Abstract

Given the changing landscape of fuel retailing, this study explores the impact of spatial competition and market concentration on diesel prices in Germany. The question of how population density and gas station density, i.e. the equilibrium pattern of locations of firms, are related is examined. In addition, the impact of gas station density, as a spatial measure of competition, and market concentration on diesel prices is investigated. Based on theory, population density should have a positive impact on gas station density. Gas station density should have a negative and market concentration a positive influence on the diesel price in a district. Using 2022 data on German gas stations and diesel prices, a positive effect of population density and on gas station density, a negative effect of gas station density on diesel price, and a positive effect of market concentration on diesel price were each found at the district level. The effects of gas station density and market concentration, however, were relatively small. The results show that fuel prices at gas stations are influenced by spatial competition and market concentration.

Keywords: diesel prices; gas station density; market concentration; retail gasoline market; spatial competition

1. Introduction

In 2022, fuel prices in Germany have come very much into focus. For the reason that it was the most expensive year ever for drivers in Germany to fill up their fuel tanks. A liter of diesel was priced at an average of 1.95 euros, and a liter of Super E10 at 1.86 euros over the year 2022. Gasoline was thus around 27 cents more expensive than in the previous record year of 2012, and the price per liter of diesel was even almost 47 cents higher than in 2012 (Prack, 2023). The mobility landscape is of great importance to society and economy. Mobility is not only a tool to fulfill individual needs, but also an important driver for economic activities and trade. In this context, fuel prices play a critical role, influencing to a large extent individual mobility costs and overall costs for the transportation sector. It is important for all population groups and economic sectors to purchase fuels efficiently and at reasonable prices. For this reason, it makes sense to examine in detail the factors that influence these prices and the underlying market structure.

Fuels can be considered a fairly homogeneous product due to their chemical composition. Nevertheless, gasoline prices at individual gas stations vary widely. Many papers explain the price differences by the intensity of local competition. This competition is determined in the retail gasoline market not only by the number of competitors, but also by the geographic distribution of gasoline stations in the area. Consumers tend to buy their fuel at gas stations close to their homes, as greater distance to gas stations results in higher transportation costs. It follows that competition in the retail gasoline market is highly localized (Bergantino et al., 2020).

The objective of this paper is to investigate the impact of spatial competition and market concentration on prices by looking at the retail gasoline market in Germany. The first question that arises is what affects the equilibrium pattern of company locations? And the second question is, what are the characteristics of equilibrium prices if there is spatial competition among firms? Clemenz and Gugler (2006) have also already studied these two questions in their work. It has already been observed that population density has a major impact on the density of gas stations (Clemenz & Gugler, 2006; Götz & Gugler, 2006). Based on this and the model of Salop

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(1979), the first hypothesis was developed that retail stores are more likely to be located more densely in areas with higher population density. Several researchers such as Barron et al. (2004), Cardoso et al. (2020), Clemenz and Gugler (2006), and Meerbeeck (2003) have looked at the relationship between spatial competition and prices at gas stations. Most of them found that higher spatial competition leads to lower prices. An important factor is the distance between gas stations. This leads to the second hypothesis that, under spatial competition, prices tend to be lower as the density of seller locations increases. The relationship between market concentration and prices has also been studied a few times, for example by Eckert and West (2005), Kihm et al. (2016), and Sen (2003). Their findings indicate that higher prices are related to higher market concentration. This also forms the third and last hypothesis of this paper, that prices tend to be higher, as market concentration increases.

To test these hypotheses, a dataset of German gas stations and their diesel prices from the year 2022 was used. The political districts in Germany were defined as local markets, following Clemenz and Gugler (2006). Based on this, average values such as diesel price, gas station density, one and four firm concentration ratio in 2022 were calculated for each district. All hypotheses were tested using multiple OLS regressions with different combinations of control variables. In the first step, a significant positive effect of population density on gas station density was found. In the second step, a significant negative effect of gas station density on diesel price was found. A robustness test was performed by removing 20% of the districts with the highest population density from the dataset, in order to exclude mainly metropolitan areas from the analysis. The effect was still negative but no longer significant. Lastly, a significant positive effect of market concentration on diesel price was found. This was also the case in the robustness test. But it should be noted that the effects of gas station density and market concentration are very small.

This paper has the following outline. Section 2 presents the theoretical background by means of relevant literature and description of important concepts and leads argumentatively to the hypotheses. Section 3 provides an overview of the German retail gasoline market. Section 4 describes the methodology used and section 5 presents the empirical results. Section 6 concludes the study with a discussion and comparison of the results with previous literature, limitations, theoretical and managerial implications.

2. Theory and Hypotheses

2.1. Gas Station Density

In this paragraph, following Clemenz and Gugler (2006), the aspects of the circular city model of Salop (1979) that are relevant to this research are described. An important feature of spatial competition is that consumers shop at the store where their total costs are lowest. These consist of the price (multiplied by the quantity) and any transport costs a customer must face. This results in each store having a "local monopoly", the geographical extent of which depends on the prices of the nearest competitors and the respective transport costs of each customer to the various stores. These transportation costs are generally substantially influenced by the distance between stores, and to some extent by road quality and the availability of public transportation, etc. The price a store can charge, increases with the distance to the nearest competitor as well as with the transport costs of a customer. Demand in such a local monopoly depends not only on the geographic size of the market, but also on the number of customers in the territory. In other words, the population density. A company wants to be at a location with many potential customers but few competitors, as the high demand is distributed among relatively few companies. The potentially high demand is distributed among relatively few companies, thus the expected profit is higher. In more densely populated areas, the gap between competitors can be smaller, as demand per square kilometer is usually much higher.

This relationship has already been observed in the retail gasoline market. Götz and Gugler (2006) looked at the relationship between population density and gas station density in Austria. Using an Ordinary Least Squares (OLS) regression, they found that if the population density in a market increases by one percentage point, then the density of gas stations increases on average by 0.835 percent. Clemenz and Gugler (2006) have defined the 121 political districts in Austria as local markets. Looking at the same relationship, they ran multiple regressions, each with different control variables, such as different variables for market concentration or number of motor vehicles per capita. Their results showed that in each of their models, the coefficient of population density is positive and significant at the 5% level or lower. Their coefficients range from 0.810 to 0.873, depending on the control variable. This means that if population station density increases by one percentage point, the gas station density increases by at least 0.8% on average. They also performed a robustness test by changing the market definition and defining each municipality as a local market. Their results have shown to be robust to the change in market definition.

This suggests that, on average, the higher the population density in a local market, the higher the gas station density. Based on this literature and the previous explanations, the following first hypothesis was developed:

> Hypothesis 1: Retail stores are more likely to be located more densely in areas with higher population density.

2.2. Diesel Price and Gas Station Density

Higher gas station density, in turn, leads to increased spatial competition. This raises the question of the extent to which this competition influences the prices at gas stations. From a theoretical standpoint, pricing differences can be explained by product differentiation.

In order to explain the concept of product differentiation, this paragraph refers to the book "The Theory of Industrial

Organization" by Tirole (1988). Two products are almost never perfect substitutes, in the sense that all customers are indifferent if the two goods have the same price. Products are almost always differentiated by a certain attribute. A good can be characterized as a bundle of different attributes: quality, availability, location, the information of the consumer about its availability and quality, etc. Each consumer has a ranking for the different characteristics. Researchers usually focus on a small part of these characteristics and a special description of the respective customer preferences. There are two cases that are used commonly. The first case is vertical differentiation. In a vertically differentiated product environment, all consumers agree on the preferred mix of features. In more general terms, they also agree on the order of preference. The most typical example of this is quality. The majority agree that a higher quality is to be favored. Given equal prices, there is a clear natural ordering over the characteristics space. For example, given the same price, most people prefer a powerful laptop over a less powerful laptop, or an Audi over a Toyota. The second case is horizontal differentiation. For some attributes, given equal prices, the optimal decision depends on the individual consumer. Preferences and tastes are very different. A common example is color, one person prefers blue, the other one red. Another important point in this context is the location. To exaggerate, it is likely that Munich residents prefer products that are available in Munich to physically identical products that are only available in New York. Broken down, customers prefer stores that are close to them. One model of horizontal differentiation is Salop's circle model, which was described at the beginning of the chapter.

In his work, Meerbeeck (2003) applied the concept of product differentiation to the gasoline market. He states that in the case of gas stations, both horizontal and vertical differentiation can be observed. Although gasoline can theoretically be considered a homogeneous commodity in terms of its physical and chemical characteristics, in practice product specifications vary due to the additives used by each brand. Although these factors could play a role, he found that location has the greatest impact on price differences between gas stations. Consumers generally prefer gas stations in their "neighborhood." Lee (2007) examined the nature of competition in San Diego's retail gasoline market using two years of panel data on weekly gas station prices. He was able to find that retail prices are strongly influenced by gas station characteristics such as brand name and amenities. But he also found that the relative geographic proximity of competing gas stations is an important factor in explaining price differences among gas stations. Gas stations compete most with gas stations that are less than 1 mile away. The intensity of competition continues to decrease with distance.

From these papers, it can be inferred that spatial competition is an important factor in the formation of prices in the gasoline market. Several researchers have already studied how this spatial competition affects equilibrium prices at gas stations. Often, local gas station density is defined using a fixed and arbitrary radius. Hosken et al. (2008) determined the number of gas stations in a 1.5-mile radius and the distance to the nearest gas station as the competitive measure. They looked at how this local competition affects prices at individual gas stations. However, no consistent relationship was found between local competition and the prices or margins of the gas stations. Barron et al. (2004) also analyzed the effect of the number of gas stations in a 1.5-mile radius on price. They observed that a 50% increase in the number of gas stations in this radius leads to a decrease in the price of about 0.5%.

Other studies have defined political areas as local markets. Meerbeeck (2003) has defined the gas stations density in a municipality as the local competition measure for the Belgian retail gasoline market. A higher number of gas stations leads to more intense competition. The results show that the number of local competitors has a negative effect on prices. This indicates that as the number of competing stations in a local market increases, diesel prices decrease. However, the magnitude of this effect is very small, but significant.

Clemenz and Gugler (2006) have defined the 121 political districts in Austria as local markets. They analyzed the influence of gas station density on the margin at gas stations. Several equations were analyzed with different control variables, such as market concentration or ALPS. ALPS describes the proportion of mountains and forest in each county. This is intended to serve as an additional proxy for the differences in transportation costs between the respective districts. Their results showed that in each of their models, the coefficient of gas station density is negative and significant at the 5% level or lower. Their coefficients range from -0.035 to -0.045. This means that if gas station density increases by one percentage point, the margin decreases by around 0.04% on average. They also performed a robustness test by changing the market definition and defining each municipality as a local market. Their results have shown to be robust to the change in market definition. This suggests that the closer competitors are to each other on average, the lower the margin.

Cardoso et al. (2020) have measured the effect on prices in the Brazilian gasoline market when a new company enters a local market. As a result of the increased spatial competition, prices decrease. The closer the location of the new competitor is to existing gas stations, the more prices are reduced.

In summary, most papers have shown that prices at gas stations are affected by spatial competition. It turns out that the distance between gas stations is a key factor. Gas station density reflects this average distance as an inverse proxy and thus can be used as a measure of spatial competition. Based on this and the model of Salop (1979), the second hypothesis was developed:

> Hypothesis 2 - Under spatial competition, prices tend to be lower as the density of seller locations increases.

As Clemenz and Gugler (2006) have already pointed out, hypothesis 2 has an obvious consequence for hypothesis 1: In the presence of spatial competition, the increase in store density has to be less than proportional to the increase in population density, since a higher station density lowers the equilibrium price.

2.3. Diesel Price and Market Concentration

So far, only gas stations have been considered individually and independently of the operating company. In reality, however, not every company operates just one gas station in each market, but in a number of cases several. For this reason, some companies could have more power than others in certain markets. This in turn could have an impact on prices.

In order to introduce the subject of the market power and oligopolies, this paragraph refers to the book "Industrial Organization: Markets and Strategies" by Belleflamme and Peitz (2015). Companies are expected to maximize profits, but the market conditions limit their ability to exploit consumers. If the paradigm of perfect competition is to be believed, firms will in the end sell at a price that equals their marginal cost. Firms do not have market power if compared to the industry they are small and price takers. But what happens when some companies have a large market share in the respective industry or local market? They cannot be described as price takers. But neither can they be described as pure price makers, compared to monopolists, as they still compete with other companies. Although these large companies unquestionably exercise market power, their smaller competitors do as well. Market power is the ability to set prices above the competitive level and thus generate profit. Industries in which a few companies compete with each other and thus market power is collectively shared are called oligopolies. Most industries are oligopolies, and so is the retail gasoline market. The characteristic feature of oligopolistic competition is that companies cannot be ignoring the behavior of their rivals. Companies' profits in the end depend on the combination of decisions taken by all companies in the market. In making decisions, firms must take into account the likely behavior of their competitors and respond to their own decisions. The analysis of this strategic interaction goes back as far as the nineteenth century. Augustin Cournot and Joseph Bertrand are considered the founding fathers of oligopoly theory. They each developed their own models for analyzing strategic interaction in such markets. It is beyond the scope of this paper to discuss them.

According to Cotterill (1986), there are several oligopoly models that predict that the price level in a market is positively associated with one or more measures of seller concentration, such as the four-firm ratio or one firm ratio.

Several researchers have already studied how market concentration affects equilibrium prices. Cotterill (1986) looked at the relationship between market concentration and prices using supermarkets in local markets in Vermont. He found that prices are significantly higher in more concentrated markets. Keeler et al. (1999) looked at this effect in for-profit and non-profit hospitals. Regarding market definition, they have assumed that the market for each hospital corresponds to the boundaries of the district in which the hospital is located. They were able to find that hospital prices were higher in markets with higher concentration. This was even the case for non-profit hospitals. Asplund and Sandin (1999) used 486 driving schools and their prices to analyze competition in 235 local markets in Sweden. The results showed that prices are increasing in firm concentration within a market. Newmark (2004) also presents several studies in his work that also support this relationship. He lists, for example, the papers of Connor (1990), Cotterill (1990), and Koller and Weiss (1989) and several more.

This relationship has also been studied by several researchers in the retail gasoline market. Sen (2003) investigated this effect for the Canadian retail gasoline market. To do this, he analyzed monthly averages in 10 major Canadian cities over a seven-year period. He found that in addition to higher average monthly wholesale prices, increasing local market concentration is also positively and significantly associated with higher retail prices. Eckert and West (2005) studied gas stations in Vancouver and also found that higher market concentration leads to higher prices. Kihm et al. (2016) found in the German gasoline market that higher market concentration, in the form of the Herfindahl-Hirschman index, leads to significantly higher prices within a 5 kilometer radius of the gas station. Clemenz and Gugler (2006) analyzed the impact of market concentration on prices at the district and municipality level in their paper. No significant relationship was found at the district level, but at the municipality level. Bergantino et al. (2018) have looked at the municipalities in Rome. They discovered that the higher the market concentration in a given municipality, the higher the price of both gasoline and diesel at gas stations. Hosken et al. (2008), on the other hand, did not identify a significant relationship. A large part of the literature, both in the retail gasoline market and in other industries, describes a positive relationship between market concentration and prices. Based on this, the third hypothesis was developed:

> Hypothesis 3 - Prices tend to be higher, as market concentration increases.

In general, it can be said that these mechanisms have been little studied in this form for the German retail gasoline market. In addition, many researchers have only looked at selected local markets in the respective countries, and very rarely have the entire country or all gas stations been included in the analysis. My work aims to fill these gaps in the literature.

3. The German Retail Gasoline Market

Oil is still the most important source of energy in Germany, accounting for 33% of total energy supply in 2018. German oil demand has fallen much more slowly than domestic oil production over the past decade, so Germany remains heavily dependent on oil imports. Germany has a high dependency on oil imports of about 97%. Oil import dependency is calculated as domestic oil production divided by total oil demand. Germany's top crude oil suppliers in 2018 were Russia (36%), Norway (12%), United Kingdom (8%), Kazakhstan (8%), Libya (8%), and Nigeria (6%). For oil products, Germany produces most of its demand in its domestic refineries. This covered 88% of total demand in 2018. Accounting for more than half of total oil usage, the transportation sector is the largest oil consumer. Diesel is the most consumed oil product, followed by gasoline (IEA, 2020). Germany has one of the largest refining capacities in Europe, with a total of 13 refineries spread across the entire country (Mineralölwirtschaftsverband, 2020). A map with the oil infrastructure of Germany is shown in Figure 1.

In this map are shown the locations of the 13 refineries, the oil pipelines and oil storage sites to get a rough idea of how the oil infrastructure looks like. In the retail fuel sector, there were 14460 active gas stations in Germany in 2022 (Statista, 2023a). Figure 2 shows a map of Germany with the individual gas stations to get an impression of how the gas stations are distributed in Germany.

In Germany, five companies together own 68% of the market share of total fuel sales in 2022. These five companies are Aral (21%), Shell (20%), Jet (10%), Total (9.5%) and Esso (7%). The market share of gas station operators by number of gas stations shows a quite similar situation. These five companies operate about half of all gas stations in Germany (Statista, 2023b).

The year 2022 was shaped by very high fuel prices in Germany. For drivers in Germany, it was the most expensive year ever to fill up their fuel tanks. A liter of diesel costs an average of 1.95 euros, and a liter of Super E10 1.86 euros. Gasoline was thus around 27 cents more expensive than in 2012, the previous record year, and the price per liter of diesel was even almost 47 cents higher than in 2012 (Prack, 2023). Figure 3 shows an overview of how the average daily fuel prices have developed in 2022.

The course of fuel prices this year has been shaped by a few striking factors. An extremely large increase in the prices of all types of fuel is seen at the end of February. On 23 February, the price of diesel was still at 1.67 euros per liter and has risen within about two and a half weeks by 38% percent to 2.31 euros per liter. This price shock was triggered by the invasion of Russian troops into Ukraine on February 24, 2022. As already described above, Russia is Germany's largest crude oil supplier.

The next sharp change in the trend took place on the first of June. Within one day, the E5 price has fallen by about 28 cents to 1.93 euro per liter. This was triggered by the so-called "Tankrabatt". In English, this means a government-funded fuel discount. Energy tax rates were reduced for a limited period of three months from June 1, 2022, for some types of fuel to the extent permitted under European law. For gasoline it was reduced by 29.55 cents per liter and for diesel by 14.04 cents per liter. As a consumption tax, the energy tax is intended to be passed on in full to the end consumer. The purpose of the "Tankrabatt" was to relieve people who depend on the car, such as commuters, families, as well as business people, especially in the crafts and logistics industries (Bundesregierung, 2022). On August 31, this benefit expired, which resulted in a huge increase in prices of all types of fuel on the first of September. The price of diesel has risen by about 10 cents, E5 by about 24 cents and E10 by about 23 cents per liter from one day to the next.

The question arises how the fuel prices for one liter are composed. Bft (2023) has illustrated this on the basis of one liter of diesel. A retail price of 1,762 per liter of diesel is used. Of this amount, 0.2813 euro is VAT, resulting in a net selling price of 1.4807 euro. 0.4704 euro is due to energy tax, 0.0950 euro is due to CO_2 pricing, 0.0030 euro is due to petroleum stockpiling levy and the value of goods excluding taxes (price of exploration, crude oil, processing and transportation) equals 0.9123 euro. This results in a total amount of statutory levies of 0.8497 euros per liter. This shows that the statutory levies form a large part of the fuel price.

4. Methodology

To test the three hypotheses, the following data and methodology is used. The methodology is strongly inspired by the paper "Locational choice and price competition: some empirical results for the austrian retail gasoline market" by Clemenz and Gugler (2006). I have a dataset of the German gas stations with the following information. For each gas station a separate ID, the company and information about the location, such as zip code, street, and coordinates. In addition, for each gas station for the most part hourly diesel prices for the complete year 2022. The data originates from the website Tankerkönig and was retrieved using an API. Based on this, first a daily and then an annual average diesel price was calculated for each gas station. Additional location information, such as the district key and federal state key, was added to each gas station based on the zip code using the OpenPLZ API. In Germany, each municipality can be precisely identified by means of the regional key. According to the Federal Statistical Office (2023c), the definition of the regional key is: "12-digit key for unambiguous identification of a municipality with the components: Federal state (2 digits), administrative district (1 digit), district (2 digits), association of municipalities (4 digits) and municipality (3 digits)." After data cleaning, i.e. removing incorrect information, duplicates and missing values, a dataset with 14097 gas stations remained. So, about 97.5% of the German gas stations were considered in the analysis. This is a very high percentage of a country's total gas stations included in the analysis, compared to many other studies. Some other studies use only a portion of a country's total gas stations such as for example Lee (2007) and Sen (2003) or Eckert and West (2005).

It is a relatively difficult thing to divide Germany into appropriate local gasoline markets. The market definition should not be too narrow and not too broad. Following Clemenz and Gugler (2006), each district was defined as a local market. If the respective markets were measured inaccurately, it is possible that the estimates underestimate the true relationship between the dependent and independent

Figure 1: Map of Germany's oil infrastructure (Source: IEA (2020))

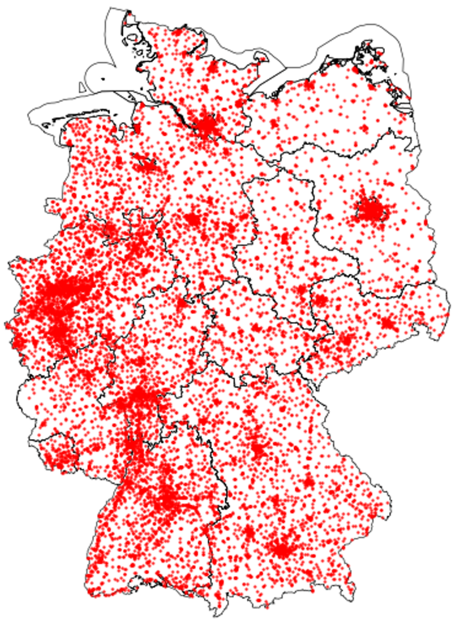

Figure 2: Map of the individual gas stations in Germany

variables. Unless these imprecisions are correlated with our relevant variables, increased white noise affecting statistical significance is the most likely consequence. In their paper, the two authors conducted a robustness test by defining municipalities in Austria as local markets. Their results are robust to the change in market definition. For this reason, it is assumed that for Germany, the districts also represent appropriate local gasoline markets. Based on this, the data was grouped by district and the corresponding values were calculated at the district level. The average diesel price ($diesel_k$) and the number of gas stations (N_k) for each district for the year 2022 were calculated. In addition, two measures of

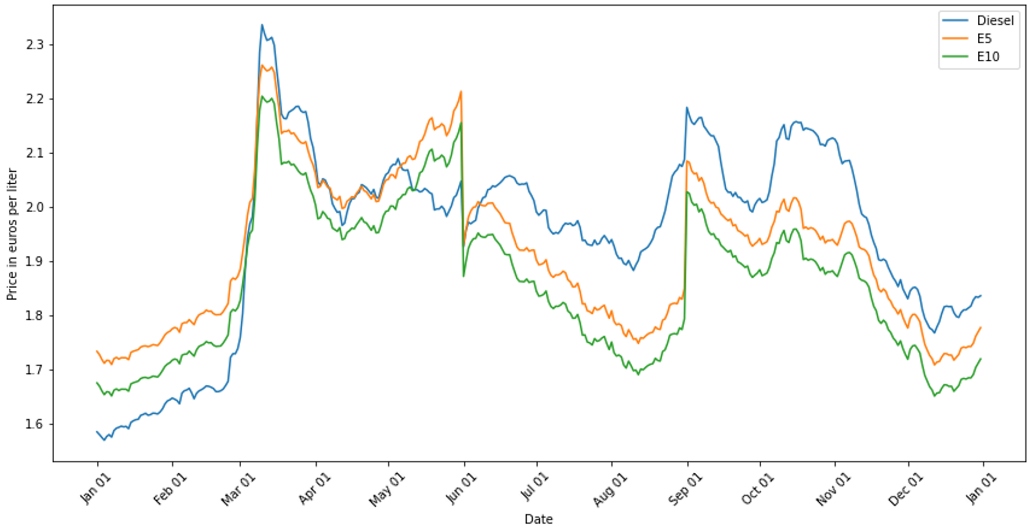

Figure 3: Daily average prices for diesel, E5 and E10 in Germany in 2022

market concentration were calculated for each district. First, the market share of the largest firm in the respective county ($C1_k$). This was calculated as follows:

$$C1_k = \frac{N_{1,k}}{N_k}$$

$N_{1,k}$ is the number of gas stations of the largest company in district k. The largest company is called the company with the most gas stations in district k. N_k is the total number of gas stations in district k. In addition, the market share of the four largest companies combined ($C4_k$) was calculated as follows:

$$C4_k = \frac{\sum_{n=1}^{4} N_{n,k}}{N_k}$$

$N_{n,k}$ is the number of gas stations operated by the n largest firms in district k. N_k is as above, the total number of gas stations in district k.

The area (A_k) (Bundesamt, 2023b), number of inhabitants (Pop_k) (Bundesamt, 2023a) and number of motor vehicles (VT_k) (Kraftfahrt-Bundesamt, 2023) were also added for each district. Based on this data, the gas station density (SD_k) was calculated as follows:

$$SD_k = \frac{N_k}{A_k}$$

The population density (PD_k) :

$$PD_k = \frac{Pop_k}{A_k}$$

The motor-vehicle density (VD_k) :

$$VD_k = \frac{VT_k}{A_k}$$

In addition, the number of motor vehicles per head (V_k). According to Clemenz and Gugler (2006), gas station density is a suitable (inverse) approximation of the average distance between gas stations. But only with the condition that gas stations do not cluster in certain areas. Their research suggests that a clustering of gas stations does not really occur often on average. Therefore, it can be assumed that gas station density is a suitable distance measure and can be used as a variable for spatial competition.

All the important variables are listed in the table 1 for sake of better overview.

4.1. Gas station density

To test the first hypothesis, several ordinary least squares regressions were performed. The superordinate equation, in analogy to (Clemenz & Gugler, 2006), looks as follows:

$$lnSD_k = \beta_0 + \beta_1 DEMAND_k + \beta_2 C_k + \varepsilon_k$$

k = 1, ..., 396 represents the districts in Germany, $lnSD_k$ is the natural logarithm of the density of gas stations per square kilometer of the respective district. $DEMAND_k = \{lnPD_k, lnVD_k\}$, with the natural logarithm respectively of population density, motor vehicle density, and motor vehicles per head. There is no sales data or the like available to reflect demand for diesel. But gasoline demand is not really price sensitive (Brons et al., 2008; Espey, 1998; Hanly et al., 2002). For this reason, the variable population density, motor vehicle density and motor vehicles per capita represent the different demand for diesel in the individual districts quite well.

Table 1: Variable Definition

Variable	Definition
Pop_k	Number of inhabitants in district k
A_k	Area of district k in square kilometers
N_k	Number of gasoline stations in district k
VT_k	Number of motor-vehicles in district k
avg_diesel_k	Retail price charged for diesel per liter averaged over the year 2022 averaged over all stations within district k in cent
$SD_k = N_k/A_k$	Density of gasoline stations in district k. (Inverse) proxy for distances between stations
$PD_k = Pop_k/A_k$	Population density in district k
$SP_k = Pop_k/N_k$	Inhabitants per gasoline station in district k
$C1_k$	Market share of the largest firm in district k defined as $C1_k = \frac{N_{1,k}}{N_k}$, where $N_{1,k}$ is the number of gasoline stations operated by the largest (most gas stations in district) firm in district k
$C4_k$	Sum of market shares of the largest four firms in district k defined as $C4_k = \frac{\sum_{n=1}^{4} N_{n,k}}{N_k}$, where $N_{n,k}$ is the number of gasoline stations operated by the n largest firm in district k
V_k	Degree of motorization defined as the number of motor-operated vehicles per head in district k
$VD_k = VT_k/A_k$	Motor-vehicle density in district k

The control variable in this model is market concentration. The natural logarithm of the market share of the largest ($lnC1_k$) or the largest four firms ($lnC4_k$) in district k. ε_k represents the error term. Here is an overview of the exact equations that were analyzed:

$$lnSD_k = \beta_0 + \beta_1 lnPD_k + \varepsilon_k \tag{1}$$

This equation was used to measure purely the effect of population density on gas station density, also it serves as a basis to compare the results to the equations with control variables.

$$lnSD_k = \beta_0 + \beta_1 lnVD_k + \varepsilon_k \tag{2}$$

In eq. 2, motor vehicle density serves as a proxy for demand. This variable could be a better proxy for demand than population density, since often in cities, i.e. very densely populated areas, there are relatively fewer people who own a motor vehicle. This would make the resulting demand less. For reasons of comparability with the results of Clemenz and Gugler (2006), this variable was not used in the other equations.

$$lnSD_k = \beta_0 + \beta_1 lnPD_k + \beta_2 lnC1_k + \varepsilon_k \tag{3}$$

$$lnSD_k = \beta_0 + \beta_1 lnPD_k + \beta_2 lnC4_k + \varepsilon_k \tag{4}$$

In eq. 3 and eq 4, market concentration was included as a control variable. In the retail gasoline market, it cannot be assumed that each company operates only one station. There is yet no clear answer as to how market concentration affects the number of gas stations in a local market. However, it is fairly safe to say that the number of stores a pure monopolist will set up in the absence of entry threat is the lower bound. On the other hand, the upper limit on the number of stores is given by the number of locations a monopolist will establish if the market is free to enter. Moreover, there is no clear indication of the relationship between market concentration and gas station density (Clemenz & Gugler, 2006). For this reason, the two market concentration measures were included in the analysis because they may alter the effect of population density.

$$lnSD_k = \beta_0 + \beta_1 lnPD_k + \beta_2 lnV_k + \varepsilon_k \tag{5}$$

In reality, the choice of a company's location is influenced by many other factors than the number of potential customers alone. The demand per individual potential customer is also a factor. For this reason, the number of cars per capita is included in equation 5 to get a better proxy for demand.

$$lnSD_k = \beta_0 + \beta_1 lnPD_k + \varepsilon_k \tag{6}$$

Equation 6 is, obviously, the same as Equation 1, but the data set that was analyzed is different. Population density varies considerably between districts, as urban areas are also considered. It could be that entry decisions of companies in cities are influenced by different factors than in rural areas, for example, availability of space, higher set up costs or higher rents, etc. For this reason, the robustness of the results is tested by removing the 20% of districts with the highest population density from the original dataset. This primarily removes cities from the analysis. Clemens & Gugler removed only the districts of Vienna from their analysis, leaving aside the fact that there are other large cities in Austria that could influence the effect. By removing the districts with the highest population density, the difference between urban and rural areas is much better controlled.

Several more equations were tested with different combinations of the control variables, but it was found that listed equations best represented the differences. OLS regression was performed for all equations.

4.2. Diesel price

To test the second and third hypothesis, several ordinary least squares regressions were performed. The superordinate equation, in analogy to Clemenz and Gugler (2006), looks as follows:

$$\begin{aligned} diesel_k =& \beta_0 + \beta_1 lnSD_k + \beta_2 lnC_k \\ &+ federalState\ fe + \ \varepsilon_k \end{aligned}$$

$k = 1, ..., 396$ again represents the districts in Germany, $diesel_k$ is the average diesel price over the year 2022 for district k. $lnSD_k$ is the natural logarithm of the density of gas stations per square kilometer of the respective district. This variable serves as an inverse proxy for the average distance between gas stations. A higher value of SD is indicative of higher local competition. Another independent variable in this model is market concentration. The logarithm of the market share of the largest ($lnC1_k$) or the largest four firms ($lnC4_k$) in district k. In this model, fixed effects were controlled for by federal S state. The spread of the diesel price is up to 5 cents per liter from state to state. These fixed effects explain a fair amount of the variation in diesel price between districts, which is why they were included in the analysis. ε_k represents the error term.

Here is an overview of the exact equations that were analyzed:

$$\begin{aligned} diesel_k =& \beta_0 + \beta_1 lnSD_k + \beta_2 lnC1_k \\ &+ federalState\ fe + \varepsilon_k \end{aligned} \tag{7}$$

$$\begin{aligned} diesel_k =& \beta_0 + \beta_1 lnSD_k + \beta_2 lnC4_k \\ &+ federalState\ fe + \varepsilon_k \end{aligned} \tag{8}$$

Equations 7 and 8 each measure the effect of gas station density and the two market concentration measures on the average price of diesel. They form the basis for testing hypotheses two and three.

$$\begin{aligned} diesel_k =& \beta_0 + \beta_1 \widehat{lnSD_k} + \beta_2 lnC4_k \\ &+ federalState\ fe + \varepsilon_k \end{aligned} \tag{9}$$

It might be a problem to estimate the diesel price by the gas station density and to ensure the direction of causality. It could be that the diesel price and the gas station density influence each other. If the diesel price is higher in certain regions due to other unidentifiable factors, it would make sense for companies to open additional gas stations in this region. This would increase the density of gas stations induced by the higher diesel price. This interaction could lead to biased results and might skew the true effect of gas station density on the price of diesel. To solve this potential endogeneity problem, a two-stage least squares (2SLS) approach is used. In the first stage, the density of gas stations is estimated by using the instrument, population density. This instrument variable is used to isolate the effect of population density on gas station density. In the second stage, the estimated lnSD is added to equation 9 to estimate the effect on the diesel price. In short, this approach instrumentalizes lnSD by lnPD. This seems like an ideal instrument since population density is exogenous to diesel prices and determines almost completely station density.

$$\begin{aligned} diesel_k =& \beta_0 + \beta_1 lnSD_k + \beta_2 lnC4_k \\ &+ federalState\ fe + \varepsilon_k \end{aligned} \tag{10}$$

Equation 10 is, obviously, the same as Equation 8, but the data set that was analyzed is different. The price of diesel in urban areas could still be influenced by additional factors, such as generally higher price levels or higher gas station operating costs due to higher rents, for example. For this reason, the same data set was used as in Equation 6, i.e., excluding the 20% of districts with the highest population density. Except for equation 9, as described above, an OLS regression was performed for all equations. Each of equations seven to ten was performed again with the logarithm of the diesel price as the dependent variable. This was done for the reason that one can later interpret the percentage change in diesel price. In addition, for a better comparability with other studies already listed in the theory part.

5. Results

To get a first feeling for the data it makes sense to look at the correlation matrix in Figure 4 with all the relevant variables. It is interesting to see that gas station density (SD_k) is very strongly positively correlated with population density (PD_k) and motor vehicle density (VD_k), the Pearson correlation coefficient being 0.91 in each case. On the other hand, however, gas station density is moderately negatively correlated with motor vehicles per capita (V_k) ($r = -0.53$). The average diesel price is only weakly correlated with the independent variables, positively as well as negatively. The highest correlation in terms of absolute value is with the combined market share of the four largest companies ($C4_k$) with a coefficient of 0.2. Gas station density (SD_k) is weakly negatively correlated with average diesel price ($r = -0.19$). It is also still interesting to note that population density (PD_k) and motor vehicle density (VD_k) are almost completely positively correlated ($r = 0.97$).

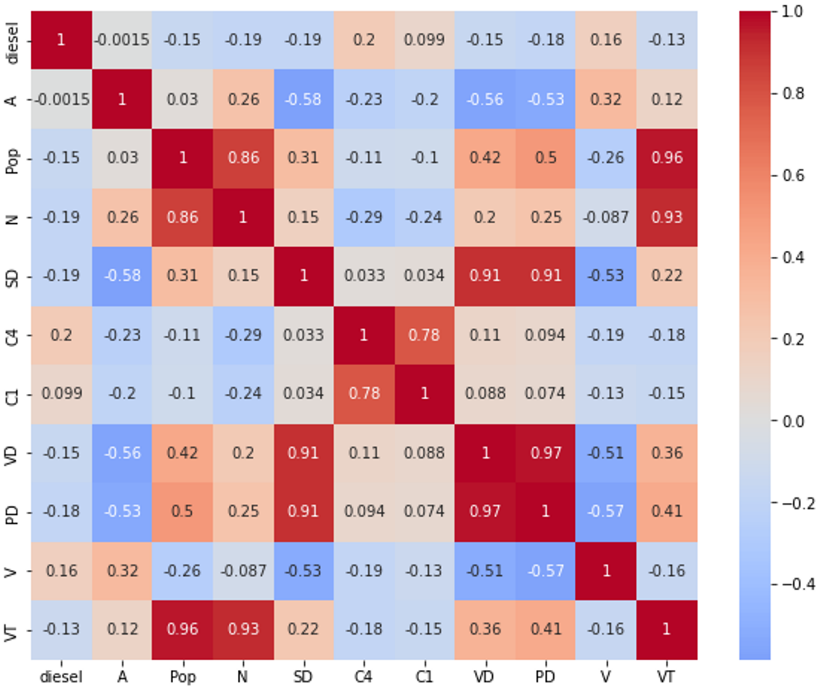

Figure 4: Correlation Matrix

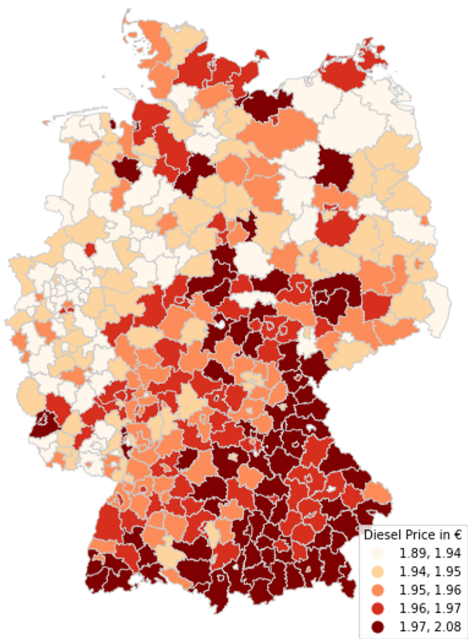

Figure 5: Average Diesel Prices on district level

To get a first impression of the average diesel prices it makes sense to look at the diesel prices by district on a map. In the annual average prices from 2022 there is a relatively large difference between the cheapest and most expensive district. In 2022, diesel was cheapest in the district of Mülheim an der Ruhr at 1.89 euros per liter, and most expensive in Trier-Saarburg at 2.08 euros per liter. That is a difference of 19 cents, or about 10%. On average across all districts, the diesel price in 2022 was 1.96 with a standard deviation of 0.024 euro per liter. The Bavarians have refueled, on average, for 1.98 euro per liter, thus approx. 5 cents more expensively than the citizens of Berlin, who had on average the most favorable prices. It can be seen very clearly that there are substantial price differences between the individual districts and even federal states.

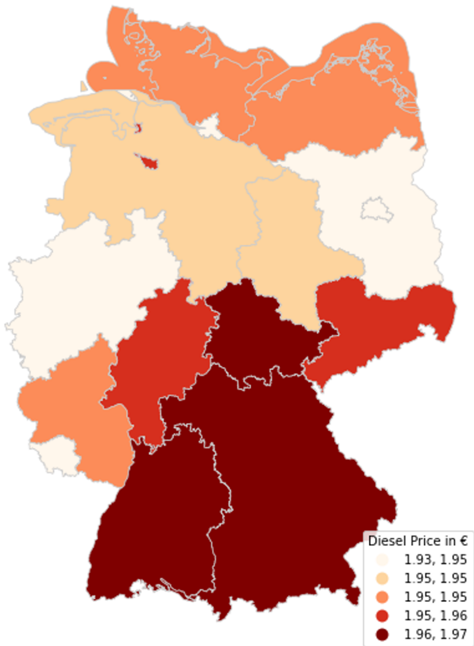

Figure 6: Average Diesel Prices on federal State

The average district in Germany has 209748.823 inhabitants with an area of 902.241 square kilometers. The largest district is Mecklenburgische Seenplatte with 5495.590 square kilometers, the smallest is Schweinfurt City with 35.7 square kilometers. The average population density is 533.264 inhabitants per square kilometer. The least densely populated district is Prignitz in Brandenburg with 35.339 inhabitants per square kilometer. The opposite is Munich City with 4788.246 inhabitants per square kilometer. In the average district, each inhabitant owns 0.758 motor vehicles. In Hohenlohekreis in Baden Württemberg, there are almost as many motor vehicles as inhabitants.

A German district has an average of 41.477 gas stations. On average, one gas station covers 25.005 square kilometers or 4991.13 inhabitants. The highest density of gas stations is in Schweinfurt City, the lowest in Uckermark in Brandenburg. The firm with the most gas stations operates an average of 21.9%, and the largest four firms together operate 58.8% of the gas stations in a district. Table 2 contains the descriptive statistics for all variables.

5.1. Hypothesis 1 – Population Density and Gas Station Density

In the scatterplot in Figure 7, there is a clear relationship between population density and gas station density. This trend shows that the higher the population density in a given district, the higher the density of gas stations. To test the hypothesis that retail stores are more likely to be located more densely in areas with higher population density, we look at the OLS regression results in table 3. The coefficients from the logarithm of population density are positive and significant at the 1% level for each equation in the model. The coefficient of 0.8212 ($p < 0.001$) shows that for every percentage point that the population density in a district increases, the gas station density increases about 0.82%. Models with control variables such as market concentration or number of motor vehicles per capita also support this trend, with coefficients for population density ranging from 0.8233 ($p < 0.001$) to 0.8289 ($p < 0.001$).

If the 20% of districts with the highest population density, i.e. primarily cities, are left out of the analysis, the effect becomes even slightly higher. The largest effect is seen for motor vehicle density, 0.9157 ($p < 0.001$). This means that if the density of motor vehicles increases by one percent, the density of gas stations increases by about 0.92%. The effect of the two market concentration measures is negative and significant. If the combined market share of the four largest firms increases by one percent, then gas station density decreases by about 0.42%.

These results support our hypothesis that retail stores are more likely to be located more densely in areas with higher population density.

5.2. Hypothesis 2 – Gas Station Density and Diesel Price

The scatterplot in Figure 8 indicates a relationship between the density of gas stations and the average price of diesel. This trend, that under spatial competition prices are lower the higher the seller density, is also supported by the results of the OLS regressions in table 4 and 5. For the equations with the absolute diesel price as dependent variable across all districts, the coefficients of ln SD range from -0.3268 ($p < 0.01$) to -0.3871 ($p < 0.01$). For the logarithm of the diesel price, the coefficients of ln SD range from -0.0020 ($p < 0.01$) to -0.0017 ($p < 0.01$). In other words, if the den-

Table 2: Descriptive Statistics

Variables	Count	Mean	Std. Deviation	Minimum	Maximum
Pop_k (inhabitants)	396	209748.823	246188.715	34091.000	3.677×10^6
A_k (in km^2)	396	902.241	722.673	35.700	5495.590
N_k (stations)	396	41.477	29.101	4.000	303.000
$diesel_k$ (in Cent)	396	195.554	2.376	188.877	207.774
$1/SD_k$ (km^2/station)	396	25.005	20.986	1.623	181.002
SP_k (inhabitants/station)	396	4991.13	1851.41	2298.2	18287.5
PD_k (inhabitants/km^2)	396	533.264	711.151	35.339	4788.246
VD_k (motor vehicles/km^2)	396	353.170	413.843	28.515	2857.350
$C1_k$ (in %)	396	0.219	0.064	0.105	0.500
$C4_k$ (in %)	396	0.588	0.109	0.344	1.000
V_k (motor vehicles/head)	396	0.758	0.139	0.001	0.985

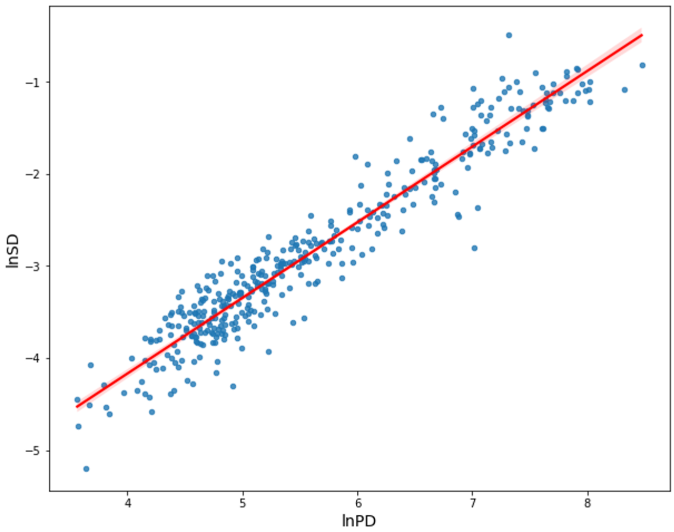

Figure 7: Scatterplot - gas station density and population density

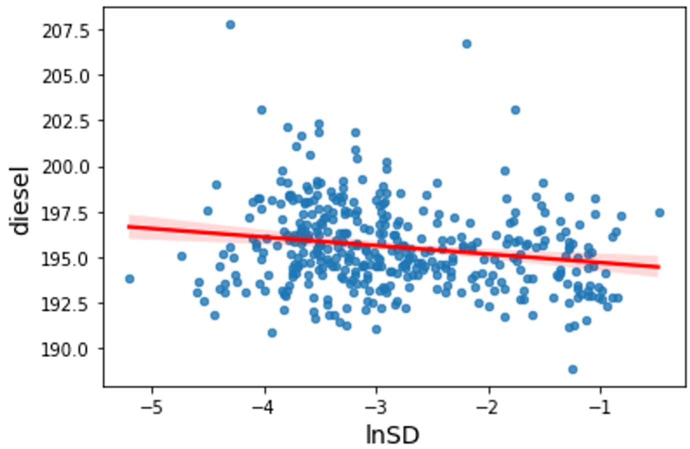

Figure 8: Scatterplot - average diesel prices and gas station density

sity of gas stations increases by one percent point, then the price of diesel falls by about 0.003 cents or 0.002%.

If the 20% of districts with the highest population density, i.e. mainly cities, are excluded from the analysis, the effect is still negative but no longer significant (p = 0.656 and p = 0.674).

Table 3: Regression Results gas station density

Dependent variable: ln SD						
Sample:	All districts				Without highest 20% PD	
Equation	1		2		3	
Independent variables	Coef	p-value	Coef	p-value	Coef	p-value
lnPD	0.8212	0.000			0.8254	0.000
lnVD			0.9157	0.000		
lnC1					-0.1698	0.002
lnC4						
lnV						
Intercept	-7.4542	0.000	-7.7333	0.000	-7.7420	0.000
Adjusted R2	0.921		0.922		0.923	
No Obs	396		396		396	
Equation	4		5		6	
Independent variables	Coef	p-value	Coef	p-value	Coef	p-value
lnPD	0.8289	0.000	0.8233	0.000	0.8325	0.000
lnVD						
lnC1						
lnC4	-0.4126	0.000				
lnV			0.0275	0.010		
Intercept	-7.7229	0.000	-7.4560	0.000	-7.5128	0.000
Adjusted R2	0.926		0.921		0.848	
No Obs	396		396		316	

Note: Standard Errors are heteroscedasticity robust (HC0)

Table 4: Regression Results absolute diesel price

Dependent variable: $diesel_k$								
Sample:	All districts						Without highest 20% PD	
Equation	7		8		9		10	
Method	OLS		OLS		2SLS		OLS	
Independent variables	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
$\ln SD_k$	-0.3406	0.009	-0.3871	0.003	-0.3268	0.006	-0.1139	0.656
$\ln C1_k$	1.0854	0.001						
$\ln C4_k$			2.8911	0.000	2.8563	0.000	3.0641	0.000
Intercept	196.0629	0.000	195.7961	0.000	195.9434	0.000	196.4656	0.000
Adjusted R^2	0.319		0.348		0.342		0.369	
federalState fixed effects	yes		yes		yes		yes	
No. Obs	396		396		396		316	

Note: Standard Errors are heteroscedasticity robust (HC0)

5.3. Hypothesis 3 – Market Concentration and Diesel Price

The scatterplot in Figure 9 indicates the tendency that the higher the combined market share of the four largest companies, the higher the price of diesel. This trend, that the higher the market concentration the higher the prices, is also supported by the OLS regressions. The coefficients of the two market concentration measurements are positive and significant across all equations, supporting the third hypothesis. If the market share of the largest company in a district increases by one percentage point, then the price of diesel increases by about 1 cent on average. Looking at the effect of the aggregate market share of the four largest firms in a district, the coefficients for absolute diesel prices are 2.8911 ($p < 0.001$) and 2.8563 ($p < 0.001$). This effect increases to 3.0641 ($p < 0.001$) when the 20% districts with the highest popula-

Table 5: Regression Results logarithm diesel price

Dependent variable: $\ln diesel_k$								
Sample:	All districts						Without highest 20% PD	
Equation	7		8		9		10	
Method	OLS		OLS		2SLS		OLS	
Independent variables	Coef	p-value	Coef	p-value	Coef	p-value	Coef	p-value
$\ln SD_k$	-0.0017	0.009	-0.0020	0.003	-0.0017	0.006	-0.0005	0.674
$\ln C1_k$	0.0055	0.001						
$\ln C4_k$			0.0146	0.000	0.0144	0.000	0.0155	0.000
Intercept	5.2783	0.000	5.2770	0.000	5.2777	0.000	5.2805	0.000
Adjusted R^2	0.322		0.350		0.344		0.371	
federalState fixed effects	yes		yes		yes		yes	
No. Obs	396		396		396		316	

Note: Standard Errors are heteroscedasticity robust (HC0)

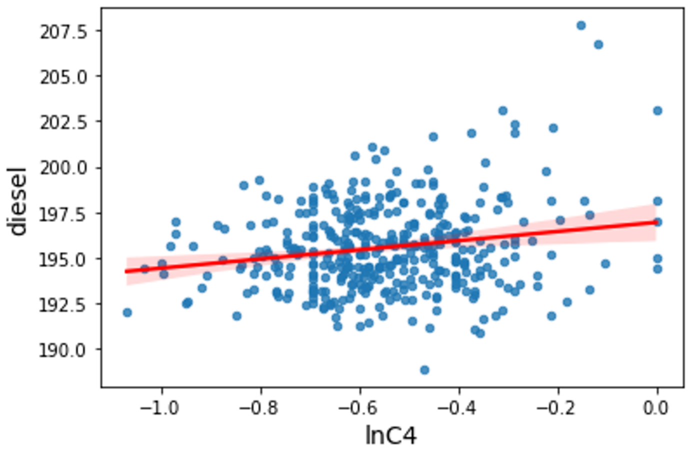

Figure 9: Scatterplot - average diesel prices and four firm ratio

tion density are excluded from the analysis. Thus, it could be concluded that the effect of market concentration is more pronounced for rural areas and has more influence on the diesel price there.

These results support our hypothesis that prices tend to be higher, as market concentration increases.

6. Discussion

The results shown above strongly support the first hypothesis that retail stores are more likely to be located more densely in areas with higher population density. This finding suggests that more densely populated areas also have more gas stations. One possible explanation could be that a larger number of potential customers in a market increases the profitability of gas stations. Areas with high population density may have higher demand for fuels. In these areas, consumers could benefit from higher availability of gas stations. Thus, potential customers can choose between a larger number of filling stations and potentially benefit from lower fuel prices.

The relationship between population density and gas station density could also provide insights into the structure of the gas station industry and its ability to adapt. High population densities may be an indicator of economic activity and mobility. This, in turn, perhaps influences the development of gas stations.

As already shown in the results, the coefficient of lnD, in the equation without control variables is 0.8212 ($p < 0.000$). In the paper from Clemenz and Gugler (2006) this coefficient was 0.810. You can see that the results are pretty much the same. The coefficients of the other equations with control variables from the two scientists closely resemble my coefficients for population density. Götz and Gugler (2006) also found a very similar relationship. This is consistent with the predictions of several spatial competition models that the relationship between retail stores and population density is not perfectly proportional since a higher density of stores causes the equilibrium price to decrease.

The observation that the effect of motor vehicle density on gas station density is higher compared to the effect of population density shows the relevance of automobility. A higher number of motor vehicles per square kilometer could potentially lead to greater use of existing gas stations, thereby increasing the demand for new gas stations in that particular area. This is also shown by the coefficient of the logarithm of motor vehicles per capita in Equation 5. If motor vehicles per capita increase by ten percent in a district, then gas station density increases by approximately 0.275%. Including variables related to motor vehicles in the analysis makes sense to possibly mitigate the effect of cities to some extent. In densely populated urban areas, public transport is often better developed, which could lead to fewer people owning a car. In turn, this could have an effect on gas station density. When the 20% of districts with the highest population density, which are mostly cities, are removed from the analysis, the effect of the population density increases slightly.

Although market concentration was only a control variable in the test of the first hypothesis, it is interesting to look at this effect as well. Market concentration has a negative impact on gas station density, so the higher the market concentration, the lower the average gas station density. This suggests that markets with few dominant players tend to have fewer gas stations. One reason could be that the competitive barriers that new players have to overcome in a highly concentrated market mean that fewer new gas stations are opened. Finding out the exact causes, however, is beyond the scope of this paper and could be the subject of further research. In a concentrated market, potential customers could face more limited options to choose from. On the one hand, due to generally fewer gas stations, and on the other hand, the large companies operate several gas stations, which makes the number of gas stations operated by various other companies smaller. The results suggest that market concentration plays a role in shaping the structure of the gas station market. In terms of competition and regulatory policy, market concentration should be closely monitored further to ensure that it does not affect competitiveness and consumer choice.

Other studies have already found a somewhat similar effect. As already shown in the results section, the coefficient of the one firm ratio was -0.1698 ($p < 0.01$), while for Clemenz and Gugler (2006) it was -0.132. The coefficients of the four firm ratio are also within the same range. It can be predicted that if the market share of the largest company in the county increases by one percentage point, then the gas station density decreases by about 0.15% on average. As you can see, there is a rather small, but nevertheless significant effect. The results of Götz and Gugler (2006) also give support to this effect.

The results shown above support the second hypothesis that under spatial competition, prices tend to be lower as the density of seller locations increases. In concrete terms, it can be observed that a one percentage point increase in the density of gas stations is associated, on average, with a decrease of about 0.002% in the diesel price in a district. One cause may be the increased spatial competition that comes with an increasing number of gas stations in a geographically defined market. If the density of gas stations increases, then logically the average distance between the gas stations becomes smaller. As already explained in the theory section, a smaller distance between competing gas stations leads to more intense competition. This more intense competition may lead gas station operators to reduce prices in order to attract potential customers and thus secure or increase their market share.

Another possible cause could be the supply and demand relationship. A larger number of gas stations in a market could increase the supply of fuel. If the demand for fuel in a market is relatively constant, an increased supply could lead to a decrease in prices.

In their paper, Clemenz and Gugler (2006) looked at the impact of gas station density on the margin at gas stations at the district level. But there are drawbacks to calculating the margin in their study. They make some generalized assumptions for calculating the costs. For example, they make blanket assumptions for transportation costs to and within Austria and do not distinguish between gas stations or districts. They thus calculate a single numerical value for the costs with which they then calculate the margin for all gas stations. I chose the diesel price rather than the margin as the dependent variable because this way the results are not distorted by possible inaccurate assumptions. Even if it makes no sense to compare the absolute values, it is at least possible to compare the direction of the effect. The two researchers also found a significant negative effect of gas station density. They also performed a robustness test by excluding Vienna districts from the analysis. Their results are robust to the change in the analyzed data. I also performed a robustness test as described earlier by excluding the 20% of districts with the highest population density. The effect is still negative but no longer significant ($p = 0.656$). The reduced dataset has an average gas station density of 0.045 gas stations per square kilometer, or inversely 30.218 square kilometers per gas station. The excluded data, on the other hand, has an average gas station density of 0.267 gas stations per square kilometer or, inversely 4.410 square kilometers per gas station. You can see that there is a very big difference between the average density of gas stations. This substantial difference could be the reason why the results in the robustness test are no longer significant. The relatively high density of gas stations in the excluded districts shows a high degree of spatial competition. Lee (2007) was able to discover that gas stations compete most when they are less than a mile apart and the intensity of competition continues to decrease with distance. Cardoso et al. (2020) found that the closer the competitor's location is to existing gas stations, the more prices fall. In rural areas, the average distance between gas stations may be too large for competition to significantly affect prices. This could be the reason why the effect of gas station density on the diesel price is no longer significant in the reduced data set. It may be that the district is chosen too large as the local market in rural areas. Another reason could be that the relationship between gas station density and diesel price in urban areas may be influenced by other factors that are more pronounced in cities. These findings may open up new research perspectives to investigate in more detail the specific influence factors in urban and rural areas and to understand the relationship between gas station density and diesel price more extensively. Kaldor (1935) has found that firms compete not only in a local market but also with firms in neighboring markets. Competition is less intense, but it is still there. This is a factor that was not included in this paper, but could be considered in further research.

The results shown above support the third hypothesis that prices tend to be higher, as market concentration increases. In concrete terms, it can be observed that a one percent increase in the four firm ration is associated, on average, with an increase of about 0.0146% in the diesel price in a district. This effect could be due to various causes based on the market power of the companies. As market concentration increases, so does a company's market power, since there are fewer competitors who could force price cuts. In such a scenario, the different gas stations of the same company could have incentives to keep prices high. Gas stations of the same company will most likely not compete with each other. If one or a few companies have a large market share, then this could lead to less price competition overall. Higher market concentration or market share would not necessarily have to be due to market power, but could also be due to the firms' efficiency.

But Mueller (1986) made clear in his work that if high concentration and high market shares were due to higher efficiency, one would expect lower prices in concentrated markets, which he did not observe. This is consistent with the presented results.

High market concentration could also result in a high entry barrier for new market participants. It may be more difficult for new competitors to establish themselves if a few companies dominate the majority of the market. As already shown in the results, market concentration has a negative impact on gas station density. For this reason, there are, on average, proportionally fewer gas stations in a concentrated market that could be in competition with each other. This would also lead to less spatial competition.

Another reason for the higher prices could be tactical collusion. Pepall et al. (2014) listed several factors in their book that facilitate collusion, including high market concentration, significant entry barriers, and product homogeneity. These are all points that play a role in the German retail gasoline market. Cotterill (1990) has shown that tacit collusion does exist in concentrated markets. Tacit collusion is also often described as price followship. Balto (2001) has shown that the higher the market concentration, the greater the risk that a further increase will lead to higher prices through collusion.

As described in the theory section, some researchers have looked at the relationship between market concentration and prices in the retail gasoline market. Clemenz and Gugler (2006) did not find a significant relationship at the district level. In contrast, I was able to find a significant relationship. In the work of Bergantino et al. (2018), the coefficients of brand market share, three firm ratio, and HHI were also all positive and highly significant in the regressions for gasoline and diesel prices. The direction of the effect of market concentration is also consistent with the findings of many other researchers, such as Eckert and West (2004), Kihm et al. (2016), and Sen (2003).

Due to the lack of sales and revenue data, the market concentration was calculated on the basis of the number of gas stations operated by each company. It is important to note that this method may not capture all the subtle nuances of the market structure. Further research could consider alternative methods of measuring market concentration, if sales data from individual gas stations are available, to validate the results.

The effect of market concentration was robust to the reduction in the size of the data analyzed. This suggests that market concentration also has an impact on prices in less densely populated areas.

It should be noted that a potential endogeneity problem could be in the interaction between market concentration and diesel prices. Singh and Zhu (2008) clarify that the fundamental problem is that "market structures are not randomly assigned". They state that companies take into account demand and cost conditions as well as potential competitors when making market entry decisions. The market structure thus emerges as a consequence of these strategic decisions. They further point out the example that markets with unobserved high costs are likely to have higher prices. On the other hand, these markets are also likely to attract fewer market participants. This may in turn lead to a higher market concentration. The price would thus be influenced to a certain extent by the relatively higher costs in certain regions and not mainly by market concentration. A topic for further research would be to what extent the market structure or market concentration in the German retail gasoline market is endogenously determined by prices.

The findings of this paper not only contribute to the theoretical understanding of the spatial relationships between population density, gas station density, market concentration, and fuel prices, but also offer potential applications for both academic research and the corporate world. For further research, some approaches have already been touched upon. In summary, the findings obtained could serve as a basis to study similar spatial relationships in other industries or geographic regions. Applications in the corporate world are also emerging from the findings of this study. For gas station owners, the results offer valuable insights into location planning. The relationship between gas station density, market concentration and prices could lead companies to adjust their competitive strategies. In markets with high concentration, differentiation strategies or cooperations could be more relevant, while in highly competitive markets, price leadership could play a role. Companies could also make strategic decisions such as acquisitions of gas station locations based on the findings on the relationship between market concentration and prices. As a conclusion for companies, one could draw that on average it makes more sense to take over gas stations from other companies than to build new sites, especially in densely populated areas. This way, the density of gas stations does not increase and does not have a negative effect on the price, but the market concentration becomes higher and has a positive effect on the price.

References

Asplund, M., & Sandin, R. (1999). Competition in interrelated markets: An empirical study. *International Journal of Industrial Organization*, *17*(3), 353–369.

Balto, D. A. (2001). Supermarket merger enforcement. *Journal of Public Policy & Marketing*, *20*(1), 38–50.

Barron, J. M., Taylor, B. A., & Umbeck, J. R. (2004). Number of sellers, average prices, and price dispersion. *International Journal of Industrial Organization*, *22*(8), 1041–1066. https://doi.org/10.1016/j.ijindorg.2004.05.001

Belleflamme, P., & Peitz, M. (2015). *Industrial organization: markets and strategies*. Cambridge University Press.

Bergantino, A. S., Capozza, C., & Intini, M. (2018). Empirical investigation of retail gasoline prices.

Bergantino, A. S., Capozza, C., & Intini, M. (2020). Empirical investigation of retail fuel pricing: The impact of spatial interaction, competition and territorial factors. *Energy Economics*, *90*, 104876. https://doi.org/10.1016/j.eneco.2020.104876

Bft. (2023). Zusammensetzung des Benzin-/Dieselpreises. Retrieved August 21, 2023, from https://www.bft.de/daten-und-fakten/benzinpreis-zusammensetzung

Brons, M., Nijkamp, P., Pels, E., & Rietveld, P. (2008). A meta-analysis of the price elasticity of gasoline demand. A SUR approach. *Energy Economics*, *30*(5), 2105–2122. https://doi.org/10.1016/j.eneco.2007.08.004

Bundesamt. (2023a). Fortschreibung des Bevölkerungsstandes. Retrieved August 21, 2023, from https://www-genesis.destatis.de/genesis/online?operation=statistic%5C&levelindex=0%5C&levelid=1682174311638%5C&code=12411%5C#abreadcrumb

Bundesamt. (2023b). Gebietsfläche: Kreise, Stichtag. Retrieved August 21, 2023, from https://www-genesis.destatis.de/genesis/online%5C#astructure

Bundesamt. (2023c). Regionales - Regionalschlüssel (RS). Retrieved August 12, 2023, from https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Glossar/regionalschluessel.html

Bundesregierung. (2022). Fragen und Antworten zum „Tankrabatt". Retrieved August 21, 2023, from https://www.bundesregierung.de/breg-de/aktuelles/faq-energiesteuersenkung-2049702

Cardoso, L. C. B., Uchôa, F., Huamani, W., & Gomez, R. V. (2020). Price effects of spatial competition in Brazilian gas stations.

Clemenz, G., & Gugler, K. (2006). Locational choice and price competition: some empirical results for the austrian retail gasoline market. *Empirical Economics*, *31*(2), 291–312. https://doi.org/10.1007/s00181-005-0016-7

Connor, J. M. (1990). Empirical challenges in analyzing market performance in the US food system. *American Journal of Agricultural Economics*, *72*(5), 1219–1226.

Cotterill, R. W. (1986). Market power in the retail food industry: Evidence from Vermont. *The Review of Economics and Statistics*, 379–386.

Cotterill, R. W. (1990). Food mergers: Implications for performance and policy. *Review of Industrial Organization*, 189–202.

Eckert, A., & West, D. (2004). A Tale of Two Cities: Price Uniformity and Price Volatility in Gasoline Retailing. *The Annals of Regional Science*, *38*, 25–46. https://doi.org/10.1007/s00168-003-0144-y

Eckert, A., & West, D. S. (2005). Price uniformity and competition in a retail gasoline market. *Journal of Economic Behavior & Organization*, *56*(2), 219–237. https://doi.org/10.1016/j.jebo.2003.09.006

Espey, M. (1998). Gasoline demand revisited: An international meta-analysis of elasticities. *Energy Economics*, *20*(3), 273–295.

Götz, G., & Gugler, K. (2006). Market concentration and product variety under spatial competition: Evidence from retail gasoline. *Journal of Industry, Competition and Trade*, *6*, 225–234.

Hanly, M., Dargay, J., & Goodwin, P. (2002). Review of income and price elasticities in the demand for road traffic. *Department for Transport, London*.

Hosken, D. S., McMillan, R. S., & Taylor, C. T. (2008). Retail gasoline pricing: What do we know? *International Journal of Industrial Organization*, *26*(6), 1425–1436.

IEA. (2020). Germany 2020 - Energy Policy Review. https://www.iea.org/reports/germany-2020

Kaldor, N. (1935). Market imperfection and excess capacity. *Economica*, *2*(5), 33–50.

Keeler, E. B., Melnick, G., & Zwanziger, J. (1999). The changing effects of competition on non-profit and for-profit hospital pricing behavior. *Journal of Health Economics*, *18*(1), 69–86.

Kihm, A., Ritter, N., & Vance, C. (2016). Is the German retail gasoline market competitive? A spatial-temporal analysis using quantile regression. *Land Economics*, *92*(4), 718–736.

Koller, R. H., & Weiss, L. W. (1989). Price levels and seller concentration: The case of Portland Cement. *Concentration and Price*, 17–40.

Kraftfahrt-Bundesamt. (2023). Bestand nach Zulassungsbezirken (FZ 1). Retrieved August 12, 2023, from https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz1%5C_b%5C_uebersicht.html

Lee, S.-y. (2007). Spatial Competition in the Retail Gasoline Market : An Equilibrium Approach Using SAR Models.

Meerbeeck, W. (2003). Competition and Local Market Conditions on the Belgian Retail Gasoline Market. *De Economist*, *151*, 369–388. https://doi.org/10.1023/B:ECOT.0000006590.66223.9a

Mineralölwirtschaftsverband. (2020). MWV-Jahresbericht 2020. https://en2x.de/service/publikationen/

Mueller, D. C. (1986). *Profits in the long run*. Cambridge University Press.

Newmark, C. M. (2004). Price-concentration studies: There you go again. *Antitrust Policy Issues*, 9–42.

Pepall, L., Richards, D., & Norman, G. (2014). *Industrial organization: Contemporary theory and empirical applications*. John Wiley & Sons.

Prack, N. (2023). Spritpreis-Entwicklung: Benzin- und Dieselpreise seit 1950. Retrieved August 21, 2023, from https://www.adac.de/verkehr/tanken-kraftstoff-antrieb/deutschland/kraftstoffpreisentwicklung/

Salop, S. (1979). Monopolistic Competition With Outside Goods. *Bell Journal of Economics*, *10*, 141–156. https://doi.org/10.2307/3003323

Sen, A. (2003). Higher prices at Canadian gas pumps: International crude oil prices or local market concentration? An empirical investigation. *Energy Economics*, *25*(3), 269–288.

Singh, V., & Zhu, T. (2008). Pricing and market concentration in oligopoly markets. *Marketing Science*, *27*(6), 1020–1035.

Statista. (2023a). Anzahl der Tankstellen in Deutschland nach Tankstellentyp von 1999 bis 2022. Retrieved August 12, 2023, from https://de.statista.com/statistik/daten/studie/72262/umfrage/anzahl-der-tankstellen-in-deutschland-nach-tankstellentyp-zeitreihe/%5C#:~:text=Im%5C%20Jahr%5C%202022%5C%20gab%5C%20es,im%5C%20Vergleich%5C%20zum%5C%20Vorjahr%5C%20nicht.

Statista. (2023b). Statistik-Report zum deutschen Tankstellenmarkt. https://de.statista.com/statistik/studie/id/26070/dokument/tankstellenmarkt-statista-dossier/

Tankerkönig. (2022). Spritpreise in Echtzeit. https://tankerkoenig.de/index.php

Tirole, J. (1988). *The theory of industrial organization* (Vol. 14). MIT Press.